

**AN EVALUATION OF THE OESOPHAGEAL FISTULA VALVE
TECHNIQUE**

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DECLARATION

**This thesis is the result of the author's own original work, unless specifically indicated to
the contrary in the text.**

A handwritten signature in black ink that reads 'Rebopa'. The signature is stylized and cursive.

The author

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ABBREVIATIONS

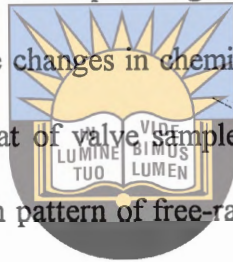
ADF	-	acid detergent fibre
ADL	-	acid detergent lignin
BW	-	body weight
Ca	-	calcium
CF	-	crude fibre
CL	-	chlorine
CP	-	crude protein
Cu	-	copper
DM	-	dry matter
DMI	-	dry matter intake
EE	-	ether extract
fb	-	fistula bag
vb	-	fistula valve
GBD/ha	-	goat browsing days per hectare
HSR	-	high stocking rate
IVDMD	-	<u>in vitro</u> dry matter digestibility
IVODM	-	<u>in vitro</u> organic matter digestibility
K	-	potassium
LSR	-	low stocking rate
Mg	-	magnesium
N	-	nitrogen
Na	-	sodium
NDF	-	neutral detergent fibre
NDS	-	neutral detergent solubles
OBS	-	observations
OM	-	organic matter
OMI	-	organic matter intake
P	-	phosphorus
S	-	sulphur
Zn	-	zinc



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ABSTRACT

The oesophageal fistula valve technique (Raats & Clarke, 1992) was evaluated in terms of its ability to reflect the daily forage selection pattern of free ranging goats over a period of four seasons and two stocking rates. During the evaluation, the oesophageal fistula valve technique was compared to the standard oesophageal fistula bag technique and observed feeding behaviour. Comparisons were in terms of: (i) proportion of grass or bush (% DM) in both the fistula bag and valve samples compared against the time spent grazing or browsing (% of active feeding period); (ii) the changes in chemical composition (CP, NDF, ADF and ADL) of the bag samples versus that of valve samples and; (iii) diurnal changes in feeding behaviour and plant species selection pattern of free-ranging goats based on observations.



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All comparisons for the evaluation of the fistula valve technique were carried at two different stocking rate treatments (HSR - 24 goats/ha and LSR - 12 goats/ha) and over a period of four seasons (winter, spring, summer, autumn). The results, though not consistent throughout treatments and seasons, indicate significant differences in grass content, chemical composition and feeding behaviour (species selection and time spent browsing). The correlation between time spent grazing and the amount of grass in extrusa samples indicates that the fistula valve technique provides a more realistic estimate ($R^2=0.73$) of the observed feeding behaviour of free-ranging goats than the fistula bag technique ($R^2=0.61$). The bag and valve samples differed significantly ($P < 0.05$) in all components (CP, NDF, ADF, ADL) on 8 occasions during the four seasons and 2 stocking rates. A highly significant difference ($P = 0.000$) in diurnal changes in plant species selection was found during different seasons and treatments. Feeding behaviour (time spent browsing) was significantly different ($P < 0.05$) between morning and afternoon feeding sessions during all four seasons and treatments. The diurnal

variation in diet selection and feeding behaviour of animals support the use of a multiple sampling technique, in order to obtain a more representative sample of the diet selected by free ranging goats.



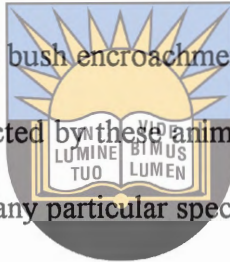
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CHAPTER 1

INTRODUCTION



Approximately 80 % (68.4 million ha) of land available for agricultural purposes in South Africa can only be utilised effectively by free ranging herbivores. Although the natural vegetation provides the bulk of the nutrients for domestic livestock and all the nutrients for wild herbivores (Harris *et al.*, 1967), its ability to sustain animal production varies substantially according to climate, geography, plant community, bush encroachment and range deterioration. Knowledge of the nutritive value of the diet as selected by these animals is of primary importance in estimating the productivity of any rangeland for any particular species of animal.



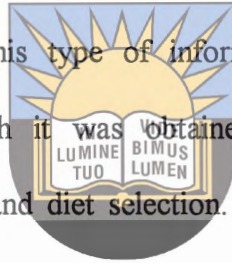
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The grazing ruminant therefore exists in a highly dynamic situation where its productivity is primarily dependent on the net nutrient intake beyond maintenance requirements (Laredo *et al.*, 1991). Nutrient intake is in turn a function of the quantity and quality of the dry matter ingested which is regulated by a series of short-term decisions made by the animal such as which plants are selected and how long to search between bites. Longer-term decisions concern the length of time to spend feeding and where to feed (Gordon, 1995). This collection of decision making processes is defined as the foraging strategy of the animal (Gordon & Illuis, 1992).

If the most efficient use of the plant and animal resources available in marginal areas is to be made, it is essential to improve our understanding of the foraging strategies of livestock, which

use these ecosystems. Knowledge of the grazing animal's food habits and forage preference is fundamental to a) the effective design of grazing systems, b) evaluation of the effects of grazing use on plant communities and c) formulation of economical supplementation programmes on nutritional deficient ranges (Malecheck & Leinweber, 1971).

Based on a review by Van Dyne *et al.* (1980), Gordon (1995) states that in the past, most studies of foraging strategy of domestic livestock and wild-grazing species have been descriptive catalogues of their diets at the taxonomic or plant part level and quantification of their daily intake. He further argues that this type of information is of limited value outside the circumstances and site from which it was obtained and does not advance our general understanding of foraging strategy and diet selection. Only through an understanding of the mechanisms involved in the decision-making processes of the foraging animal will it be possible to develop more widely applicable predictive models to meet agricultural, conservation or landscape objectives (Rice *et al.*, 1983; Armstrong, 1991; Blackburn & Kothmann, 1991; Baker *et al.*, 1992). However, notwithstanding this shift in emphasis in both the approach and objectives of free range animal research, the methodology and techniques required in both approaches remain basically the same.

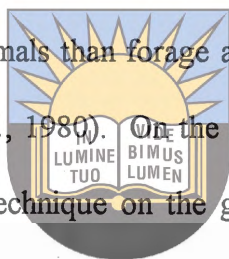


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Apart from studies on the impact of livestock on vegetation, the majority of techniques available for studying the foraging behaviour of free ranging animals are directly or indirectly associated with the assessment of the nutritional value of the forage. In this assessment, the quantity and quality of dry matter intake forms an integral part and provides an estimate of the net amount of

nutrients available to the grazing animal. This information can be used, as in the past, to describe or quantify a grazing situation, or on the other hand, with the aid of an appropriate experimental design, be used to explain relevant mechanisms of foraging behaviour. Whichever approach is followed, the basic requirement centres around obtaining a representative forage sample as ingested by the animal. This sample, whether obtained in a direct or indirect way, is fundamental in determining (a) dry matter intake through the use of markers or weight changes, (b) quality or nutrient composition and (c) digestibility (use of markers or *in vitro*) of the free ranging animal's diet. In this respect, oesophageal fistula samples have been accepted as more indicative of the true diet of grazing and browsing animals than forage and/or browse sampled by other methods (Theurer *et al.*, 1976; Van Dyne *et al.*, 1980). On the contrary, however, due to the limitations imposed by the oesophageal fistula technique on the grazing area sampled and the number of samples that can be collected per day, the reliability of this technique to reflect the total daily feeding period has been questioned (Gordon & Short, 1990; Molechek *et al.*, 1982; McInnis *et al.*, 1983; Coates *et al.*, 1987 and Jones & Lascano, 1992). In an attempt to overcome some of these problems, Raats & Clarke (1992) developed a remote controlled oesophageal fistula valve for the collection of multiple extrusa samples with the aim to closely reflect the total daily feeding period of small ruminants.



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'Any research technique has inherent assumptions and limitations, and once these are acknowledged and understood, the technique can be applied to its optimum, the results interpreted appropriately and meaningful conclusions drawn. Where a technique is applied without an understanding of the potential sources of error and bias, the results may be misleading

and the conclusions incorrect' (Henley, 1993). The objective of this study is, therefore to evaluate the fistula valve technique in terms of its ability to reflect the daily forage selection pattern of free ranging goats over a period of four seasons.

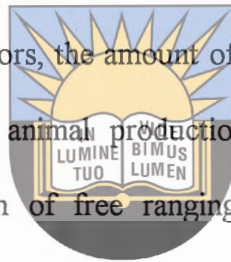


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CHAPTER 2

LITERATURE REVIEW

Animal nutrition has generally been recognized as being dependent upon four basic factors, namely, the animal's requirements and the nutrient content, digestibility and amount of the feedstuff the animal will consume (Allison, 1985). In free ranging animals, the first factor is probably best known, though effects of physical activity and environmental stresses are difficult to quantify. Of the remaining three factors, the amount of forage dry matter ingested has long been recognized as the most critical in animal production (Crampton, 1957). Reviews on the methodology to study the nutrition of free ranging animals include those by Bohman & Lesperance (1967), Harris *et al.* (1967), Kartchner & Campbell (1979), and Gordon (1995).



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Gordon (1995) listed four main reasons for studying foraging behaviour of animals. Firstly, to estimate intake and energy budgets. Secondly, to understand the relationships between resource distribution, sward structure and herbage intake. Thirdly, to explain between-animal variation in intake and performance in relation to animal nutritional status, grazing regime and management practices and finally, to provide answers on questions about the distribution of impact of livestock on vegetation. This also includes the effect of topographic features, climatic conditions and land use on the relative use of resources by herbivores. By linking locational data with Geographic Information System (GIS) databases, fine scale aspects of habitat can be used to develop habitat suitability modelling (Morrison *et al.*, 1992). A further reason for measuring the diet composition

of range animals (plant species preference, nutrient composition and harvesting rate of different plants) is to rank plant species according to their potential feeding value in different animal production systems. This plant value system provides a basis for the assessment of veld condition in relation to both primary and secondary production. In order to obtain answers to these questions or to understand the intrinsic animal/plant interaction, a wide range of both animal- and plant-based techniques were developed in the past. The present review is extensively based on the review by Gordon (1995) and will be limited to animal-based techniques only.

2.1. Animal based techniques to study the foraging strategy of free ranging animals.



2.1.1. Intake rate.

Reviews on the methodology to determine the intake of grazing ruminants are available by Van Dyne (1969), Cordova *et al.* (1978) and Allison (1985). Generally, intake is divided into short- and long-term intake rates. Short-term intake rate is normally measured over a period of not more than one hour and is defined as a combination of bite size and rate of biting, with units given in mg s^{-1} or g min^{-1} . A number of techniques are available to estimate the short-term intake rate. Firstly, it can be estimated by the visual monitoring of the size and rate of bites from tamed, free ranging animals, followed by clipping or hand-plucking simulated bites from the vegetation (Bjugstad *et al.*, 1970; cited by Gordon 1995). Secondly, changes in body mass during grazing, using very accurate balances or pressure transducers attached under each hoof, are used to determine short-term intake rates (Penning & Hooper, 1985). The third option is to determine the number of boluses swallowed by measuring the changes in the geometry of the oesophagus

(Stuth *et al.*, 1981) or the change in the conductance or pressure on an oesophageal cannula (Forwood *et al.*, 1985) with the passing of food boluses down the oesophagus. Finally, short-term intake rate and bite size can be estimated from the amount of extrusa obtained from oesophageal fistulates over a known time period and the simultaneous recording of bite rates (Stobbs, 1973). The development of the remote controlled oesophageal fistula valve (Raats & Clarke, 1992) makes it possible to even measure harvesting rates per bite or unit time of specific plant species under free range conditions (Mogorosi *et al.*, 1996). According to Gordon (1995), the oesophageal fistula method appears to provide the most accurate estimate of intake rate per bite. An alternative approach to estimate short-term intake rate is to present plant material to animals confined in pens, arenas or using a 'grazing cage' (Burlison *et al.*, 1991; Gordon, 1995).



Techniques for measuring medium-term (daily) intake rates are based on either the rate of depletion of offered forage or the amount of herbage ingested using internal or external markers. Gordon (1995) states that the majority of pasture-based methods are of limited value except on simple swards. Markers, on the other hand, provide a more direct measure, though the estimation of faecal output and digestibility on which this method relies, has its' own set of problems and errors. More recently, however, the use of long-chain *n*-alkanes as both internal and external markers (Mayes *et al.*, 1986) has been proven very effective in determining diet digestibility and intake in a number of animal species. The use of slow release capsules (Mayes *et al.*, 1991) which deliver a constant dose over a period of up to 30 days (20 days sampling), further improved the accuracy of this method and avoid the need for frequent dosing of animals. Recently, Staaland

& Hove (1999) demonstrated the use of Na^{341} replacement rate in Reindeer to measure long-term (seasonal) changes in intake rate.

2.1.2. Foraging behaviour.

The oldest and most frequently used method for measuring foraging behaviour is by direct observation, usually recording events with a manually operated data logger or video recorder. As with most observational techniques, this method is time consuming, it is difficult to collect data over 24 hr period without night vision equipment, and the presence of a human observer can alter the behaviour of even tame animals (Gordon, 1995). In order to avoid these problems, a number of mechanical and electronic devices have been developed to measure one or more of these variables automatically. These systems monitor leg or jaw movements (Penning, 1983; Alkon *et al.*, 1989; Janeau *et al.*, 1987; Matsui & Okubo, 1989) for estimating the rate and interval between bites and grazing time which allows the differentiation between grazing and ruminating. Most of these devices were developed for use on cultivated pastures and are generally found less effective under natural grazing conditions. In this regard, Raats (1990, unpublished data) found the equipment for measuring jaw movement (Penning, 1983) ineffective with goats browsing *Acacia karroo* due to the transducer being punctured by thorns.



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2.1.3. Diet composition.

Reviews on the methodology to determine diet composition of grazing ruminants are available by Harris *et al.* (1967), Harris (1968), Van Dyne (1969), Theurer *et al.* (1976), Van Dyne *et al.* (1980), Holechek *et al.* (1981), Holechek (1982) and McInnis *et al.* (1983). A popular method to

obtain qualitative estimates (plant species preference) is to follow an animal and record the species that are grazed/browsed. Obtaining, simultaneously, clipped or hand-plucked samples which mimic each bite taken could supply additional quantitative data on the nutrient composition of the diet (Bryant *et al.*, 1981). Major disadvantages of this technique are the difficulty of identifying grass species in a mixed vegetation (Holechek *et al.*, 1982) and the error involved in clipped or hand-plucked samples (Langlands, 1974). Alternatively, the remains of plant cuticles in the faeces or alimentary tract can be used to obtain qualitative information on diet composition (Crocker, 1959; Ward, 1970). Oesophageal fistulated animals has been used widely to determine the diets of domesticated livestock (Vavra *et al.*, 1978) and is accepted as the most accurate method available for this purpose (McInnis *et al.*, 1983) provided proper protocols and management are implemented.



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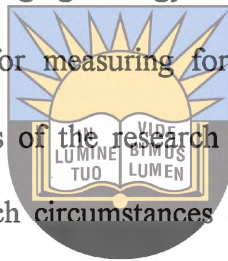
Unique plant markers are increasingly being used to distinguish between tropical grasses (C4 plants) and legumes (C3 plants) in the diet of grazing animals (Jones & Lascano, 1992). In addition, diet composition can be determined from the odd-chain *n*-alkane (C₂₅-C₃₅) concentrations in the herbage and faeces of grazing animals (Mayes, 1989; Dove & Mayes, 1991). The usefulness of both these marker techniques is, however, limited to pastures with small number of species (Gordon, 1995).

2.1.4. Location.

The decision-making processes invoked by the foraging animal may differ in relation to the landform scale (Senft *et al.*, 1987; Stuth, 1991) and spatial dispersion of resources (Gordon,

1989). Traditionally, information on the location of animals was gathered by direct observation (Arnold, 1984). In order to overcome some of the problems associated with this method, highly advanced technology, such as radiotelemetry (Warren & Mysterud, 1991) and Global Positioning Systems (GPS) (Roberts *et al.*, 1993) to track animals and record their positions are being used to monitor the position of free range animals.

From the above it is clear that the grazing ecologists, today, have a wide variety of techniques available to measure components of foraging strategy. Of these techniques, Gordon (1995) states that: "There is no 'best' technique for measuring foraging strategy. The most appropriate technique will depend upon the goals of the research and the circumstances under which the measurements are made including such circumstances as the time scale of the study, grain of heterogeneity, the availability of tame animals, logistics and funding".



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In view of the objective of this study (evaluation of the oesophageal fistula valve technique), it is appropriate to discuss the development and validity of this technique in more detail than the other techniques mentioned above.

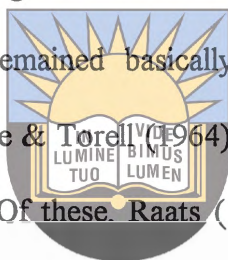
2.1.5. The oesophageal fistula valve technique

The prototype fistula valve technique developed by Raats & Clark (1992), consists of an oesophageal fistula valve which allows the fistula to be opened and closed, a rechargeable battery pack and motor to operate the valve, a portable radio and receiver to activate the valve motor, and a harness to attach the equipment to the body of the animal. This sampling system is

generally referred to as the oesophageal fistula valve technique. In most respects, this technique is identical to the standard oesophageal fistula (bag) technique (Torell, 1954), with the added advantage that the number and size of extrusa samples can be varied and collected throughout the day. In the rest of this discussion, these two techniques will be referred to as the fistula valve and fistula bag techniques.

2.1.5.1. History and development of the oesophageal fistula technique

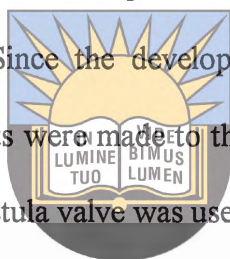
Since the introduction of the oesophageal fistula to study the diet selection of farm animals (Torell, 1954), this technique has remained basically the same, in spite of a number of modifications as reviewed by Van Dyne & Torell (1964), Harris *et al.* (1967), McManus (1981), Holechek (1982) and Raats (1993). Of these, Raats (1993) singled out five modifications for their originality and potential to solve some of the problems associated with the oesophageal fistula technique:



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- (1) simplicity of the removable sleeve and plug (Torell & Bredon, 1961 cited by Van Dyne & Torell, 1964), and the split plug designs (McManus *et al.*, 1962),
- (2) rotation of the "off center" sleeve (Van Dyne, 1962 cited by Van Dyne & Torell, 1964) and use of the latex moulded plug (Hamilton *et al.*, 1960; McManus *et al.*, 1962) in order to reduce the build-up of scar tissue,
- (3) oval shaped plug for larger fistulae (Hofmeyer & Voss, 1964), temporary cannula that prevents fistula contraction during sampling (Olson & Malechek, 1987), and the use of rubberized belting as a seal in order to reduce leakage from the fistula (Karn, 1987).

The development of the fistula valve technique (Raats & Clarke, 1992) substantially improved the versatility of this technique. Raats (1993) listed four improvements to the standard fistula technique, namely: (a) The collection of different numbers and sizes of samples throughout the day is possible without disturbing the animals' normal feeding behaviour. (b) The collection of forage samples as selected by goats in extensive areas having heterogeneous plant populations is possible. (c) Sampling from specific plants or plant communities is facilitated. (d) The need to starve animals overnight in order to reduce the possibility of extrusa samples being contaminated with rumen contents is obviated. Since the development and testing of the first prototype sampling system, further improvements were made to the fistula valve, radio and receiver (Raats, unpublished data) of which the new fistula valve was used in the present study.



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2.1.5.2. Validity of the oesophageal fistula technique.

A number of validation studies, based on indirect methods, have been reviewed by McManus (1980) to confirm that the oesophageal fistula technique provides extrusa samples that closely resembles the total diet of the animal. On the other hand, however, due to the limitations imposed by the oesophageal fistula technique on the grazing area sampled and the number of samples that can be collected per day, the reliability of this technique to reflect the total daily feeding period has been questioned. Theurer (1970a) listed several additional factors that may limit the preciseness with which fistula forage samples represent the ingested feed. These include extrusa

recovery rate, chemical changes during mastication and salivation, contamination with rumen contents, sample preparation for laboratory analysis and sampling period.

2.1.5.2.1. Fistulated vs. non-fistulated animals and type of animal.

As a result of the problems involved in estimating the true diet of non-fistulated, free ranging herbivores, few studies have critically examined the extent that fistulated animals represent the larger population of their normal counterparts (Raats, 1993). The same author concluded: "Based on the limited information available, it seems that successfully fistulated animals that are equipped with effective fistula plugs, and are observed to behave normally and are well adapted to the experimental procedure are not physiologically different from non-fistulated animals." On the other hand, fistulated animals that are not properly cared for or in cases of excessive salivary loss due to long collection periods or malfunctioned fistula plugs are not representing normal animals and should not be used. It is also reasonable to expect that differences in feeding behaviour may occur as a result of differences in handling or management which emphasise the importance of a sufficient period of adaptation to both the vegetation and experimental animal group.

In his review, Raats (1993) concluded that dry fistulated females and possibly castrates could be used to collect forage samples representing pregnant females of the same and related breeds. However, in the case of lactating animals, multiple suckled ewes, young growing animals and non-related breeds, fistulated animals of similar physiological status and genetics should be used.

2.1.5.2.2. Collection period and area sampled.

Bredon & Short (1971) concluded that the biggest drawback of the oesophageal fistula technique is the short period of sampling, which might introduce considerable error in representing a full days grazing. Holechek *et al.* (1982a) stated that the inability to obtain a representative sample in a large pasture is the primary shortcoming associated with the oesophageal fistula technique. McInnis *et al.* (1983) concluded "there is at least one reason for regarding the oesophageal fistula method with some suspicion: plant fragments found in oesophageal extrusa represent the diet of the animal for only that length of time during which the sample is being collected". Based on results from the faecal carbon isotope ratio technique, Coates *et al.* (1987) stated: "the possibility that one or more extrusa samples may not reflect the total daily intake is well recognized", while Jones & Lascano (1992) argued that "diet selection during the collection period (of only 20 to 30 min) may not reflect the 24 hour average value". The limitations imposed by the oesophageal fistula technique on the grazing area sampled and the number of samples that can be collected per day, are of particular importance where browsing animals are being studied in a large heterogeneous plant community (Raats, 1993). This was also the main reason for the development of the remote controlled forage sampling technique (Raats & Clarke, 1992).



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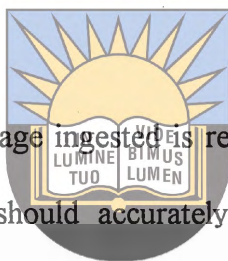
2.1.5.2.3. Diurnal variation in diet selection

It is known that ruminants can have between 8 and 10 grazing periods per day (Arnold, 1962), and that diet selection changes with increasing satiation and with changes in pasture and weather (McManus, 1980). Diurnal variation in the feeding behaviour of goats have been observed by

Bjelland & Grøva (1997). Similar variations were also found in the diet composition of fistulated animals, in nitrogen (N) content (Langlands, 1965; Hodgson, 1969; Obioha *et al.* 1970), lignin (Obioha *et al.*, 1970), digestibility (Hodgson, 1969) and botanical composition (Coates *et al.*, 1987). Based on this evidence, it seems important that oesophageal fistula samples should be collected throughout the day in order to fully represent the diet of the free range animal, which, according to Raats (1993) is one of the major advantages of the remote controlled forage sampling technique.

2.1.5.2.4. Extrusa recovery rate.

Raats (1993) stated that if all the forage ingested is recovered through the oesophageal fistula, then the extrusa samples obtained should accurately represent the forage eaten during the collection period. In practice, however, this seems not to be the case as extrusa recovery rates for smallstock range between 35 to 73% as reviewed by McManus (1980) and Holecheck *et al.*, (1982a). Holecheck *et al.* (1982a) cited Blackstone *et al.* (1965), saying that the degree of sample recovery from oesophageal fistulated animals is strongly related to the size of the opening. McManus *et al.*, (1962) concluded that an optimum size of the fistula in sheep is approximately 600 mm², while Arnold *et al.* (1964) found that fistulae of more than 1000 mm² aperture gave consistently good extrusa rates. This viewpoint is supported by Raats (1993) who found that the mean extrusa recovery rate from fistulated goats with standard fistulae (500-700 mm²), increased from 49.6 % (SD; 24.6) to 86.9 % (SD; 3.8) when the aperture size increased to 1050 mm². In the same study, the mean extrusa recovery rate of the improved oesophageal fistula valve was 86.6 % (SD; 7.5). This has led to the conclusion that large oesophageal fistulae, with or without



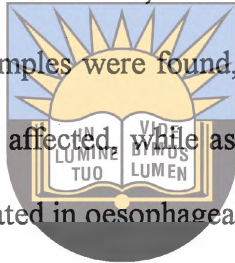
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the fistula valve, is essential for sampling with fistulated animals and confirm the results of Arnold *et al.* (1964).

2.1.5.2.5. Mastication, salivation and leaching.

The most frequently used method to test the accuracy of sampling is to feed oesophageal fistulated animals a known diet which is then compared to the chemical and/or species composition of the extrusa obtained from the oesophageal fistula (Raats, 1993). Although some contradictory results on the effects of saliva, mastication and leaching on the chemical composition of oesophageal fistula samples were found, indications are that nitrogen (N), crude fibre (CF), and calcium (Ca) are least affected, while ash, phosphorus (P), and sodium (Na) and potassium (K) are normally overestimated in oesophageal samples (Raats, 1993).



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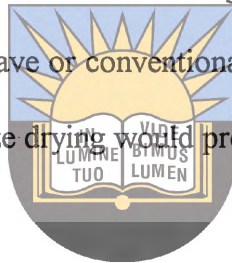
2.1.5.2.6. Contamination with rumen contents.

Another factor affecting validity of oesophageal fistula samples is the occurrence of contamination of oesophageal samples by regurgitated rumen ingesta. Samples contaminated with rumen contents cannot be used for accurate chemical and botanical composition (Holecheck *et al.*, 1982). McManus (1961) found that some sheep are more prone than others to contaminate their extrusa samples by regurgitation. The collection period should be restricted to not more than 30 minutes (Crimes & Watkin, 1990; Bath *et al.*, 1956) in order to minimize the risk of contamination by rumen contents during regurgitation. Holecheck *et al.*, (1982) stated that the problem with regurgitation is primarily related to time since previous eating and can be prevented if the animals are starved for a few hours prior to sampling. Raats (1993) stated that overnight

starving should be avoided unless it is a normal management practice because it has an effect on diet selection, rate of eating and acid detergent fibre (ADF) but not on nitrogen (N), ash, hemicellulose and acid detergent lignin (ADL).

2.1.5.2.7. Sample preparation.

Sample preparation can affect the chemical content of fistula forage samples (Theurer, 1970a). In the review by Raats (1993), it is concluded that extrusa samples should not be squeezed nor rinsed. In addition, Karn (1991) stated that if nitrogen (N) or ash are to be determined in oesophageal extrusa samples, microwave or conventional oven drying (50 °C) is acceptable, but if fibre levels are to be determined, freeze drying would provide the most accurate results.



2.2. Conclusion.

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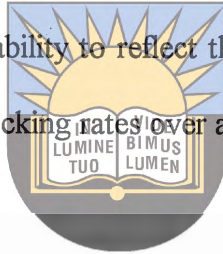
From the above it is clear that in order to collect forage samples that represents the diet of free ranging animals it is important to ensure that:

- 1) fistulated animals are of the same sex, age and physiological status as the target population of non-fistulated animals,
- 2) oesophageal fistulae are of sufficient size (1000 mm²) and equipped with effective plugs,
- 3) sufficient time is allowed for the fistulated animals to adapt to the vegetation and to become part of the group structure of the larger population,
- 4) fistulated animals are not fasted prior to sampling unless it is a normal management

practice,

- 5) collect samples throughout the active daily feeding period,
- 6) extrusa samples should not be squeezed or rinsed but should be frozen soon after collection, followed by freeze drying.

Because the fistula valve technique makes it possible to collect multiple extrusa samples, which can be varied, both in number and size and be collected throughout the day, it seems to satisfy most of the conditions as mentioned above. It was therefore the objective of the present study to evaluate this technique in terms of its ability to reflect the daily selection pattern of free ranging animals, using goats at two different stocking rates over a period of four different seasons.



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CHAPTER 3

MATERIALS AND METHODS

3.1. Hypothesis

The oesophageal fistula valve technique provides a more representative sample of forage selected by free ranging goats throughout the day and throughout the period of stay in a paddock than the standard oesophageal fistula bag technique.



3.1.1. Testing the hypothesis

Due to the difficulties involved in the direct measurement of the diet of free ranging ruminants, the following indirect measurements to evaluate the oesophageal fistula valve technique were employed. Testing of the hypothesis involved comparisons between the fistula valve and the standard fistula bag techniques in terms of:

- a) Proportion of grass or bush (%) in fistula bag and fistula valve samples vs. time spent grazing or browsing, expressed as a percentage of the active feeding time. Although grazing/browsing time is not a direct measure of intake due to differences in harvesting rate between plants, the assumption is made that a strong positive relationship exists between the observed frequency of grazing/browsing and the amount of grass/bush consumed. In this study the correlation between time spent grazing and the amount of grass in extrusa samples was therefore, used as an indication of how close the fistula bag and fistula valve techniques resemble the actual feeding behaviour of

the animal.

b) Chemical composition of fistula bag- vs. fistula valve samples obtained from the same goat on the same day. Because it is impossible to measure the true diet of the free ranging animal, this comparison provides only a measure of contrast between the two techniques and does not necessarily indicate the accuracy of either one technique.

(c) The fistula bag and valve methods will be evaluated in terms of both grass/bush ratios and chemical composition at similar levels of grazing/browsing pressure (± 120 Goat browsing days/ha) in two different stocking rate treatments

d) Diurnal changes in feeding behaviour and plant species selection. Diurnal changes in diet selection or plant species preference implies that a single sample per day is not sufficient to represent the diet of free range goats and therefore favours the fistula valve technique which enables the collection of multiple samples. On the other hand, however, lack of a clear diurnal change in diet selection would indicate that a single extrusa sample as collected by the fistula bag technique may effectively represent the daily diet.



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The following treatments and measurements were applied in order to test the hypothesis:

3.1.1.1. Treatments:

Two plots (1 ha each) classified as False Thornveld of the Eastern Cape (Acocks, 1975) were stocked with eight and 24 Boer goat ewes for a period of three weeks. The trial was repeated four times: May/June 1993, August/September 1993, October/November 1993 and February/March 1994.

Table 1. Experimental design.

	High stocking rate	Low stocking rate
Size of plot	1 ha	1 ha
Number of animals	24 mature Boer goat ewes	8 mature Boer goat ewes
Types of animals	3 dry fistulated ewes 19 lactating ewes 2 dry fistulated ewes used as replacements.	3 dry fistulated ewes 5 lactating ewes

3.1.1.2. Measurements:

Twice a week, on Tuesdays and Fridays, during each of the four experimental periods (seasons), fistula bag and fistula valve samples were collected from six fistulated Boer goat ewes (three in each plot). On the same days, the feeding of twelve goat ewes was also recorded (six per plot, consisting of 3 fistulated and 3 lactating ewes).



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3.1.1.3. Comparisons:

For each of the fistulated goats, the proportion of grass (% DM) in the fistula bag and/or fistula valve samples was correlated with the time spent grazing (% of active feeding period). The analyses was restricted to data obtained from the same animal on the same day. Comparison of the fistula bag and valve samples in terms of nitrogen (N), neutral detergent fibre (NDF) and acid detergent lignin (ADL). Comparisons were made between pairs of samples obtained from the same goat on the same day. Species selection pattern, using observational data to determine species selection pattern with the main aim of providing information on diurnal variation in the diet of free ranging goats.

In testing the above hypothesis it is important to ensure that the results reflect differences between the techniques only, and not other intrinsic factors. The following precautions were taken in order to remove or standardise variables not directly associated with the techniques under study, but which influence diet selection.

Seasonal factors: Variation may occur in diet selection due to changes in forage quality and availability between seasons. As a result, both techniques were applied simultaneously in all four seasons.

Vegetation factors: In order to minimise differences in vegetation, two small plots, one ha in size were demarcated within an existing paddock (\pm 9ha) that forms part of a 12-camp wagon-wheel system. In order to minimise the influence of the abiotic environment and plant community physiognomy on foraging behaviour, forage availability and forage quality, the two techniques were compared in both the high and low stocking rates simultaneously.



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Animal factors: As the physiological requirements of an animal and behavioural idiosyncrasies will influence diet selection, the two techniques were applied to the same individual animals.

This study formed part of a multidisciplinary research project on the feeding behaviour of browsers with the aim to (a) determine the effect of season, stocking rate, period of occupation and physiological state (lactation) of the animal on feeding behaviour and (b) identify and test "nutritional stress indicators" in free grazing/browsing ruminants, using the goat as a model.

3.2. Location.

The research was conducted on the University of Fort Hare Research Farm (Honeydale) near Alice, South Africa (32°49'S, 26°54'E). The area lies at an altitude of 500-600 m.

3.3. Vegetation.

The vegetation is representative of Acocks (1975) "False Thornveld of the Eastern Cape" and ranges from grassland through Acacia Karroo savannah to dense, clumped, medium short evergreen thicket.



3.4. Experimental area. University of Fort Hare *Together in Excellence*

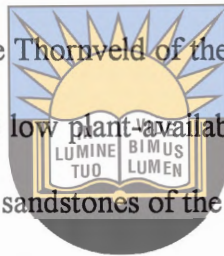
Four paddocks (8-9 ha each in size) which form part of a wagon wheel system, were rested for at least one growing season prior to the start of the experiment. In each paddock an area of two ha, judged to be uniform in terms of vegetation was identified, enclosed and subdivided into two 1ha plots. During each of the four seasons, one pair of plots in one paddock was grazed/browsed by the 32 experimental goats during the three week evaluation period of the fistula valve technique.

A seven-strand electric fence was used to confine the experimental goats to a specific plot during each of the three-week evaluation periods. Two handling kraals, capable of handling 24 animals,

were erected at the entrances to the two plots. Each plot had its own water trough placed near its entrance. A complete botanical survey, was done for each plot according to the methods described by Trollope (1980) and Danckwerts (1981) of which the results are shown in Appendix Table 1. In addition, phytomass of grass at the beginning and the end of each trial was estimated, using a disc pasture meter (Bransby & Tainton, 1977).

3.5. Soil type.

The predominant soil forms in the False Thornveld of the Eastern Cape are Glenrosa and Mispah. These have shallow topsoils and hence low plant-available water storage capacities. Since most of the soils are derived from shales and sandstones of the Beaufort and Ecça series, they have high silt and fine sand contents, which result in very poor infiltration capacities. Although low in phosphates, these soils are moderately fertile (Hensley & Eaker, 1979).



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3.6. Climate and rainfall.

Mean daily summer temperature range from 18-21°C and mean daily winter temperatures from 10-13°C. Frost is common during July and August. Owing to the frost and low rainfall during the dry season, late winter and early spring (May-October) may be considered to be the more critical period with regard to foraging. The mean annual rainfall is 574 mm and varies between 227 mm and 967 mm. The rainfall pattern is bimodal with a distinct peak in March and a lesser one in October. The rainfall pattern during the research period is shown in Fig. 1.

3.7. Management of animals and data collection.

The experiment comprised four trials with a total of 32 Boer goat ewes in each trial. At the start of each trial, there was an adaptation period of two weeks on the veld immediately adjacent to the experimental area. Five days prior to the start of each of the experiments, alkanes were dosed, blood and faecal samples collected and fistulated animals trained with harnesses in order to acquaint the animals with the handling procedures.

Approximately six months before the start of each of the four experiments, a group of about 30 Boer goat ewes were synchronised and naturally mated to ensure that they were at the same stage of lactation (three weeks post kidding) at the beginning of each trial. Twenty-four lactating Boer goat ewes were randomly selected from this group and added to the eight fistulated goats to make up the 32 experimental animals.

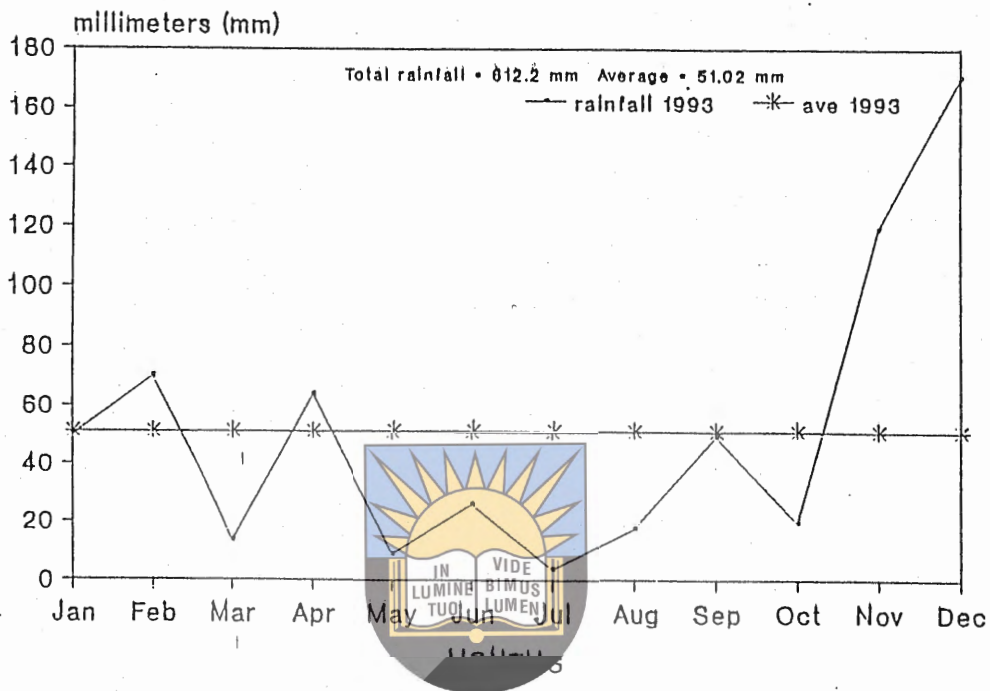


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The fistulated goats were trained with great care, to the extent that they showed no signs of abnormal behaviour, stress or discomfort during sampling and allowed the operators to approach and handle them in the open without resistance. For easier identification of the 12 animals that were observed during sampling, numbers (± 300 mm in size) were painted on both flanks with a livestock marker or enamel paint.

RAINFALL 1993



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RAINFALL 1994

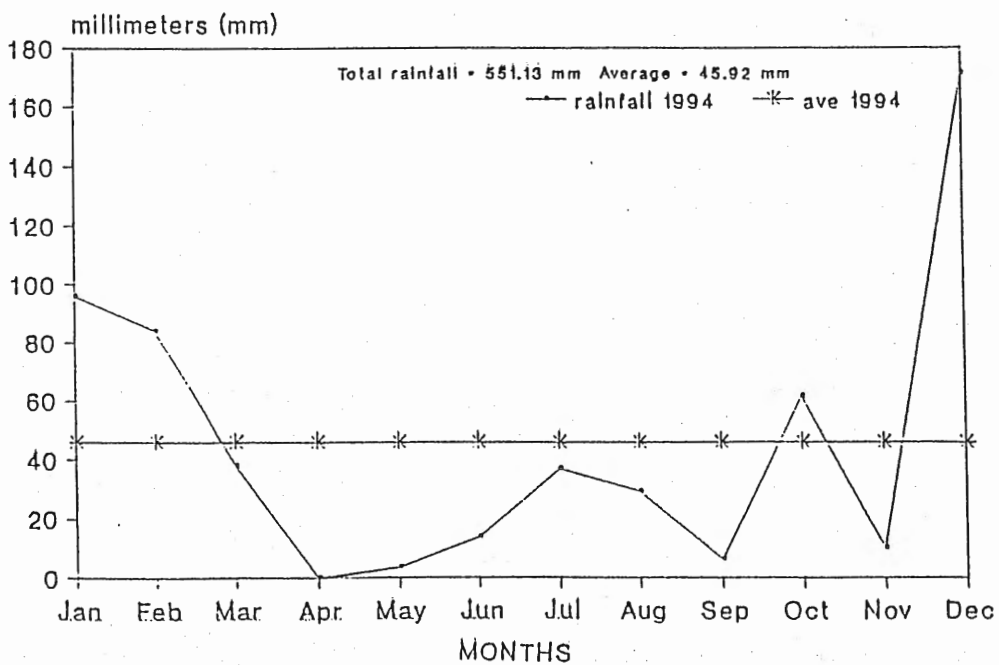


Figure 1. Rainfall pattern during the 1993 and 1994 research period

During the three-week evaluation periods, goats had daily access to the experimental plots only, but kraaled at night and only fistulated animals supplied with a commercial lick (block). Kids were separated from their mothers during the day to prevent them being accidentally trapped in the electric fence and only united in the evenings. Similar vegetation in adjacent paddocks was used as browsing for the fistulated animals during the interim period between experiments.

3.7.1. Oesophageal fistula sample collection.

At 7:00h on Tuesdays and Fridays the six fistulated goats (three in each paddock) were prepared for standard fistula bag collection, followed by a twenty minute sample collection period. Following removal of the fistula bags, the same six fistulated goats were equipped with remote controlled fistula valves and then allowed back into the plots to graze/browse. Fistula valve samples were collected from the six fistulated goats during the rest of the day (until 15:00) at one hour intervals assuming that the animals were actively grazing/browsing. During collection, the valve remained open until sufficient extrusa had been collected (1-15 minutes) and then closed when the oesophagus was clear. Samples were allowed to drop on the ground where they were collected. Any debris adhering to these samples were removed and the clean samples kept in labeled plastic bags on ice in a cooler box.



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3.7.2. Feeding behaviour.

Feeding behaviour of twelve goats (six in each plot; three lactating + three fistulated) was observed and recorded every four minutes from 7:30 h to 15:00. Observations included the following categories: browsing, grazing and non-feeding activities. Browsing activity includes bi-pedal stance (recorded separately) and represents the browsing of all woody species. These

species were also identified and recorded separately. Grazing activity represents grazing of both grasses and forbs without identification of species. Non-feeding activities include separate recordings of walking, standing and lying.

3.8. Sample preparation.

All extrusa samples were stored in a deep freeze prior to drying and milling. Each sample was freeze-dried and hand separated into bush (woody species) and grass components (including forbs) which were then weighed separately and the combined sample milled through a 1 mm sieve. Samples were analysed by the Animal Nutrition and Animal Products Institute, Irene in Pretoria for N, NDF, ADF and ADL.



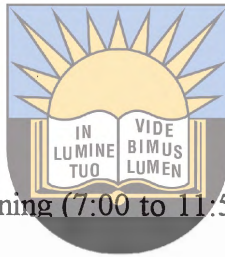
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3.9. Presentation of results and statistical analysis *Together in Excellence*

During this study, a total of 34 560 observations were recorded on the feeding behaviour of twelve goats of which half (six fistulated goats) was used in the present analyses. In addition, 1 152 valve samples and 144 bag samples were collected and hand separated into grass and bush components. Because fistula valve samples differ in mass, the grass/bush ratios of each individual fistula valve sample were weighted according to the mass (DM) of sample after which it was pooled within day for each goat. Grass content (% of DM) of extrusa samples is presented together with percentage time spent grazing (% of active feeding time) as observed from the same animals on the same day.

3.9.1. Statistical analysis

The grass/bush ratio and chemical composition data sets were first tested for normality (standard skewness and standard kurtosis with limits of -2 and +2 using descriptive statistics. Data sets that exceeded the limits of the normal distribution curve were transformed, using arcsine transformation. The normally distributed data sets were analysed and tested for significant differences between techniques, using Multi-factor Analysis of Variance. Although the results on the grass/bush ratios and time spent grazing as measured by all three techniques (bag, valve and observations) are presented together, only differences between the bag and valve techniques were statistically tested for significance.



Behavioural data was divided into morning (7:00 to 11:56) and afternoon (12:00 to 15:00) periods. Because the same animals were repeatedly observed during each of the 3-week observational periods, the "AREPMEASURES" procedure of Genstat 5 (release 3.2; IACR, Rothamsted) was used to analyse the data and test for significant differences in behaviour between morning and afternoon, between days and between seasons. Unbalanced data sets were analysed using Residual Maximum Likelihood (REML) procedure of Genstat, with goats as the random model.

Woody-species selection during each day was divided into four periods, namely: Early morning (07:00 to 08:56), late morning (09:00 to 10:56), midday (11:00 to 12:56) and afternoon (13:00 to 15:00). The number of times that goats were observed to browse a specific woody-plant species during any of the above periods were used as a basis to determine diurnal variation in species selection. Only the three most preferred bush species (*Grewia occidentalis* {GO}, *Rhus Longispina* {RL} and *Scutia Myrtina* {SM}) were used in this analysis.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. PROPORTION OF GRASS IN OESOPHAGEAL FISTULA SAMPLES AND TIME SPENT GRAZING.

The average grass consumption of fistulated goats as measured by the fistula valve, fistula bag and observation methods, during the four seasons at two stocking rates are shown in table 2.



Table 2. The average grass consumption as measured by the fistula bag, fistula valve and observation methods during the four seasons at two stocking rates

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Season & stocking rate	Bag % grass	SE	Valve % grass	SE	Obs % grass	SE	F Probability	
Winter	HSR	49.37	15.72	29.39	5.58	33.92	4.49	P > 0.05
	LSR	11.31	6.50	32.50	4.78	34.98	2.70	P = 0.04
Spring -	HSR	77.46	18.14	49.90	5.72	56.90	3.99	P = 0.02
	LSR	50.99	11.09	34.72	7.79	37.72	5.36	P > 0.05
Summer -	HSR	77.88	13.66	71.01	4.76	59.73	3.24	P > 0.05
	LSR	46.39	8.54	41.57	3.61	36.44	2.57	P > 0.05
Autumn -	HSR	12.55	10.47	23.17	5.56	15.22	4.12	P > 0.05
	LSR	0.81	0.59	1.3	0.73	6.89	2.78	P > 0.05

The average grass consumption as measured by fistula valve and the observations methods pooled over four seasons and two stocking rates were similar (35.11 & 35.20 % respectively) while the

bag was about 6 % points higher (40.85 %). When the data was arranged according to season (pooled over stocking rates and sampling days) as illustrated in Fig. 2, the average composition of the extrusa samples and time spent grazing showed a clear seasonal effect.

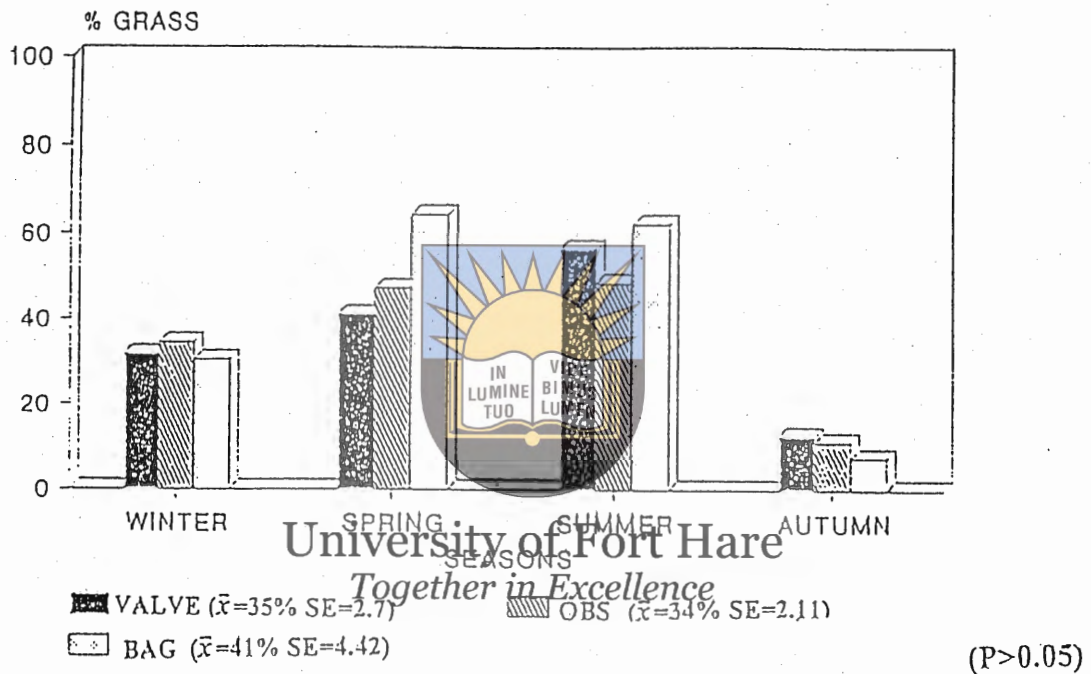
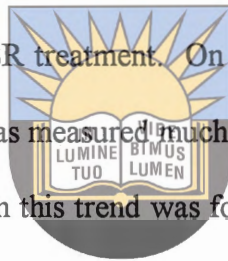


Figure 2. The average daily proportions of grass in the fistula valve and fistula bag samples and time spent grazing, pooled over stocking rates and sampling days.

The average grass consumption (techniques combined) increased from about 30 % during winter to over 50 % during spring and summer and decreased to less than 10 % during autumn. The most prominent difference (± 20 % points) between techniques was found during spring when the

grass consumption as measured by the fistula bag was 63.3 % compared to the 43.6 % and 47.2 % of the fistula valve and observation techniques, respectively. In spite of differences of up to 20 % points in the grass content between the two direct sampling methods, these differences were not significant during any of the four seasons.

The average proportions of grass in the fistula valve and fistula bag samples and time spent grazing during the different seasons as affected by stocking rate are shown in Fig. 3. Considering all three techniques, grass consumption varied from as little as 3 % during autumn in the LSR to almost 70 % during summer in the HSR treatment. On average, the proportion of grass/grazing as measured by the three techniques was measured much higher in the HSR- compared to the LSR treatments. However, a deviation from this trend was found during winter, when both the fistula valve and observation data showed slightly lower grass consumption in the HSR- than the LSR treatment which is contrary to the fistula bag results (50 % & 10 % respectively). In both stocking rate treatments, the average grass consumption as measured by the fistula valve and observation techniques were within 12 % points of each other. On the other hand, 20 to 25 % differences in grass consumption were observed between the fistula bag and the other two techniques during spring (HSR) and winter (LSR).

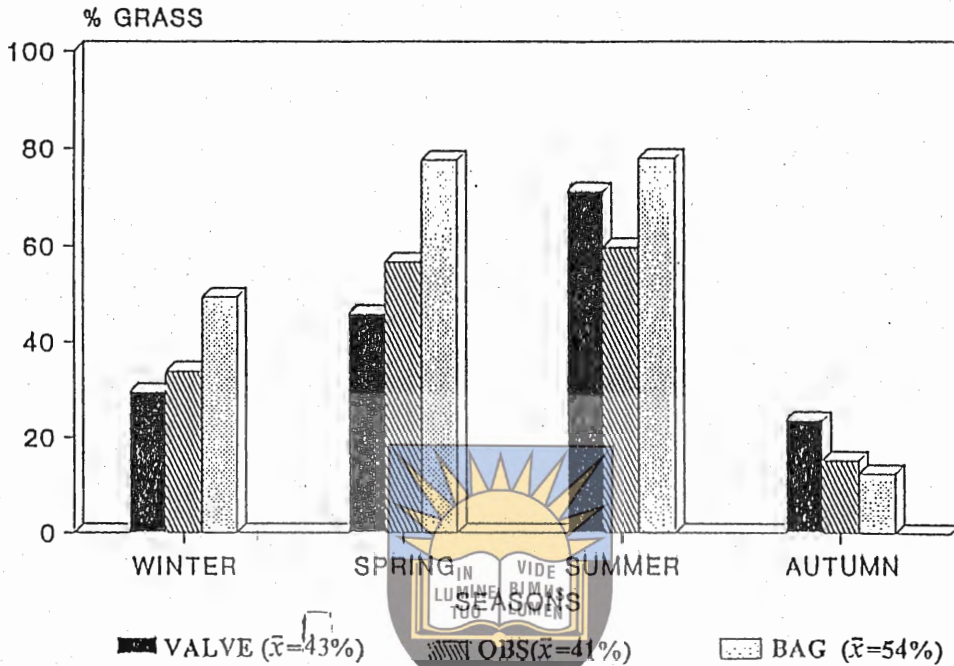


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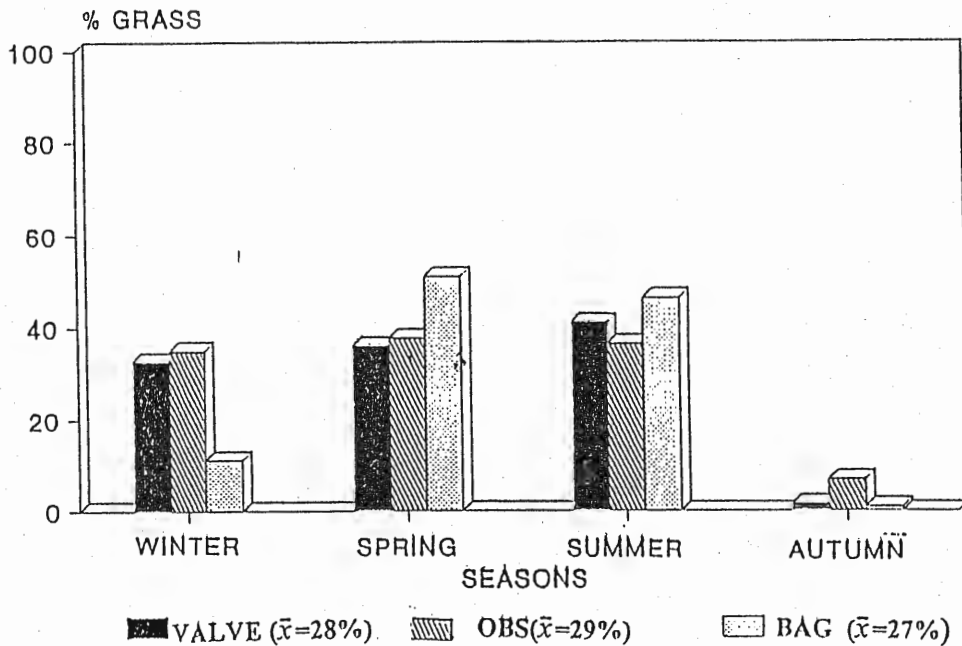
When comparing the two direct sampling methods, significant differences ($P < 0.05$) in the proportion of grass between the fistula bag and fistula valve samples were observed in the HSR treatment. In this treatment the average grass content in the fistula bag samples was 12 % points higher ($P = 0.00$) than that of the fistula valve samples. This difference was highest during spring

HIGH STOCKING RATE



(P= 0.00**)

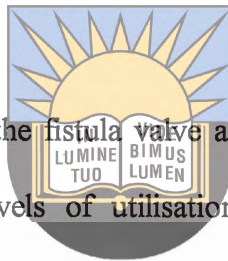
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 LOW STOCKING RATE
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(P> 0.05)

Figure 3. The average daily proportions of grass in the fistula valve and fistula bag samples and time spent grazing during the different seasons as affected by stocking rate.

(27 % points) which is significant ($P = 0.02$) and decreased through winter (20 % points) and summer (7 % points). During autumn, however, the fistula valve samples showed a (9 % point) higher grass content than the fistula bag samples. In the LSR treatment, both fistula methods yielded similar averages. During spring and summer, the fistula bag samples contained more grass (8 and 5 % points, respectively) than the fistula valve samples. This trend was reversed during autumn and winter with the fistula valve samples containing more grass (1 and 20 % points, respectively) than the fistula bag samples. The difference between direct sampling techniques was significant ($P = 0.04$) during winter only.



The average proportions of grass in the fistula valve and fistula bag samples together with the time spent grazing at increasing levels of utilisation, measured in goat browsing days/ha (GBD/ha), within each season and stocking rate are shown in figures 4, 5, 6 and 7.

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Figures 4, 5, 6 and 7 show that differences between techniques in the estimated amount of grass consumed varied considerably, not only between seasons and stocking rates but also with advanced period of occupation. In general, the largest differences between the sampling techniques were found during winter (Fig. 4) and spring (Fig. 5).

Winter: During winter (Fig. 4), contrasting trends in grass consumption were obtained by the three techniques. In general, there appears to be a closer association between the observed grazing frequency and the grass content of fistula valve samples. On average, the grass consumption as estimated by these two methods were 34 % and 29 % in the HSR- and 35 % and

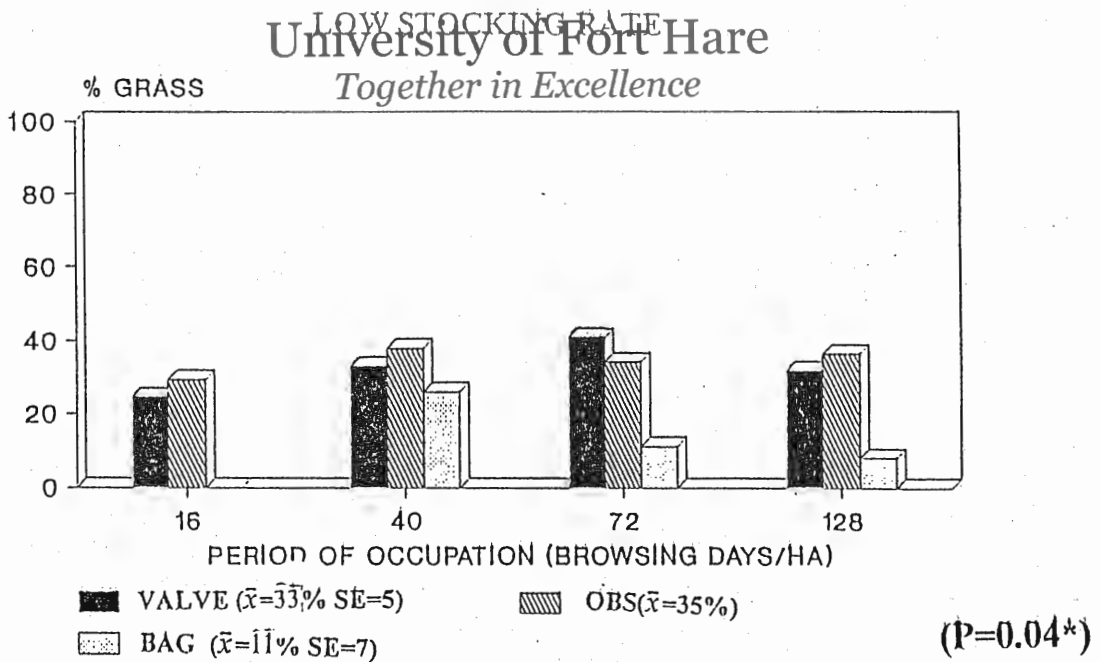
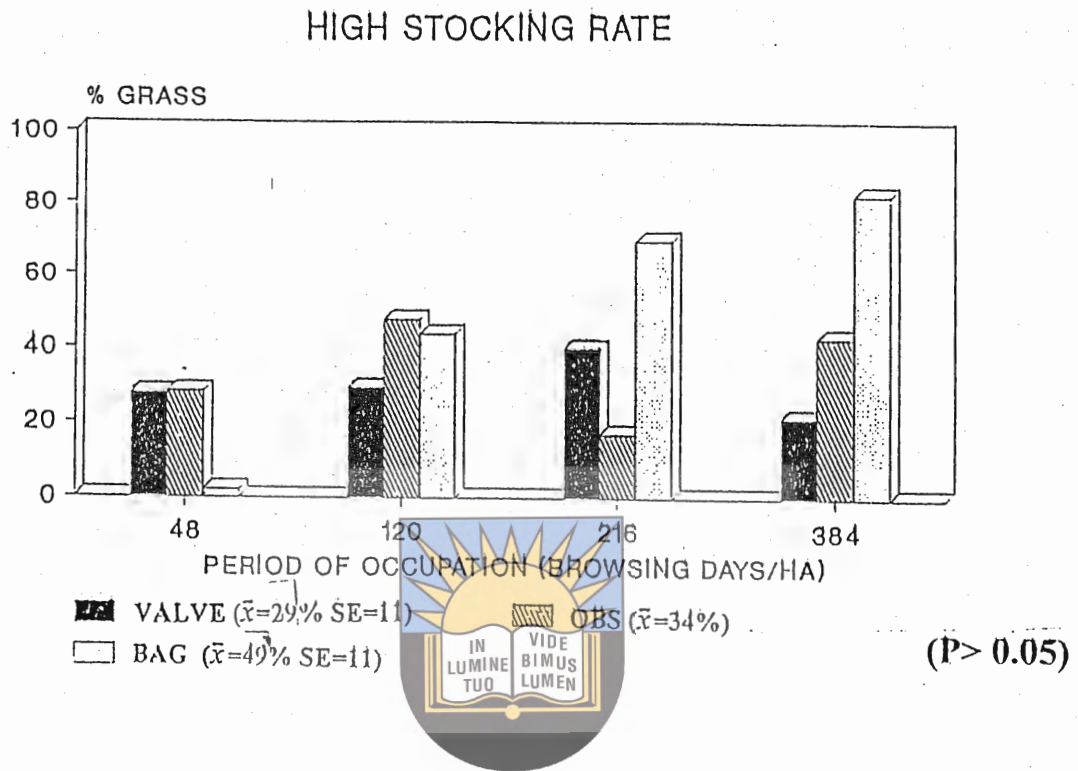
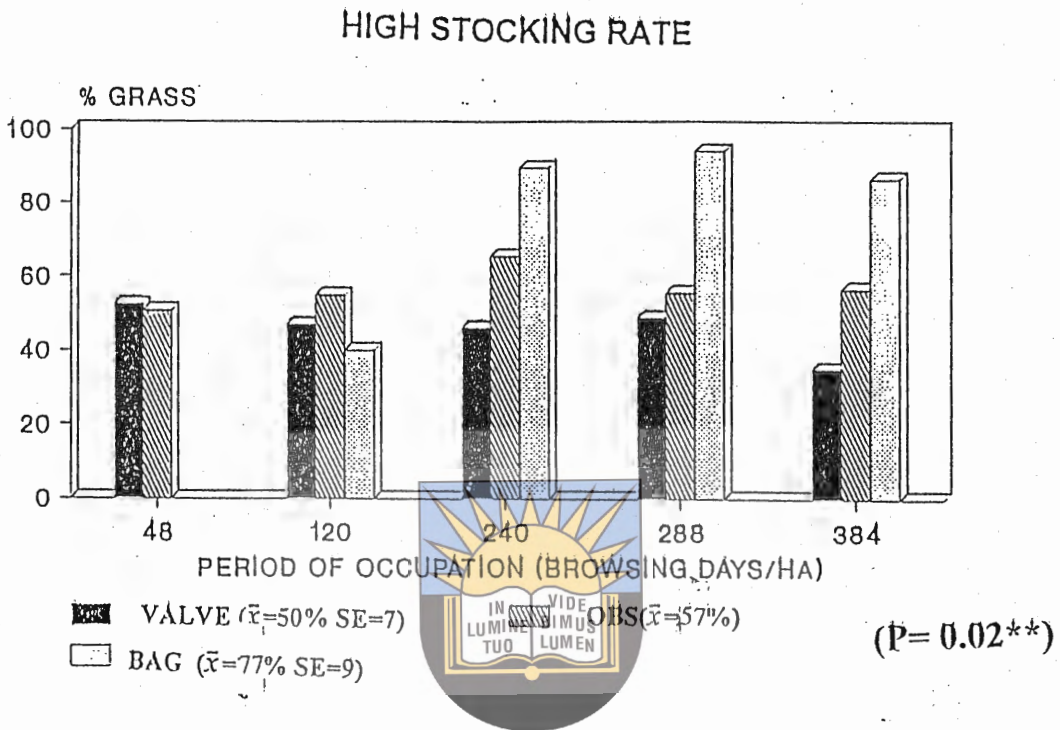


Figure 4. The effect of period of occupation on the average daily proportions of grass in the fistula valve and fistula bag samples and time spent grazing during WINTER in the HSR- and LSR treatments.



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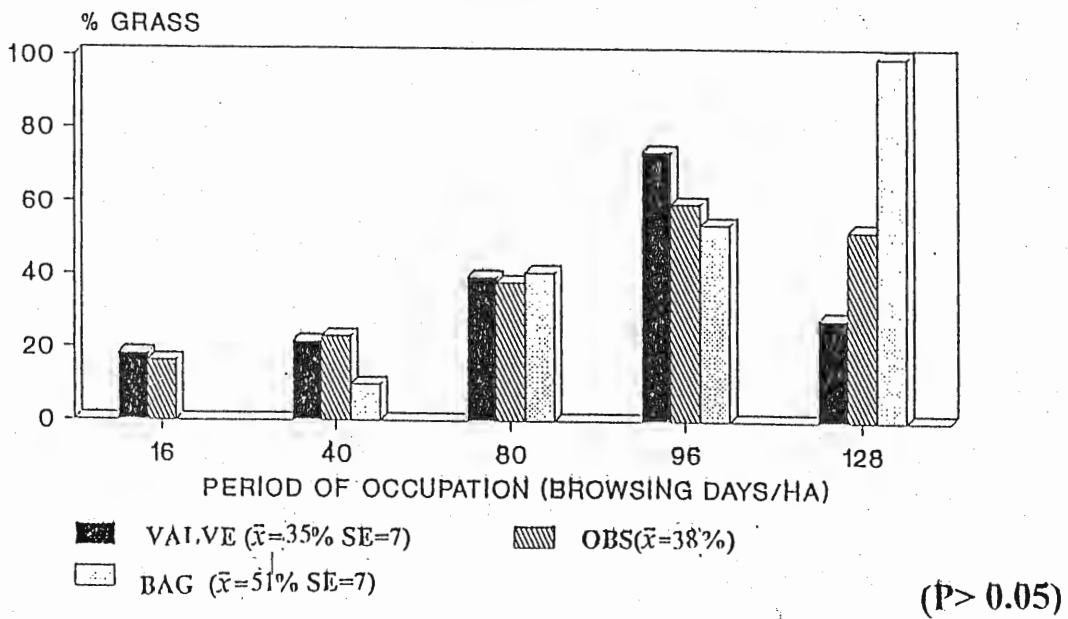
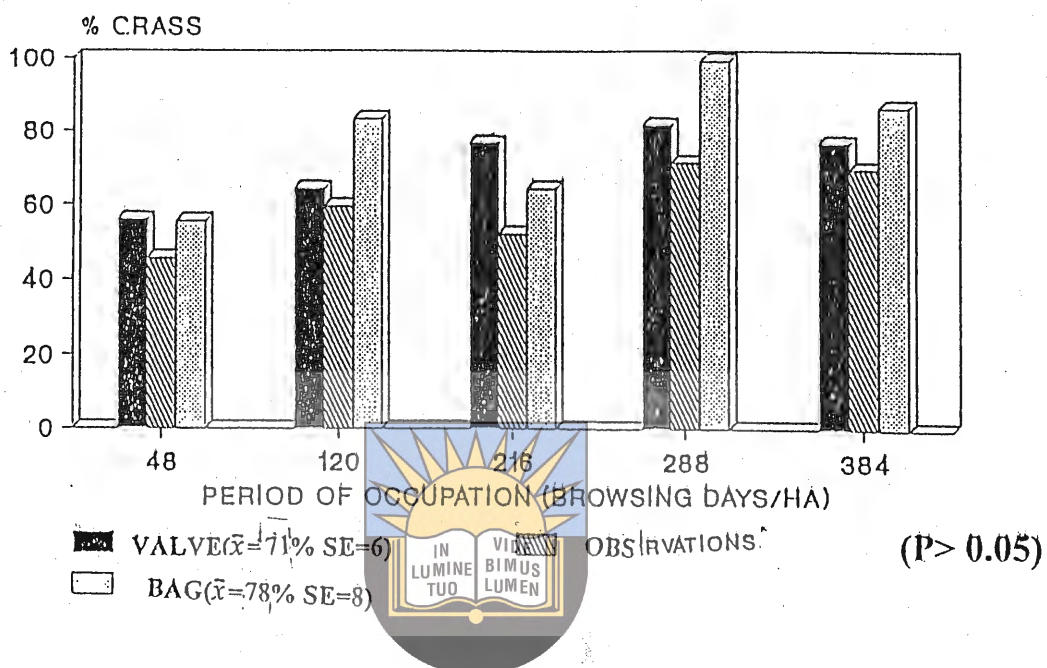


Figure 5. The effect of period of occupation on the average daily proportions of grass in the fistula value and fistula bag samples and time spent grazing during SPRING in the HSR- and LSR treatments.

HIGH STOCKING RATE



LOW STOCKING RATE
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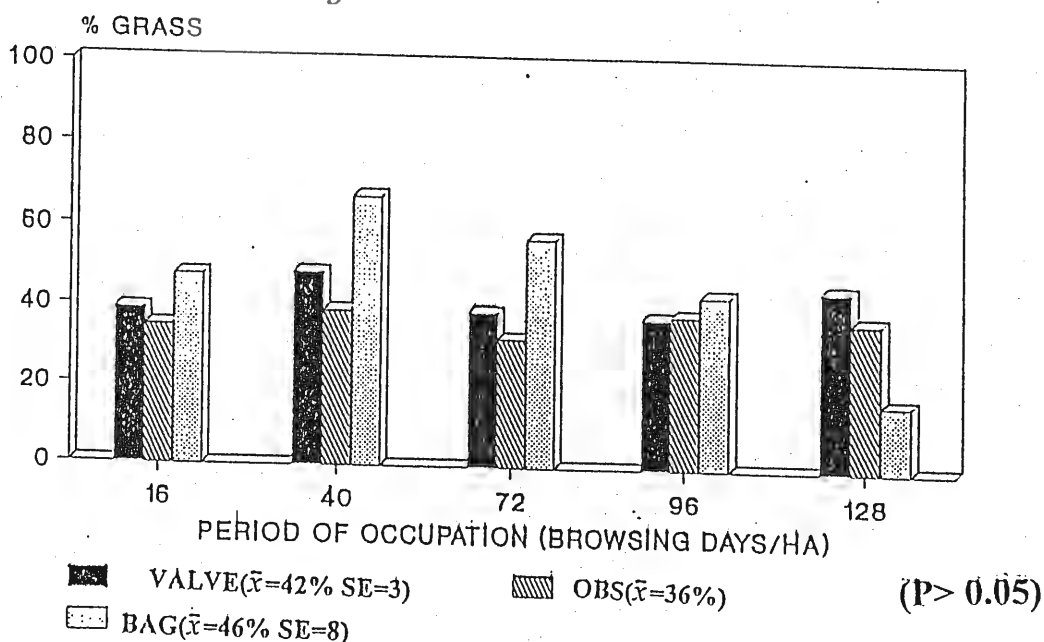
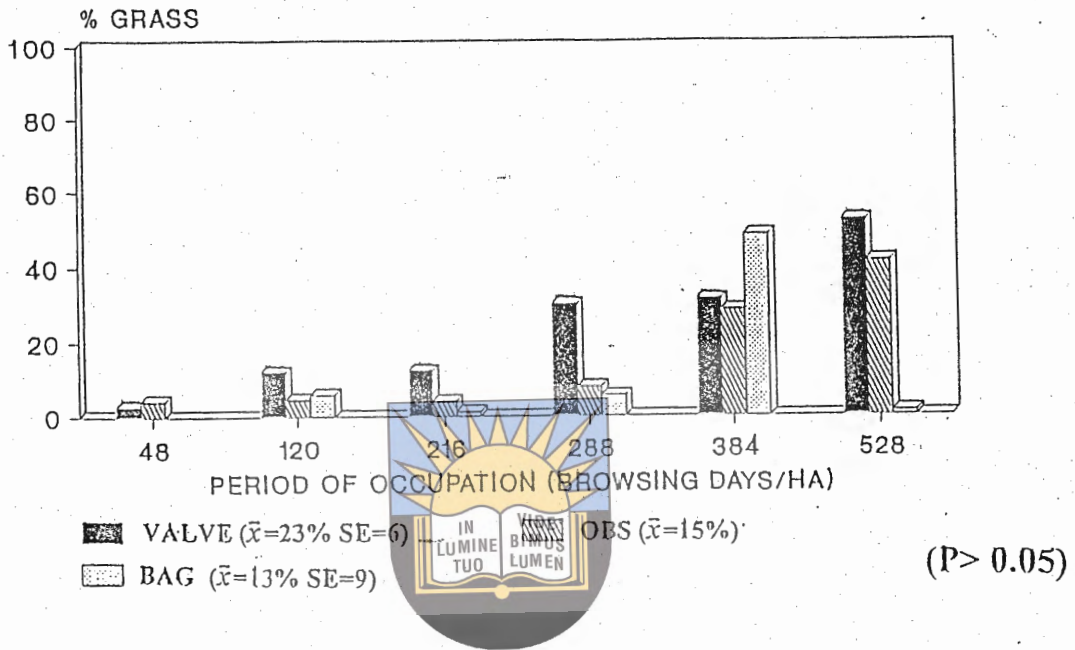


Figure 6. The effect of period of occupation on the average daily proportions of grass in the fistula valve and fistula bag samples and time spent grazing during SUMMER in the HSR- and LSR treatments.

HIGH STOCKING RATE



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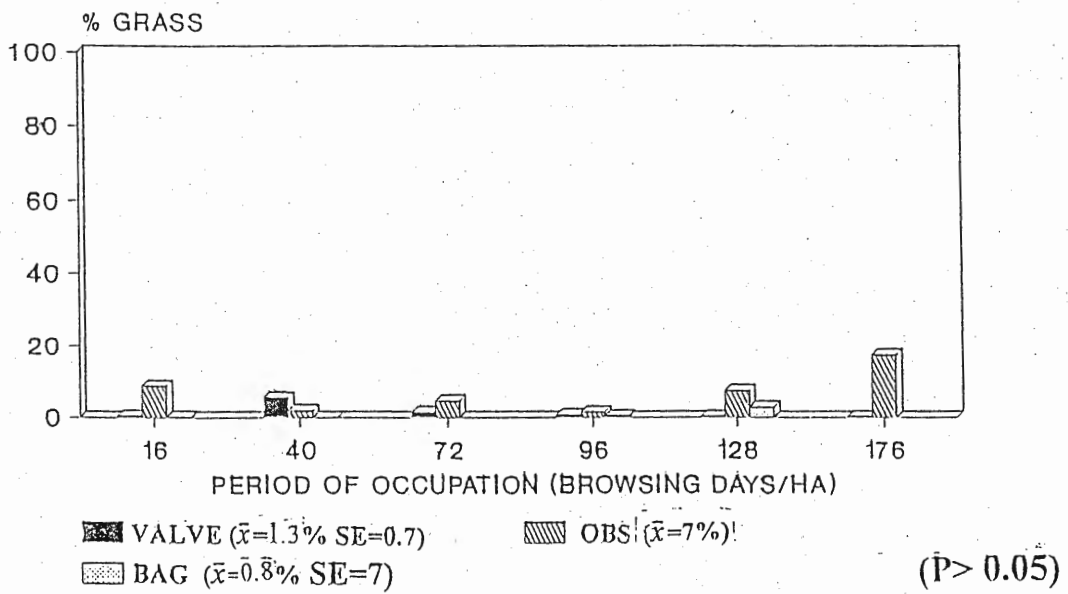


Figure 7. The effect of period of occupation on the average daily proportion of grass in the fistula valve and fistula bag samples and time spent grazing during AUTUMN in the HSR- and LSR treatments.

33 % in the LSR treatments. The fistula bag method, on the other hand, indicates higher consumption of grass (49 %) in the HSR treatment and a significantly ($P = 0.04$; Fb vs. Fv) lower consumption (11 %) in the LSR treatment. According to the fistula bag technique, grass consumption increased almost linearly from 4 % to 80 % towards the end of the HSR-grazing/browsing period, compared with the fistula valve and observation technique's higher initial values which level off or decrease towards the end. In the LSR-treatment, the fistula bag technique indicated a greater reduction in grass consumption as a result of increased period of occupation compared to a flatter curve obtained by the other two methods. The results from both the fistula valve and observation techniques correspond well at similar levels of grazing/browsing pressure in both the HSR- (120 GBD/ha) and LSR- (128 GBD/ha) treatments. A substantial difference (44 % and 8 %) in grass consumption was, however, measured by the fistula bag method at 120 GBD/ha (HSR) and 128 GBD/ha (LSR).



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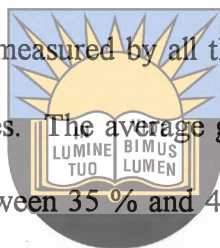
Spring: Due to the contamination of bag samples with rumen ingesta, no data for the fistula bag technique was obtained on the first sampling day in both the spring stocking rate treatments (Fig. 5). Based on the averages, it appears that a close association exists between the observed grazing frequency and the grass content of fistula valve samples in the HSR- (57 % & 50 %) while the fistula bag method indicated substantial higher (77 %) grass consumption. The difference of 28 percentage points in the grass content between the two direct sampling methods (Fv vs. Fb) was highly significant ($P = 0.02$). In the LSR treatment, grass consumption was estimated by all three techniques within 10 % of each other and no significant difference could be found ($P > 0.05$). Differences between techniques (max. 70 % points) on different sampling days were more

prominent during the latter parts of the grazing/browsing periods in both stocking rate treatments. Grass consumption as measured by both the fistula valve and fistula bag techniques at similar levels of grazing/browsing pressure in the two stocking rate treatments (HSR: 120 and LSR 128 GBD/ha) were poorly correlated, with differences of 20 % and 60 %, respectively. On the other hand, time spent grazing as observed on these days was much more similar (55 % & 51 %).

Summer: During summer (Fig. 6), in both the HSR- and LSR treatments, the average consumption of grass as measured by the fistula bag method (78 % & 46 %) was marginally ($P > 0.05$) but consistently higher than the fistula valve (71 % & 42 %) and the observation methods (60 % & 36 %). Compared to winter and spring, differences between techniques on different sampling days were also smaller. However, substantial differences in grass consumption, as measured by all three techniques at similar levels of grazing/browsing pressure in the two stocking rate treatments were poorly correlated in the same level of forage utilisation in both the HSR- (120 GBD/ha) and LSR- (128 GBD/ha) treatments, the difference in grass consumption as measured by the fistula bag, fistula valve and observation methods were 70, 20 and 23 percentage points, respectively.

Autumn: On average, grass consumption as measured by the fistula bag corresponds well with the time spent grazing (13 % & 15 %, respectively) in the HSR treatment compared to the 23 % obtained by the fistula valve method. The higher estimate of grass consumption by the fistula valve method is also contrary to the results found during winter (HSR), spring (HSR & LSR) and summer (HSR & LSR) when the fistula bag estimates were higher. Although minimal amounts of

grass in extrusa samples, and time spent grazing were observed in the LSR treatment during autumn, all three sampling methods were relatively consistent throughout the period. Except for the fistula valve method, the grass consumption at similar levels of grazing/browsing pressure in both the HSR- (120 GBD/ha) and LSR- (128 GBD/ha) treatments as measured by the fistula bag and observation techniques, corresponds well. A difference of 10 percentage points in grass consumption at 120 GBD/ha (HSR) and 128 GBD/ha (LSR) was measured by the fistula valve method.



The estimates on grass consumption as measured by all three techniques in this study are within the expected range found in other studies. The average grass consumption (including forbs) for the three different techniques varied between 35 % and 40 % and agrees well with the generally accepted figure of 40 %. On a year-long basis, goats were found to select about 60 % bush, 30 % grass and 10 % forbs (Malecheck and Provenza, 1981). Similar results were obtained with Boer goat ewes on False Thornveld of the Eastern Cape (Raats, 1997). These animals spent on average 61 % and 39 % of their active feeding time browsing and grazing (including forbs), respectively.

The effect of season, stocking rate and period of occupation on the feeding behaviour of goats is well documented. Winter is characterised by forages low in digestibility and nutrients, but high in fibre and chemical defences (Danckwerts & Teague, 1989; Palo *et al.*, 1992). As a result of the seasonal changes in the vegetation, Raats (1996) found that the percentage time (active feeding) that goats spent grazing varied from as low as 14 % in January to as high as 73 % in June. This

trend is, however, not static and may change drastically due to the amount and distribution of rainfall and the occurrence of frost. In this regard, Bjelland & Grøva (1997) found, during a study with Boer and Indigenous goats in False Thornveld of the Eastern Cape, that the time spent grazing during July to be substantially lower (48 % grazing) than that recorded by Raats (1997). In the present study the average grass consumption (techniques combined) increased from about 30 % during winter to over 50 % during spring and summer and decreased to less than 10 % during autumn. Except for spring, these figures differ markedly from the 73 %, 49 %, 40% and 35 % time spent grazing during the same seasons recorded by Raats (1996).

4.1.1. Relationship between grass in oesophageal fistula samples and time spent grazing.



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The relationship between the observed grazing frequency (% of active feeding time) and the proportion (% DM) of grass in the fistula bag and fistula valve samples is shown in Figures 8 and 9, respectively. Although the R^2 values are relatively low, it seems that of the two direct sampling methods, the fistula valve technique provides a more realistic estimate (R^2 of 0.73 vs. 0.61) of the observed feeding behaviour over a wide range of grazing : browsing ratios.

From figure 8 it is clear that the relationship between the fistula bag and observed grazing frequency is not linear. This figure suggests that at low levels of observed grazing frequency the fistula bag may under-estimate grass consumption whereas the opposite seems true at high levels of observed grazing frequency. The coefficients of variation obtained for the fistula bag method

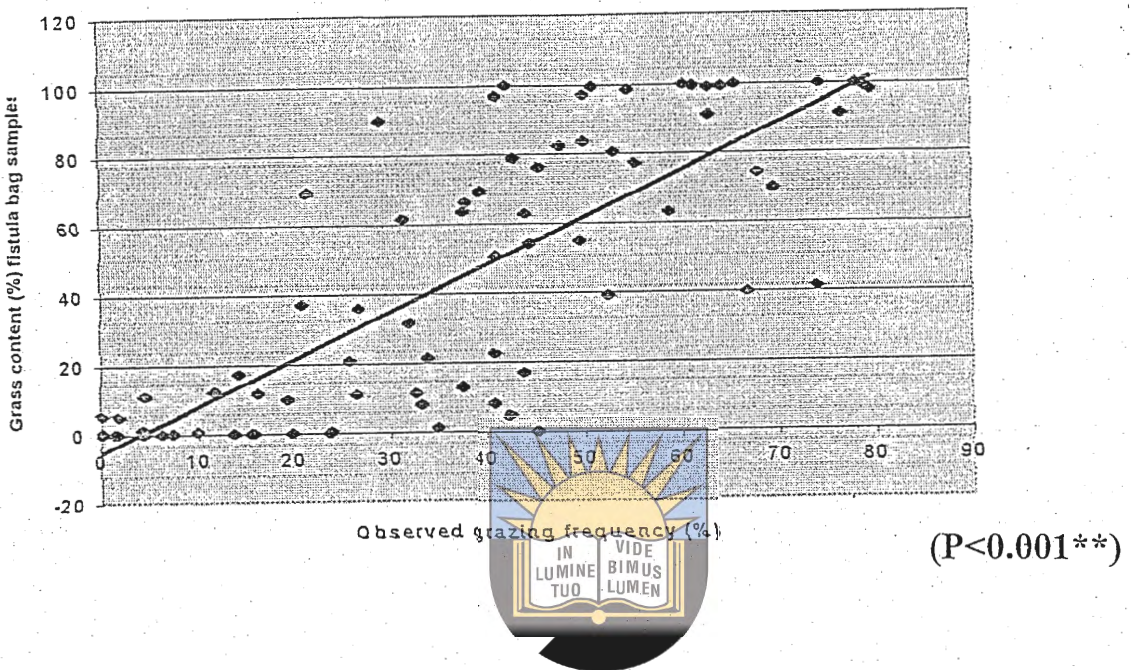


Figure 8. Relationship between observed grazing behaviour and grass content of fistula bag samples. [$R^2 = 61.3$; $SE = 24.5$]

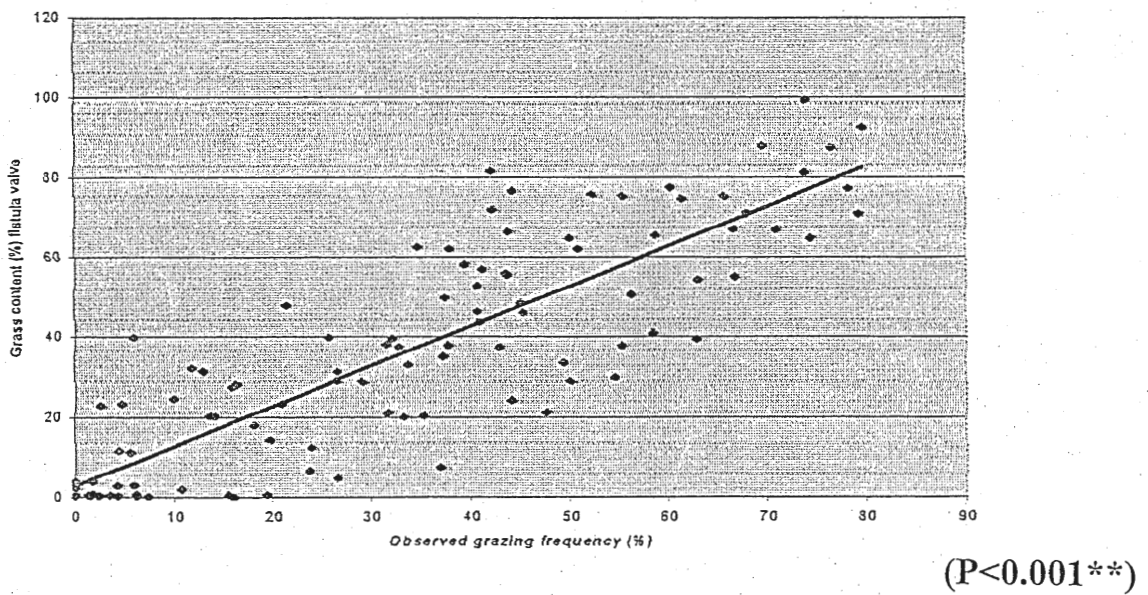


Figure 9. Relationship between observed grazing behaviour and grass content of fistula valve samples. [$R^2 = 72.8$; $SE = 14.4$]

(observational vs. fistula bag method $R^2 = 0.61$) is similar to the 0.63 (R^2) reported by Raats (1993), while that of the fistula valve method (observational vs. fistula valve method $R^2 = 0.73$) is considerably less than the 0.90 (R^2) reported by the same author. One possible explanation for this discrepancy is the shorter time intervals between behavioural observations (2 min.) and fistula valve samples (30 min.) in the quoted study compared to the respective four and 60 minute intervals used in the present study.

4.2. CHEMICAL COMPOSITION OF THE FISTULA BAG AND VALVE SAMPLES

Although this study was repeated during the four seasons of the year, the extended drought (spring) and the above average rainfall during summer and autumn (Fig. 1), effectively divided the study period into two distinct periods, namely a dry period (winter and spring) and a wet period (summer and autumn). The changes in the chemical composition of the diet as selected by goats during the dry and wet periods (pooled over all treatments) are shown in Table 2.



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Table 3. Chemical composition of oesophageal fistula samples in the dry (winter & spring) and wet (summer & autumn) periods.

Component	Dry period (% \pm SE)	Wet period (% \pm SE)	F Probability
CP	9.94 \pm 0.27	14.05 \pm 0.33	P < 0.001
NDF	51.21 \pm 0.85	49.18 \pm 0.51	P = 0.034
ADF	35.18 \pm 0.68	32.79 \pm 0.49	P = 0.004
ADL	14.29 \pm 0.55	13.81 \pm 0.53	P = 0.535

Against expectations, only small differences, though significant, in NDF, ADF and ADL (percentage points) were found in the extrusa samples between the dry and wet periods. On the other hand, the CP content of extrusa samples increased by about four percentage points during the wet period. Except for ADL, all these differences were significant ($P < 0.05$).

The effect of the fistula bag and valve techniques on the chemical composition of extrusa samples during different seasons and stocking rates is shown in Figure 10. According to Figure 10, the CP, NDF and ADF contents of the fistula bag samples were consistently higher than the fistula valve samples during all four seasons and two stocking rates. The only exceptions to this trend were found in ADL content during spring and in the HSR treatment. When sampling methods were compared in each of the four seasons, significant differences were found in CP, NDF, ADF ($P < 0.01$) and ADL ($P < 0.05$). When compared in two stocking rate treatments, sampling methods differed also significantly in CP, ADF ($P < 0.05$) and NDF ($P < 0.01$) while the difference in ADL was not significant.

4.2.1. Crude Protein

On average, the crude protein content of extrusa samples (pooled over all treatments and methods) varied significantly ($P < 0.001$) between seasons (winter: 11.71 % SE=0.39; spring: 8.66 % SE=0.24; summer: 16.89 % SE=0.27, autumn: 11.34 % SE=0.18). When the sampling methods are compared separately in the high and low stocking rate treatments, a highly significant difference ($P = 0.01$) between methods was found in the LSR treatment during spring. There was also a highly significant difference between the two sampling methods ($P = 0.00$) on specific

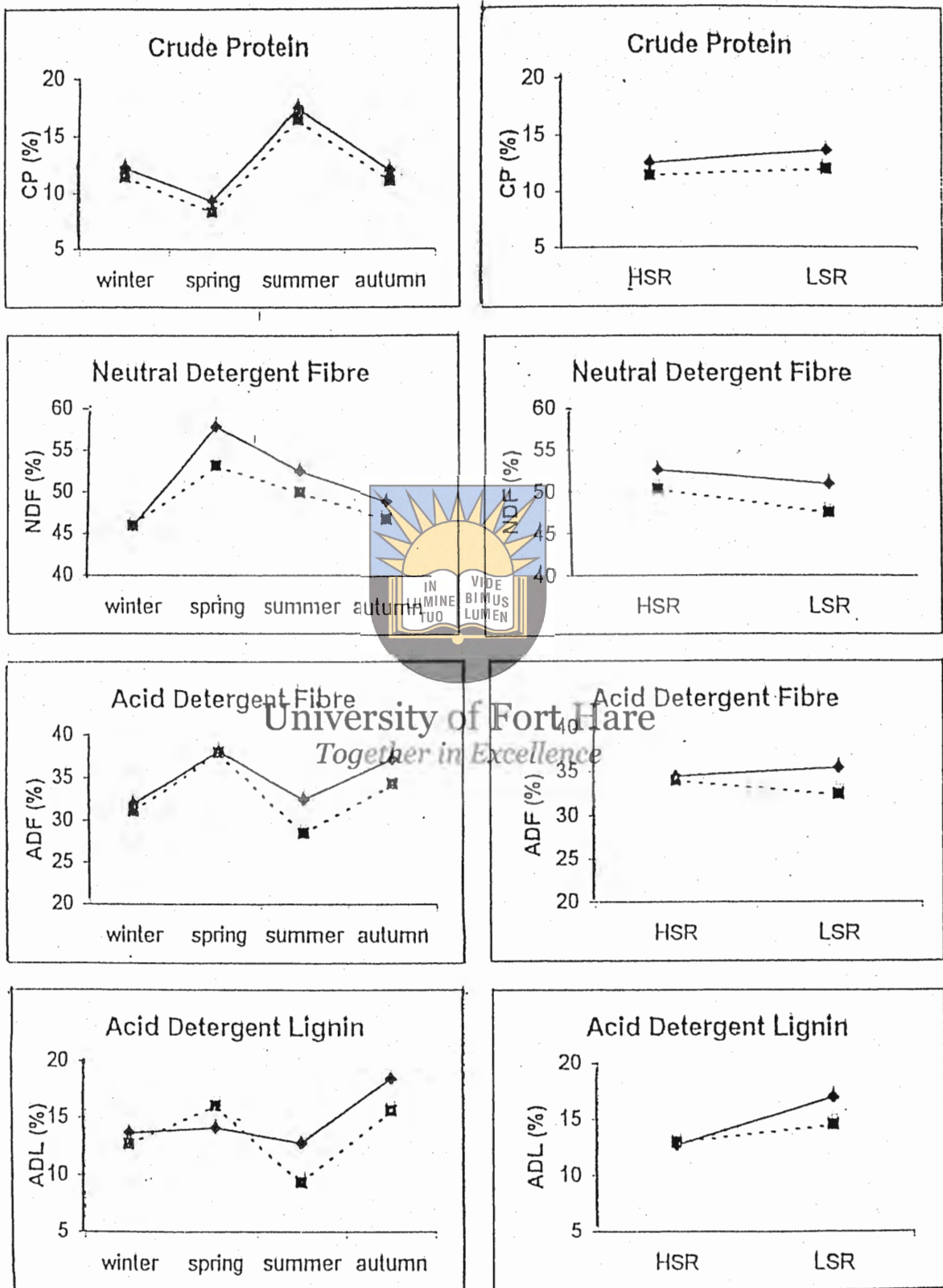


Figure 10. The effect of the fistula valve [■] and the bag techniques [◆] on the chemical composition of extrusa samples during different seasons and stocking rates.

sampling days as affected by stocking rate. It is also interesting to note that in spite of the high grazing/browsing intensity in the HSR treatment (384 GBD/ha), the only significant effect of period of occupation on crude protein was found during Winter ($P = 0.02$) and Autumn ($P = 0.00$).

The average crude protein content of fistula bag and valve samples during the four seasons and two stocking rates is shown in Figure 11.

Winter: On average, the crude protein content of the fistula bag and valve samples collected in the HSR treatment were 11 % and 10 %, respectively. In the LSR treatment, the average crude protein content of both the fistula bag and valve samples was the same, namely 12 %. Both techniques showed a decline in the CP content of extrusa samples with advancing period of occupation. This decline was highly significant ($P = 0.02$) in the HSR treatment. The CP content of both the fistula bag (14 % and 14 %) and fistula valve (11.66 % and 11.50 %) samples compare well at similar levels of grazing/browsing pressure in the HSR- (120 GBD/ha) and LSR- (128 GBD/ha) treatments.

Spring: In the HSR treatment, the average crude protein content of the bag and valve samples were 8 % and 9 %, respectively. This one percentage point difference is not significant. On the other hand, in the LSR treatment, the average difference in the crude protein content between the bag (11 %) and valve samples (9 %) was highly significant ($P = 0.01$). In contrast to the winter results, no significant difference in crude protein content was found between days during the

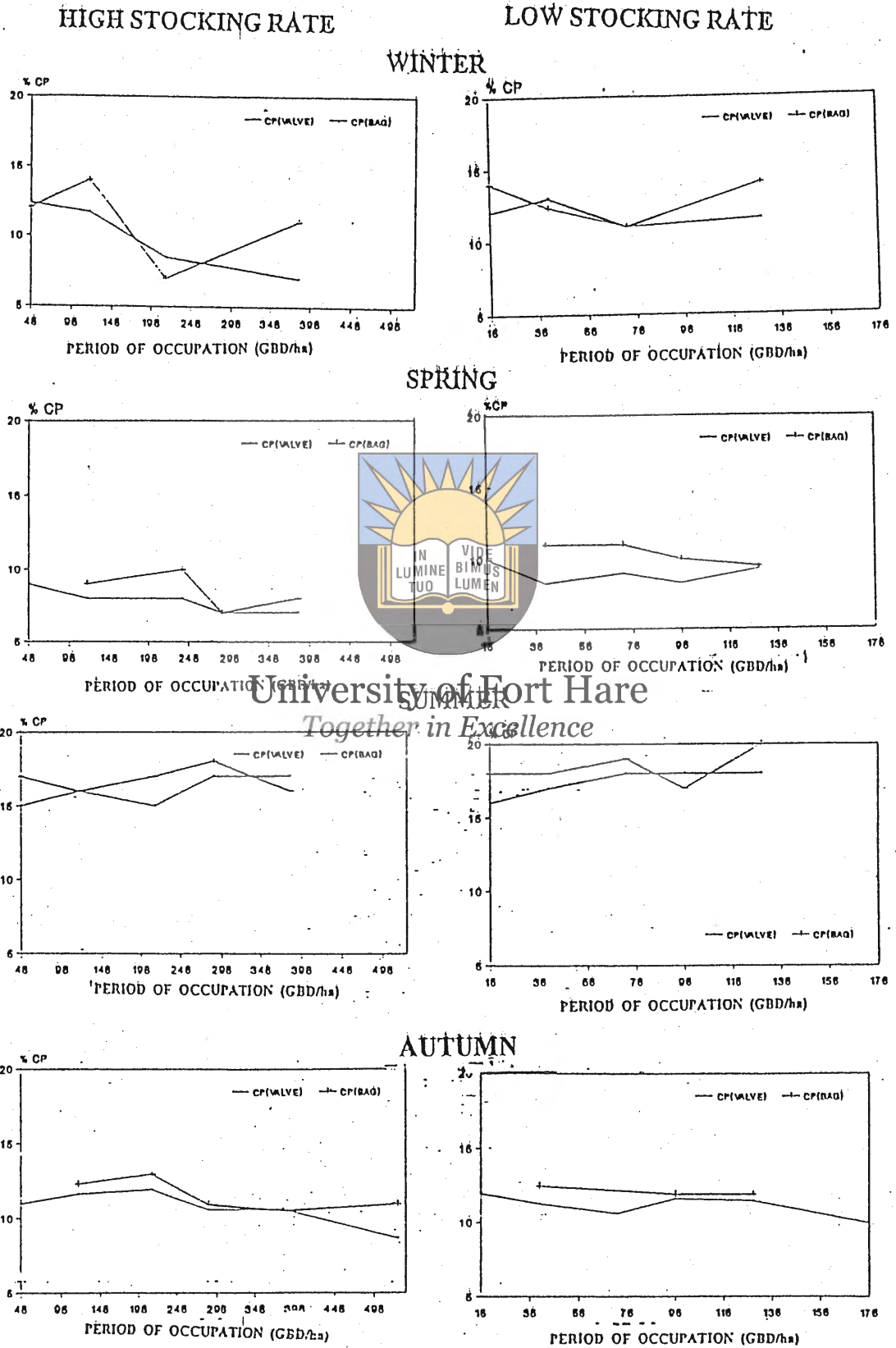
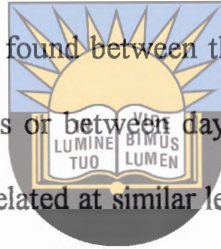


Figure 11. Average CRUDE PROTEIN content of fistula bag and valve samples during four seasons and two stocking rates.

spring replicate. The CP content of both the fistula bag (9.00 % and 9.50 %) and valve (8.00 % and 9.03 %) samples compares reasonably well at similar levels of grazing/browsing pressure in the HSR- (120 GBD/ha) and LSR- (128 GBD/ha) treatments.

Summer: No significant difference in CP content was found between the two sampling methods in either of the two stocking rate treatments. In the HSR treatment, the average crude protein content of the bag and the valve samples were 17 % and 16 %, respectively. In the LSR treatment the average CP content as measured by the respective techniques were 18 % and 17 %. Also, no significant difference could be found between the crude protein content of the bag and valve samples on specific sampling days or between days. The CP content of the fistula valve (15.54 % and 17.78 %) was better correlated at similar levels of grazing/browsing pressure in the LSR- (128 GBD/ha) treatments compared to a slightly bigger difference in the bag samples (16.46 % and 20.22 %).

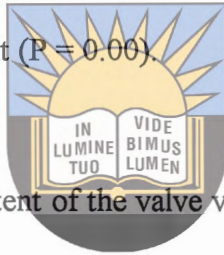


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Autumn: In the HSR treatment, the average crude protein content of the bag and the valve samples were the same, namely, 11 % and not significantly different. In the LSR treatment the average crude protein content of the bag and valve samples were 12 % and 11 %, respectively with no significant difference. On specific sampling days, however, highly significant differences in the crude protein content were found between the two sampling methods ($P = 0.00$). The CP content of both the fistula bag (12.33 % and 12.00 %) and valve (11.66 % and 11.55 %) samples compare well at similar levels of grazing/browsing pressure in the HSR- (120 GBD/ha) and LSR- (128 GBD/ha) treatments.

4.2.2. Neutral Detergent Fibre (NDF)

The average NDF content of extrusa samples, pooled over all treatments, varied by about 10 percentage points over the four seasons (winter: 45.81 %, SE=0.99; spring: 55.08 %, SE=0.91; summer: 51.08 %, SE=0.62; autumn: 47.36 %, SE=0.72), though no significant differences were found between seasons. As is the case with crude protein, the two sampling methods were found to be different ($P < 0.01$) in NDF content, but only during spring in the LSR treatment ($P = 0.01$) and during summer in the HSR treatment ($P = 0.00$).



The average neutral detergent fibre content of the valve versus that of the bag samples during the four different seasons and two stocking rates are shown in Figure 12.

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Winter: HSR treatment, the average NDF content of the fistula bag and valve samples was the same (46 %). Similarly, in the LSR treatment the average NDF content was the same for both sampling methods (46 %). Both techniques showed an increase in the NDF content of extrusa samples with advancing period of occupation. This increase was highly significant ($P = 0.02$) in the HSR treatment. The NDF content of both the fistula bag (43.30 % and 49.29 %) and fistula valve (44.89 % and 47.86 %) samples do not compare well at similar levels of grazing/browsing pressure in the HSR- (120 GBD/ha) and LSR- (128 GBD/ha) treatments.

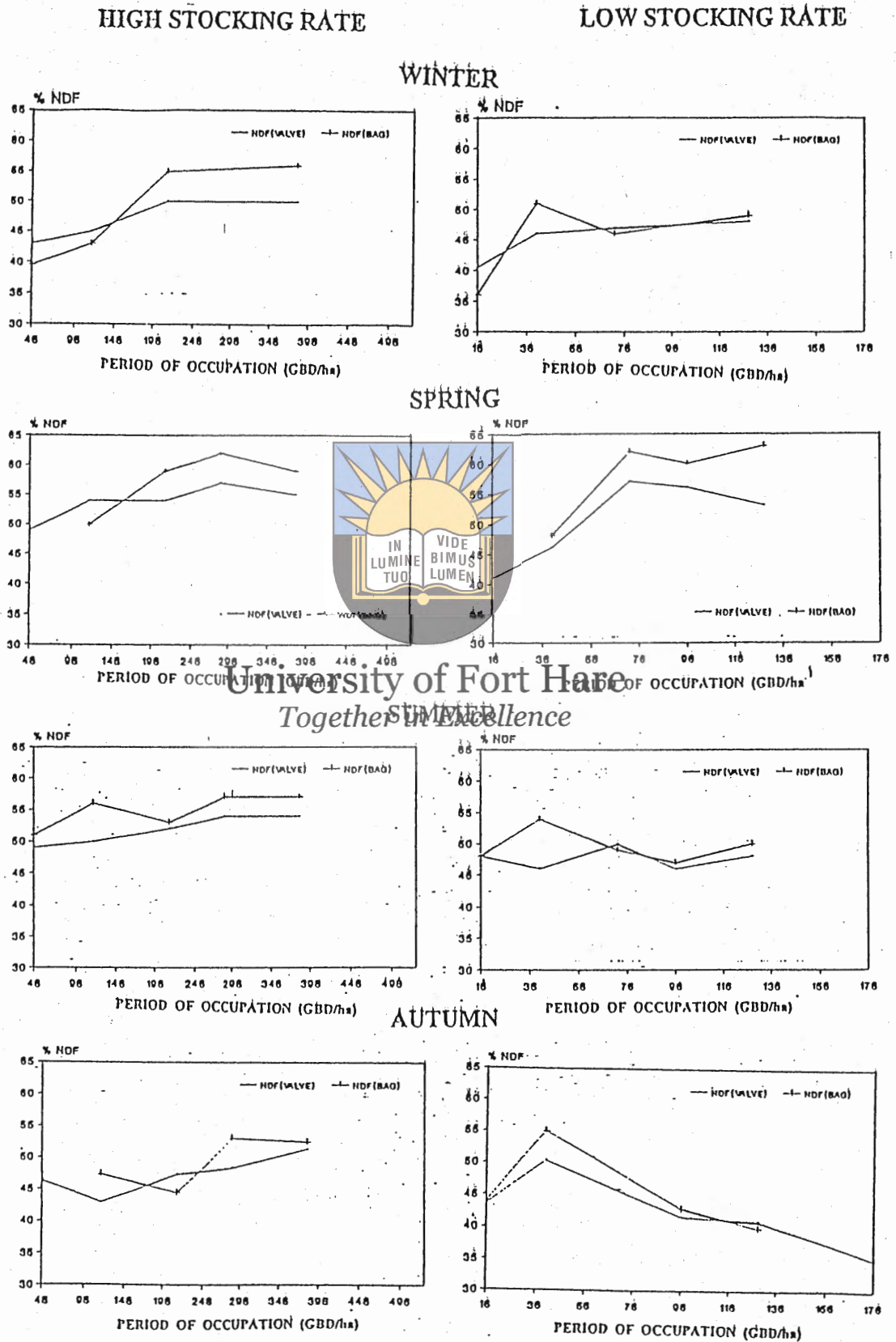


Figure 12. Average NEUTRAL DETERGENT FIBRE content of fistula bag and valve samples during four seasons and two stocking rates.

Spring: Results from the HSR treatment indicate a lower NDF average for the fistula bag samples (53 %) compared to the valve samples (56 %) but with no significant difference. On the other hand, in the LSR treatment, the average NDF content of the bag samples (56 %) was significantly higher ($P = 0.01$) than that of the valve samples (51%). Similar to the winter season, both techniques showed an increase in the NDF content of extrusa samples with advancing period of occupation. Against expectations, this increase was more pronounced in the LSR- than in the HSR treatment. This increase was also highly significant ($P = 0.02$) in the LSR treatment. The NDF content of the fistula valve (53.58 % and 52.96 %) samples are closely related at similar levels of grazing/browsing pressure in the HSR- (120 GBD/ha) treatments, compared to a considerable difference in the bag samples (50.07 % and 63.00 %).



Summer: In both the HSR- and the LSR- treatments, the average NDF content of the fistula bag samples (56 % HSR, 50 % LSR) were higher than the valve samples (50 % HSR, 48 % LSR). This difference between the two sampling methods was only significant ($P = 0.01$) in the HSR treatment. In the HSR treatment, both techniques show a slight but not significant increase in NDF with advancing period of occupation. Similar to the spring results, the NDF content of fistula valve samples (50 % and 48 %) were better correlated than the bag samples (56 % and 50 %) at similar levels of grazing/browsing pressure in the HSR- (120 GBD/ha) and LSR- (128 GBD/ha) treatments.

Autumn: Similar to the summer results, NDF contents of fistula bag samples (50 % HSR, 43 % LSR) were higher than the valve samples (48 % HSR, 41 % LSR). The small differences

between the two sampling techniques were, not significant. In the HSR treatment, both techniques showed an increase in NDF content with advancing period of occupation. In the LSR treatment after an initial increase, both techniques show a sharp decrease in NDF over time. This initial increase was also highly significant ($P = 0.02$) in the LSR treatment. At similar levels of grazing/browsing pressure in the HSR- (120 GBD/ha) and LSR- (128 GBD/ha) treatments, the NDF content of both the fistula valve (43 % and 41 %) samples were better correlated compared to a slightly bigger difference in the fistula bag (47 % and 40 %) samples.

4.2.3. Acid detergent Fibre (ADF)



The average ADF content of extrusa samples, pooled over treatments, varied by about 6 percentage points over the four seasons (winter: 31.39 %, SE=0.78; spring 37.90 %, SE=0.83; summer 30.35 %, SE=0.59; autumn 35.14 %, SE=0.61). No significant difference was found between seasons. Significant difference ($P < 0.05$) between the fistula bag and valve sampling methods was found in the low stocking rate treatments only (summer: 31.63 % and 27.62 %; autumn: 38.00 % and 32.55 %, respectively).

The average acid detergent fibre content of the valve versus that of the bag samples during the four different seasons and two stocking rates are shown in Figure 13.

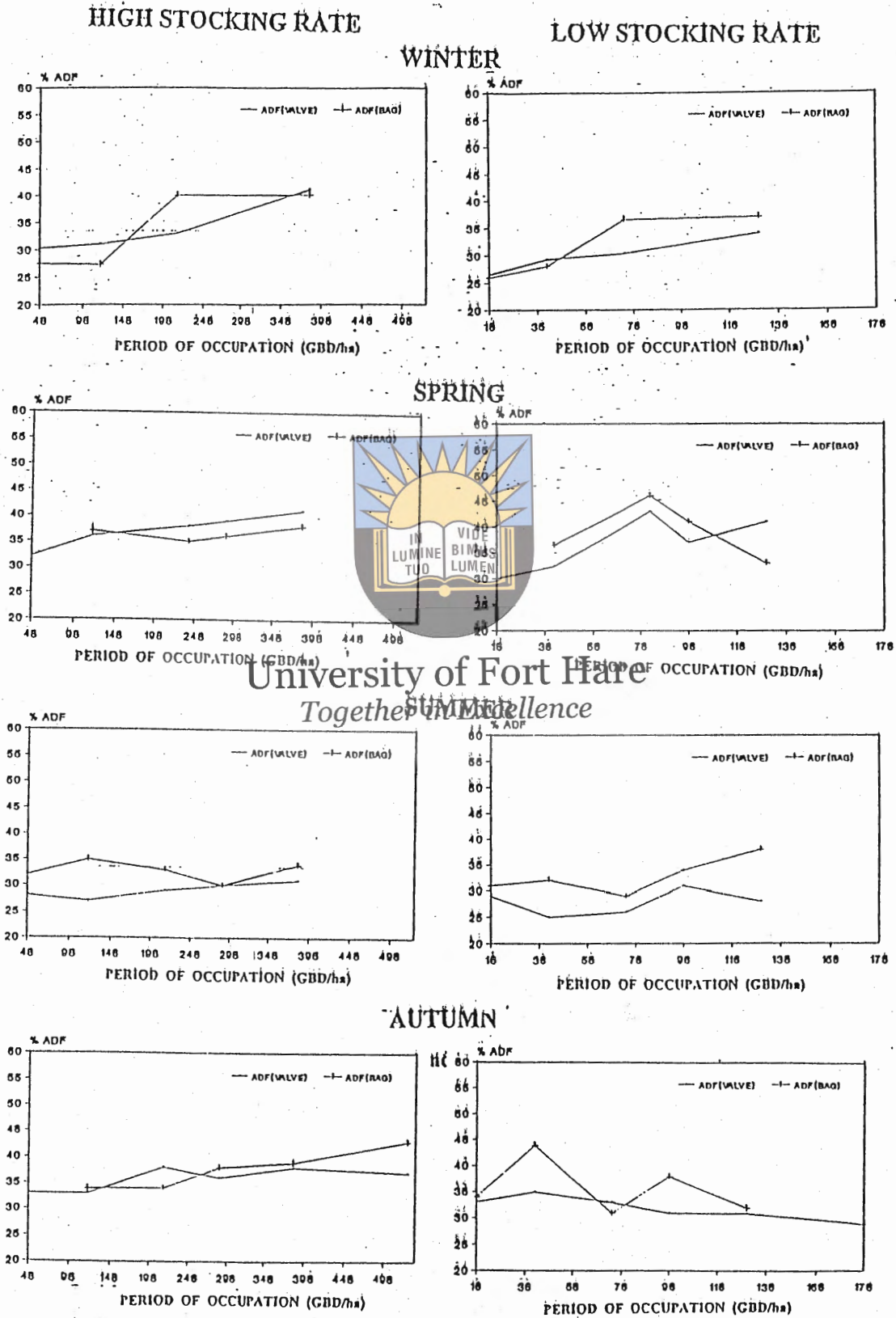


Figure 13. Average ACID DETERGENT FIBRE content of fistula bag and valve samples during four seasons and two stocking rates.

Winter: HSR treatment, the average ADF content of the fistula bag and valve samples were very similar (31 % and 32 %). This difference increased slightly in the LSR treatment (33 % and 30 %, respectively) with the fistula bag showing the highest ADF content. Both techniques showed an increase in the ADF content of extrusa samples with advancing period of occupation. This increase was highly significant ($P = 0.02$) in the HSR treatment. The ADF content of the fistula valve (31.13 % and 33.97 %) samples are better related at similar levels of grazing/browsing pressure in the HSR- (120 GBD/ha) and LSR- (128 GBD/ha) treatments compared to a considerable difference in the bag samples (27.33 % and 37.00 %).



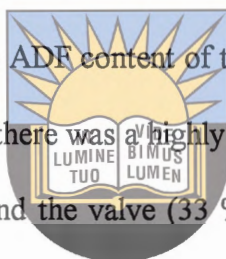
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Spring: The average ADF content of the fistula bag and valve samples were also similar in the HSR- (37 % and 38 %) and the LSR (40 % and 38 %) treatments. No significant difference was observed. In the HSR treatment, both techniques showed a slight increase in the ADF content of extrusa samples with advancing period of occupation, while in the LSR treatment, the fistula bag in particular, showed a major decrease after 72 GBD/ha. The ADF content of both the fistula bag (37 % and 33 %) and fistula valve (36 % and 41%) do not compare well at similar levels of grazing/browsing pressure in the HSR- (120 GBD/ha) and LSR- (128 GBD/ha) treatments.

Summer: The average ADF content of the bag and the valve samples in the HSR treatment were 33 % and 29 %, respectively. The difference of 4 % points was however not significant. Similarly, in the LSR treatment the difference of 4 % points in the average ADF content of the bag (32 %) and valve samples (28 %) was also not significant. In the HSR treatment, both sampling methods showed a slight increase in the ADF content of extrusa samples with advancing

period of occupation. In the LSR treatment, the fistula valve showed an increase in the ADF content of extrusa samples after (72 GBD/ha) while the bag showed an increase in the ADF content of extrusa samples at an earlier stage of occupation (40 GBD/ha) followed by a slight decrease after 96 GBD/ha. The ADF content of the fistula valve samples (27 % and 28 %) are better related at similar levels of grazing/browsing pressure in the HSR- (120 GBD/ha) and LSR- (128 GBD/ha) treatments than the bag samples (35 % and 38 %).

Autumn: HSR treatment, the average ADF content of the bag and valve samples were the same, namely 36 %). In the LSR treatment, there was a highly significant difference ($P = 0.01$) between the ADF content of the bag (38 %) and the valve (33 %) samples. In the HSR treatment both sampling methods showed a slight increase in the ADF content of extrusa samples with advancing period of occupation. In contrast, the LSR results indicate a slight decline in the average ADF content of the two sampling methods with advancing period of occupation. Similar to winter and summer results, the ADF content of the valve samples (33 % and 31 %) are slightly better correlated than the bag samples (34 % and 38 %) at similar levels of grazing/ browsing pressure in the HSR- (120 GBD/ha) and LSR- (128 GBD/ha) treatments.



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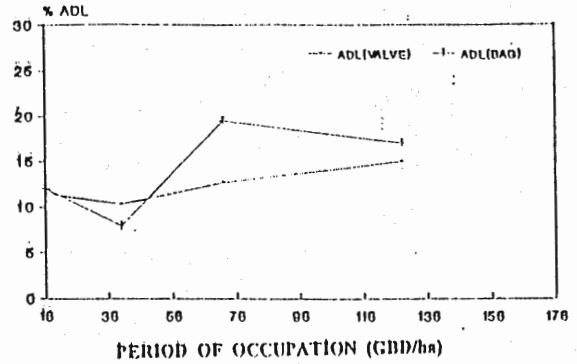
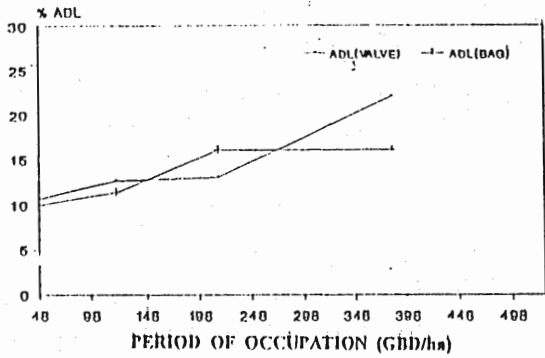
4.2.3. Acid Detergent Lignin (ADL)

The ADL content of extrusa samples, pooled over treatments varied by about 9 percentage points over four seasons (winter:12.46 %, SE=0.61; spring:30.37 %, SE=0.81; summer:21.56%, SE=0.68; autumn:16.93 %, SE=0.59), though no significant differences was found between seasons. Significant differences between the two sampling methods were found in Winter (LSR), Spring (HSR), Summer (LSR) and Autumn LSR. The average acid detergent lignin content of the valve versus that of the bag samples during the four different seasons and two stocking rates are shown in Figure 14.

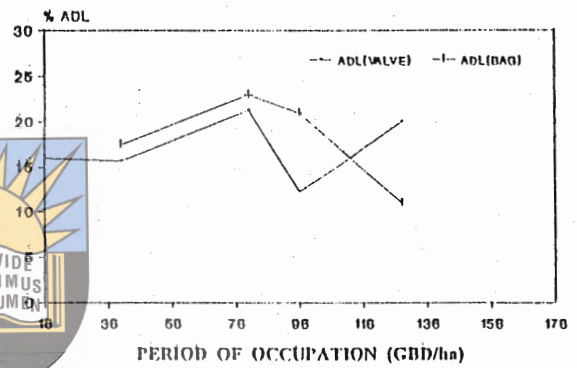
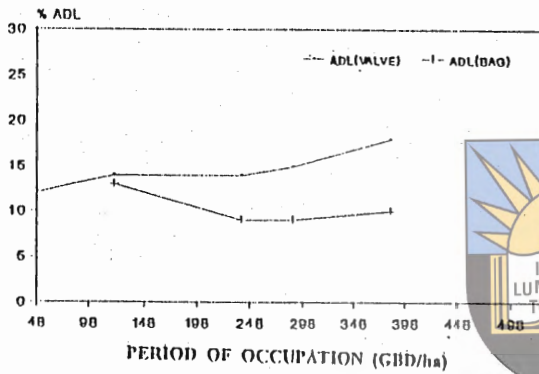


Winter: On average the ADL content of fistula bag and valve samples collected in the HSR treatment were 12 % and 13 % respectively. In the LSR treatment, the average difference in the ADL content between the bag (15 %) and the valve (12 %) was highly significant ($P = 0.01$). No significant difference due to advancing period of occupation occurred in any one of the HSR- or LSR treatments. At similar levels of grazing/browsing pressure in the LSR- (128 GBD/ha) and the HSR- (120 GBD/ha) treatments, the ADL content of the fistula valve samples (13 % and 15 %) are slightly better related compared to a considerable difference in the bag (11 % and 17 %).

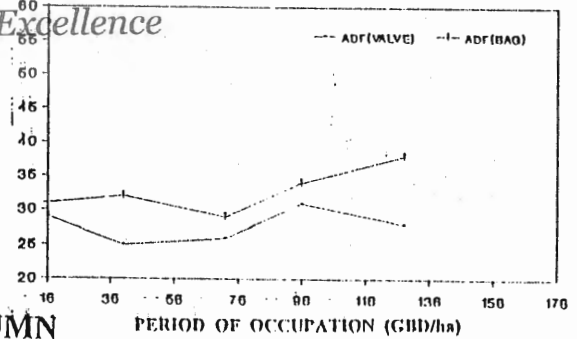
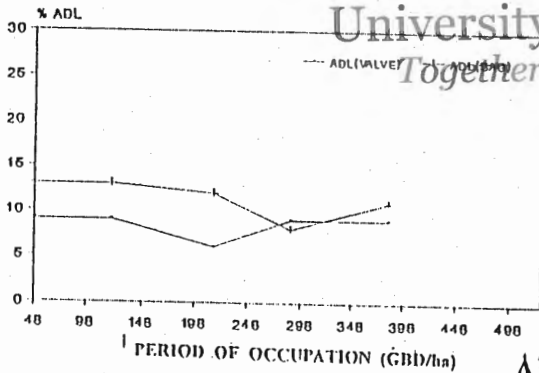
Spring: A highly significant difference ($P = 0.01$) between the two sampling methods was found in the HSR treatment. The average ADL content of the bag and valve samples were 10 % and 15 % respectively. In the LSR treatment, the average ADL content as measured by the fistula bag by



SPRING



SUMMER



AUTUMN

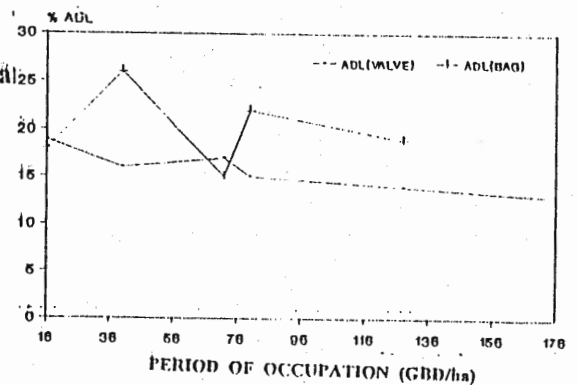
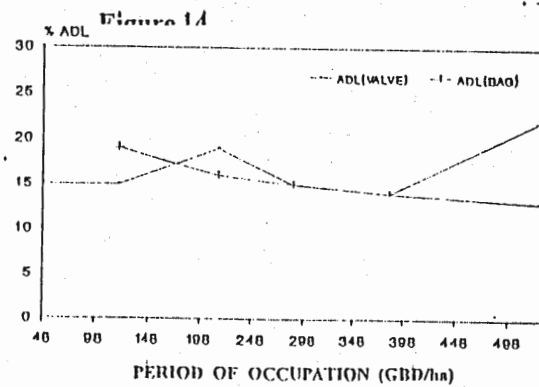


Figure 14

Figure 14. Average ACID DETERGENT LIGNIN content of fistula bag and valve samples during four seasons and two stocking rates.

the fistula bag and valve were 18 % and 17 %, respectively with no significant difference. Contrasting trends in ADL were produced by the two sampling methods in the LSR treatment, but similar to the winter results, no significant differences resulted from advancing period of occupation in any one of the stocking rate treatments. The ADL content of the bag samples in the LSR treatment showed a slight decrease while the valve samples showed a slight increase with advancing period of occupation. The ADL content of the fistula bag samples (13 % and 11 %) are better related at similar levels of grazing/browsing pressure in the HSR- (120 GBD/ha) and the LSR- (128 GBD/ ha) treatments compared to a considerable difference in the valve samples (14 % and 20 %).

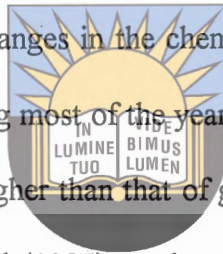


Summer: HSR treatment, the average ADL content of the bag and valve samples were 11 % and 8 %, respectively. This difference was not significant. A highly significant difference ($P = 0.02$) was found in the LSR between the bag (14 %) and the valve (10 %) samples. No significant difference in the ADL content was found with advancing period of occupation. The ADL content of the fistula valve samples (9 % and 9 %) are more comparable at similar levels of grazing/browsing pressure in the HSR- (120 GBD/ha) and the LSR- (128 GBD/ ha) treatments compared to the slightly bigger difference in the bag samples (13 % and 19 %).

Autumn: There was no significant difference in the ADL content between the bag (16 %) and valve samples (15 %) in the HSR treatment but, in the LSR treatment, there was a highly significant difference ($P = 0.01$) between the bag (21 %) and valve (16 %) samples. No significant difference in the ADL content of either technique was found with advancing period of

occupation. The ADL content of both the fistula bag (19 % and 19 %) and the fistula valve samples (15 % and 14 %) are better related at similar grazing/browsing pressure in the HSR- (120 GBD/ha) and the LSR- (128 GBD/ha) treatments.

The chemical composition of the diet varied substantially over seasons and to a much lesser extent between stocking rates. This variation occurred in spite of the large seasonal changes in grass : bush ratios as shown in Figure 2. With the wide range of forage plants available to goats, including evergreen bush species, it is expected that these animals should be able to compensate to a far greater degree for seasonal changes in the chemical composition of plants, especially in the low stocking rate treatment. During most of the year, the foliage of many woody plants has a protein content which is appreciably higher than that of grasses, even after senescence and death.



A study carried out Otsinya & McKell (1985) on the comparison of browse to tropical grasses showed browse to be richer in protein than grasses in the dry season. Experiments from the Eastern Cape Province indicate a seasonal tendency of crude protein to increase during spring, decrease in autumn and reach a minimum during winter (Trollope, 1981). Contrary to this, the lowest CP values in the present study were measured during spring (8 % to 9 %) which is understandable in view of the extended winter drought. However, with the availability of evergreen bush, it is surprising that the goats allocated a maximum of only 60 % of their feeding time to browsing activities (see Fig. 2). On the other hand, it could be argued that the limited amount of browse forced the goats to consume more grass and if correct, clearly show as a difference in the grass : bush ratios between the HSR- and LSR treatments. When considering the results in Figure 3, differences in grass consumption between the two stocking rate treatments

(extrusa samples and observations) varied between 10 % and 25 % while time spent browsing in the LSR treatment was still not more than 60 % as measured by any of the three techniques. However, support for the above argument is found in Figure 5 when during the first 40 GBD/ha in the LSR treatment (spring) goats spent about 80 % of their active feeding time, browsing. During winter, the same trend is shown (Fig. 4), but unlike the spring results, time spent browsing at the beginning of the occupation period was high (± 70 %) in both the LSR- and HSR treatments. The higher CP content of the diet during summer (16 % - 17 %) is expected due to the availability of new growth in both the grass and woody components. During this period, average grass consumption was also the highest of all seasons.

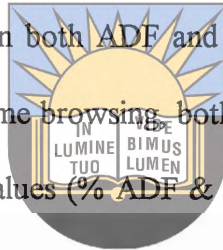


The highest amounts of bush was consumed during autumn (> 95 %, LSR), though the percentage CP of the diet was less than 12 %. It is expected that the quality of the grass would decrease during autumn and therefore limit the amount of grass browsing. However, during winter when the quality of grass is expected to deteriorate even further, the grass consumption was found to be higher than during autumn. This is probably due to the availability of large amounts of browse (evergreen and deciduous bush species) during autumn, but limited to only the evergreen species during winter.

Although NDF content of the selected forages varied little between the dry and wet periods, it increased by about 10 percentage points from winter to spring. This is difficult to explain, especially as the spring drought resulted in conditions almost similar to winter. To a certain degree, NDF content of the diet seems to be negatively correlated to browse consumption (see

Fig. 2 and 10). Except for spring, this relationship seems also to exist between browse consumption and both ADF and ADL. The relatively high ADF and ADL values during spring is again difficult to explain.

The differences in the chemical composition of the diet between the HSR- and LSR treatments were surprisingly small. Against expectations, the ADL content of the diet was higher in the LSR- than the HSR treatment during autumn. This is probably due to the higher browse component from the LSR treatment during all four seasons. To a certain extent, this argument is supported by the seasonal variations in both ADF and ADL. During autumn, when the goats spent the highest proportion of their time browsing, both these components were high. Again, it is difficult to explain why the spring values (% ADF & ADL) with more grazing are higher than that of winter.

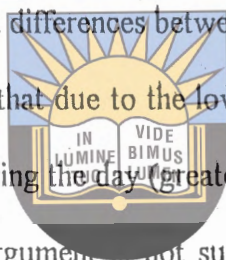


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Diet composition during winter, as determined by oesophageal fistulated goats on similar vegetation (Raats, 1997), show that CP and NDF values are highly related to period of occupation. In the same study, CP in the diet was found to be significantly higher and NDF significantly lower during the first 22 GBD/ha compared to the subsequent period (23-205 GBD/ha). This corresponds with lower levels of NDF during the early days of sampling in this study, followed by an increase in NDF during the later observation days in the HSR treatment. The same trend in CP and NDF was observed in the LSR treatment, but only during winter and spring. During summer, the CP level remained high during the total period of occupation while NDF was initially low, followed by a slight increase and finally declined towards the end of the

experimental period. During the same season, NDF showed an increase, which was followed by a clear reduction during the latter part of the experiment.

The results also indicate that the method of sampling does have a significant influence on the chemical composition of extrusa samples, but that these differences are relatively small. Significant differences ($P \leq 0.01$) occurred in all seasons and in both stocking rates; CP (2 % points, LSR spring); NDF (5 % points, LSR spring and 6 % points, HSR summer); ADF (5 % points, LSR autumn); ADL (3 % points, LSR winter, 5 % points, HSR spring and 4 % points LSR summer). Although no clear trend is visible, the majority of these significant differences between sampling methods occurred in the LSR treatment. A possible reason for this is that due to the low stocking density in this treatment, goats had the opportunity to vary their diet during the day (greater selectivity) which shows as difference in the multiple samples. However, this argument is not supported by the diurnal pattern of feeding behaviour as discussed in section 4.3.



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4.3 FEEDING BEHAVIOUR.

4.3.1 Feeding activities.

The average proportion of the active feeding time spent browsing (grazing = 100 - browsing) during the mornings (07:00 - 11:55) and afternoons (12:00 - 15:00) for each season is shown in Figure 15. From this figure, and especially during winter and spring in both the HSR- and LSR treatments, it is clear that a consistently larger proportion of time was spent on browsing during the mornings than during the afternoon feeding sessions. On the other hand, during summer and autumn, these differences were not only smaller but in a number of cases, more time was spent browsing during the afternoon than during the morning feeding sessions. Time spent browsing was significantly different ($P < 0.05$) between morning and afternoon feeding sessions during all four seasons.

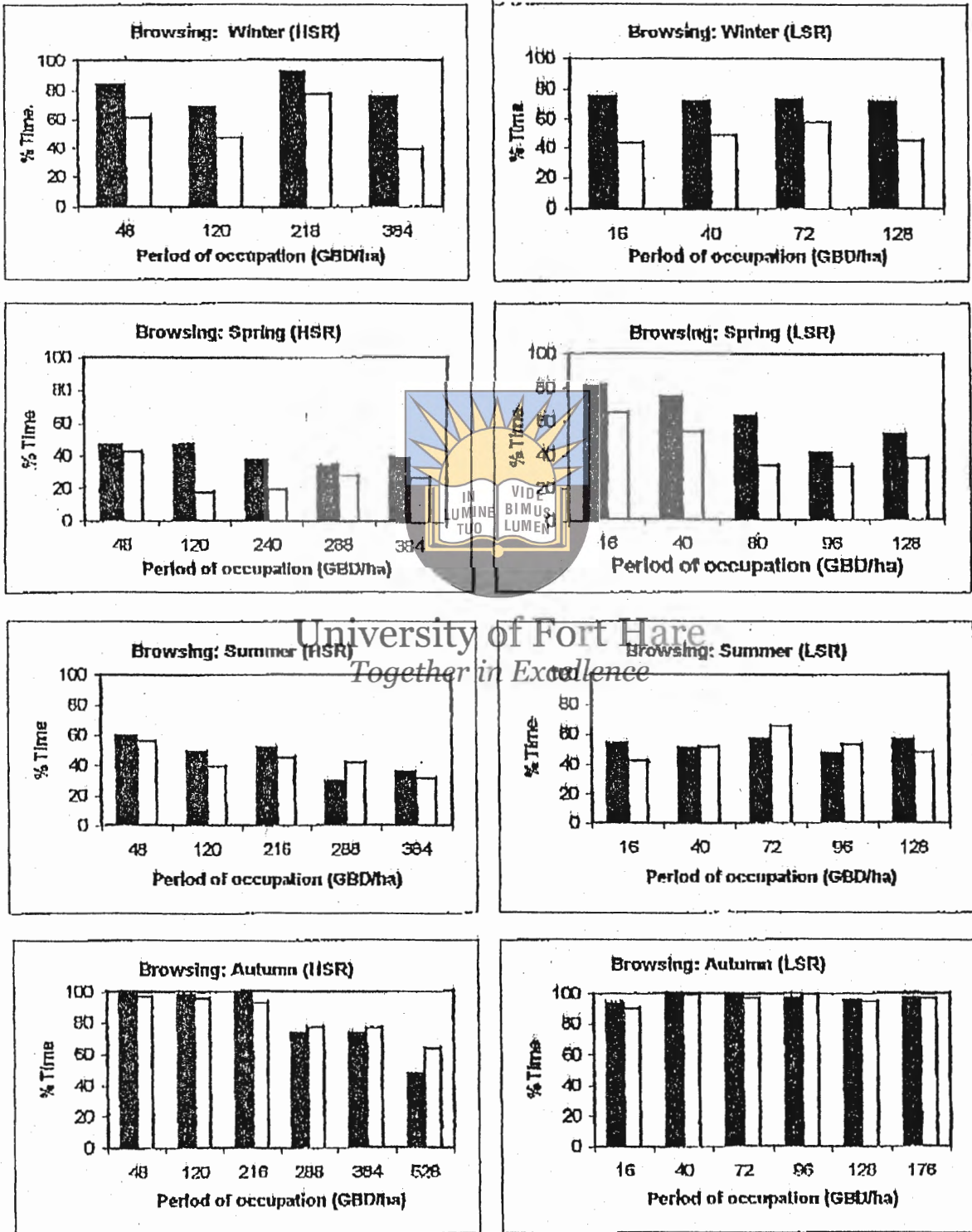


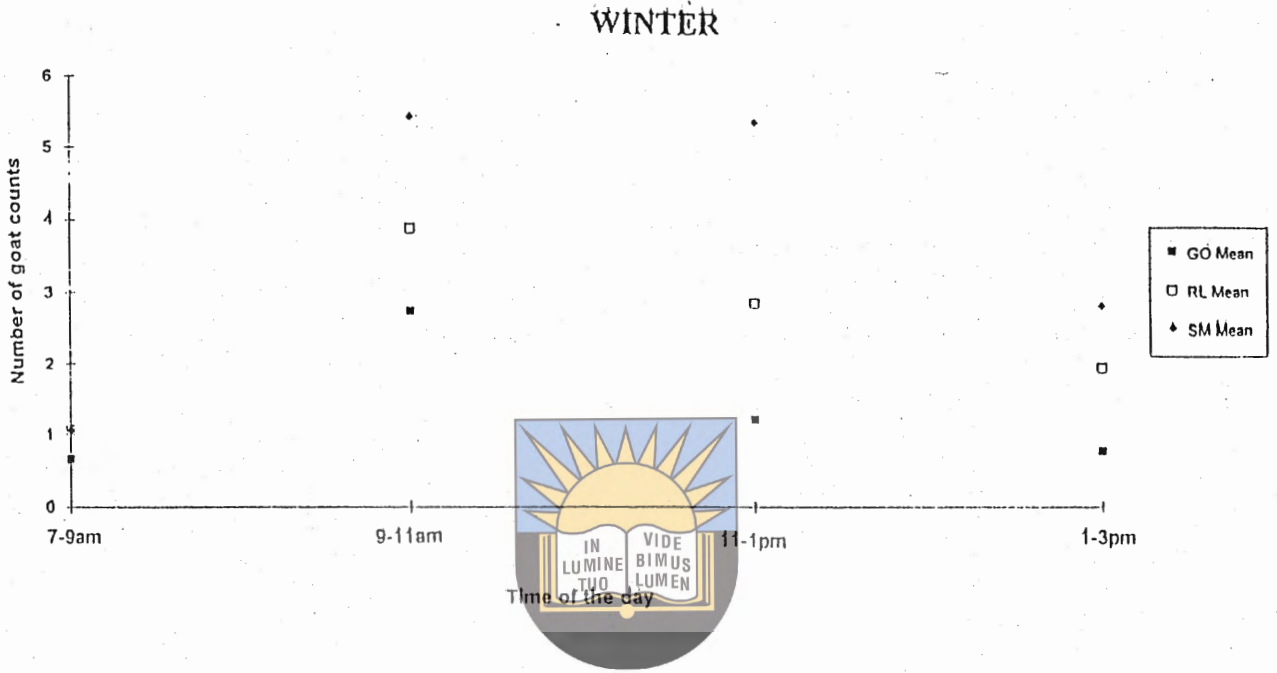
Figure 15. The average proportion of active feeding time spent browsing during the mornings [■] and afternoon [□] for each season.

4.3.2. Species selection.

The woody-species selection pattern changed during the four periods of the day, namely : early morning (07:00 to 08:56), late morning (9:00 to 10:56), midday (11:00 to 12:56) and afternoon (13:00 to 15:00) in all four seasons as illustrated in figures, 16, 17, 18 and 19. These results indicate that when goats are first let out onto pastures in the mornings, they will initially feed unselectively, and later during the day start to wonder and become more selective. The results of all four seasons indicate selectivity to be the lowest during the early morning period, and the highest during the late morning and midday periods.



The winter and spring results indicate *Scutia myrtina* (SM) to be the most preferred species followed by *Rhus longispina* (RL) and lastly *Grewia occidentalis* (GO) during all four periods of the day. This diurnal difference in selection was highly significant for all three species, *Scutia myrtina*, ($P = 0.00$), *Rhus longispina* ($P = 0.00$) and *Grewia occidentalis* ($P = 0.04$). Similar to winter results, the spring results also indicate a significant diurnal change; *Scutia myrtina* ($P = 0.00$), *Rhus longispina* ($P = 0.00$) and *Grewia occidentalis* ($P = 0.00$) during the four periods of the day. During summer, the order of preference early in the morning was *Scutia myrtina* followed by *Rhus longispina* and *Grewia occidentalis*. During the late morning, the order of preference changed to *Grewia occidentalis*, *Scutia myrtina* and *Rhus longispina*, while during midday and late afternoon the order of preference changed again to *Scutia myrtina* followed by *Grewia occidentalis* and *Rhus longispina*. This diurnal variation in species selection during the different periods of the day was highly significant, *Scutia myrtina* ($P = 0.00$), *Grewia occidentalis*



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Figure 16. Species selection pattern during Winter

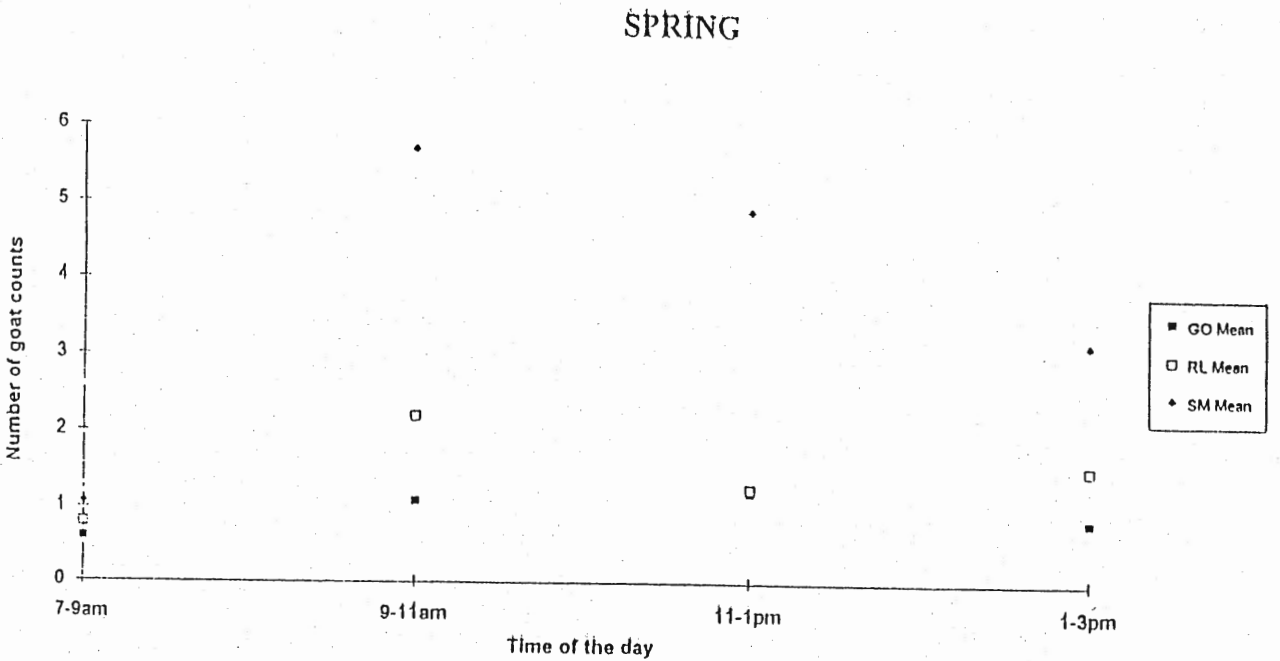


Figure 17. Species selection pattern during Spring.

SUMMER

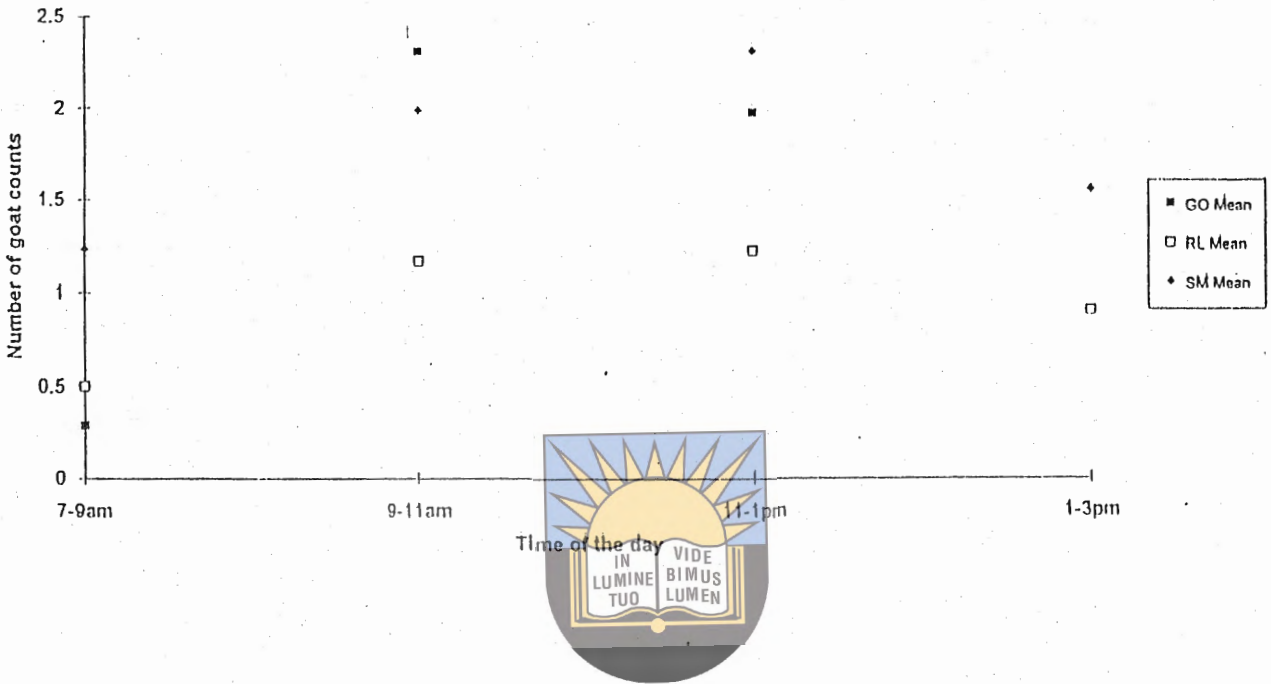


Figure 18. Species selection pattern during Summer.
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AUTUMN

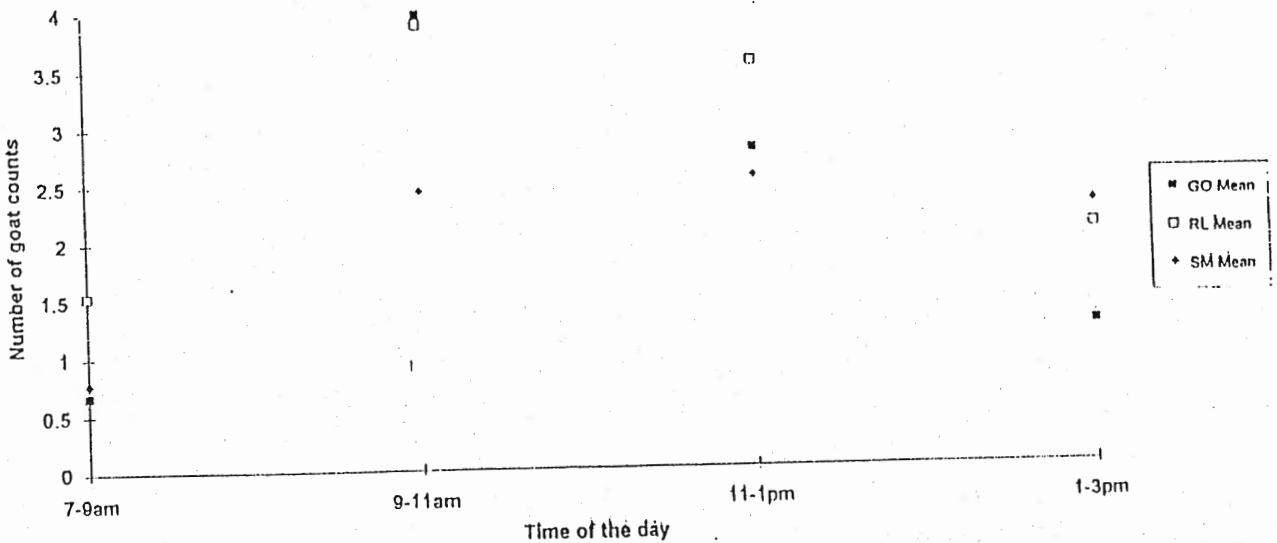
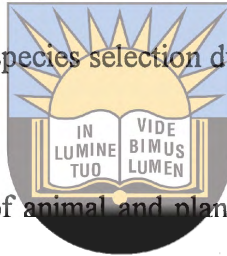


Figure 19. Species selection pattern during Autumn

($P = 0.00$) and *Rhus longispina* ($P = 0.00$).

Diurnal variation in species selection during the four periods of the day was also observed in autumn. During the early morning the most preferred species was *Rhus longispina* while *Grewia occidentalis* was the most preferred during the late morning. Similar to early morning, midday was dominated by the selection of *Rhus longispina* while the most preferred species in the afternoon was *Scutia myrtina*. These diurnal variations were also highly significant, *Scutia myrtina* ($P = 0.00$), *Grewia occidentalis* ($P = 0.00$) and *Rhus longispina* ($P = 0.00$). The results also indicate a significant difference in species selection during the four seasons ($P < 0.05$).

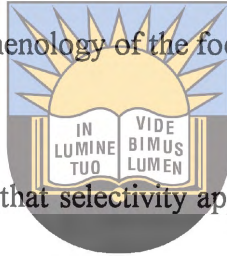


Diet selection is a major determinant of animal and plant production through its effect on sward structure. The herbivore is surrounded by an apparent super-abundance of potential food items. What it actually chooses to eat is determined by the selection criteria which will alter as the relative quantities and qualities of items change (Pellew, 1983). Large differences have been demonstrated in the nutritional qualities and quantities of available food items between season, species and plant parts of the same species.

The rate of food ingestion, that is the foraging efficiency of the herbivore (Owen-Smith, 1979) is influenced both by plant structure and by the total time per day devoted to feeding. The nutritional quality of the diet determines the nutrient and energy intake, which after allowance of daily maintenance activities, may or may not meet the requirements for reproduction.

Diet selection may be viewed as a function of the preferences which would be exhibited between the individual components of the sward if choice was unlimited, modified by the degree to which the characteristics of the vegetation canopy influence the opportunity for selection (Hodgson, 1979).

Results of a study carried by Pellew (1983) showed feeding to be a principal diurnal activity. These results showed the proportions of day light hours spent feeding to increase during the dry season compared to the wet season. Pellew (1983) associated seasonal changes in diet and species selection with changes in the phenology of the food species.



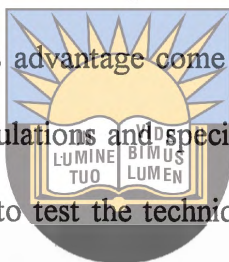
The patterns of dietary habits indicate that selectivity appears to be a means of compensation for variation in local conditions. This small compensation would be performed well within the physiological limits of each species to maximise nutrient intake.

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CHAPTER 5

CONCLUSIONS

Grazing ecologists have a wide variety of techniques available to study the foraging behaviour of free ranging animals. Whichever technique is used, the basic requirement centres around obtaining a representative forage sample as ingested by the animal. In this respect, it is claimed that the oesophageal fistula valve technique is more versatile as samples are collected throughout the day. Furthermore, its advantage come to the fore when sampling extensive areas having heterogeneous plant populations and specific plants or plant communities. The treatments in this study were chosen to test the technique under a wide range of conditions and not to benefit any one of the two techniques under review. However, due to the uniform vegetation within the small (1ha) experimental plots, careful consideration should be given prior to the extrapolation of the present findings when these techniques are used in large grazing areas with heterogeneous plant communities.



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Though not consistent throughout the seasons and treatments, significant differences in grass content, CP, NDF, ADF and ADL were found between the fistula bag and fistula valve techniques. In the absence of a "true" estimate of the diet, it is difficult to know which one of the two techniques is the most correct. The fact that in a number of cases in the present study, similar results were obtained from the comparison of the chemical composition of the bag and valve samples, the use of the cheaper and more simpler bag technique would be favoured, but it is not possible to predict before hand how well a specific technique would perform. However, indirect measurements of diet selection (behaviour and plant species selection

pattern) suggest that diet selection varies considerably during the day and would therefore support the multiple sampling technique. Based on this evidence, although not conclusive, the results from this study clearly support the multiple sampling technique.

As both digestibility and dry matter intake are based on the composition of a representative forage sample, small errors in sampling can result in unrealistic estimates of the quantity and quality of intake of free ranging animals. The same is true in determining the plant species selection in large heterogeneous plant communities. It is therefore important to use the fistula valve in quantifying diet of these animals under natural conditions. One of the major limitations of the valve technique is the different size of individual extrusa samples and the problem of making up a composite sample for the day. In this study, all samples collected from a specific goat on a specific day were pulled on an equal dry mass basis. However, this does not take into account differences in harvesting rates from different plants, which is a reality. A suggestion which has since been tested with great success at Fort Hare is to measure the active feeding time while the valve is open. In this way, samples are pooled on an equal harvesting time basis. Other limitations to the use of the multiple sampling technique are financial and labour costs. In comparative studies where these limitations pose a problem, the simpler fistula bag technique could be used.

The choice of the most appropriate technique will depend upon the goals of the research and the circumstances under which the measurement are made including such considerations as time scale of the study, grain of heterogeneity, the availability of tamed animals, the welfare of the animals, logistics and funding.

CHAPTER 6

SUMMARY

The objective of this study was to evaluate the oesophageal fistula valve technique in terms of its ability to reflect the daily forage selection pattern of free ranging goats. The evaluation was carried out over a period of four seasons (winter, spring, summer and autumn) and two stocking rates (HSR=24 goats/ha and LSR=8 goats/ha) in the False Thornveld of the Eastern Cape.



The grass:bush ratio of fistula valve and fistula bag samples together with observed feeding behaviour and species selection pattern, formed the basis for the evaluation of this sampling method.

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In terms of grass:bush ratios, inconsistent results were obtained and the difference between techniques varied between seasons, stocking rates and period of occupation. Overall, the standard fistula bag method indicated a higher grass component (41 %) compared to the fistula valve method (35 %) but was not significantly different. When compared with time spent grazing, the fistula valve method (% DM grass) corresponds better ($R^2=0.73$) with the observed feeding behaviour (time spent grazing) than the fistula bag method ($R^2=0.61$). The largest difference ($P > 0.01$) between the two techniques were found during spring in the high stocking rate treatment when the grass content of the fistula bag was 77.46 % compared to 49.90 % of the fistula valve. Differences in grass content of up to 70 percentage points ($P <$

0.01) were found between techniques on specific sampling days, especially during winter and spring towards the end of the grazing/browsing period in the experimental plots.

The results indicate that the method of sampling does have an influence on the chemical composition of extrusa samples, but that these differences are small. The CP, NDF and ADF contents of the fistula bag samples were constantly higher than the fistula valve samples during all four seasons and two stocking rates. The only exception in this trend were found in the ADL content during spring and in the HSR treatment. When sampling methods were compared in each of the four seasons, significant differences were found in the CP, NDF, ADF ($P < 0.01$) and ADL ($P < 0.05$). Sampling methods also differed significantly in CP, ADF ($P < 0.05$) and NDF ($P < 0.01$) while the differences in ADL was not significant when compared in the different stocking rate treatments



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Feeding behaviour (time spent browsing and bush species selection) was significantly different ($P < 0.05$) between morning and afternoon feeding sessions during all four seasons.

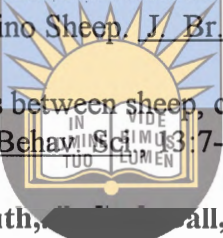
These results are also supported by those of the feeding behaviour (time spent browsing), where it was observed that especially during winter and spring in both the HSR- and LSR treatments, a consistently larger proportion of time was spent on browsing during the mornings than during the afternoon feeding sessions. On the other hand, during summer and autumn, these differences were not only smaller but in a number of cases, more time was spent browsing during the afternoon than during the morning feeding sessions. Time spent browsing was significantly different ($P < 0.05$) between morning and afternoon feeding sessions during all four seasons. The results also indicate that a larger proportion of time was spent on

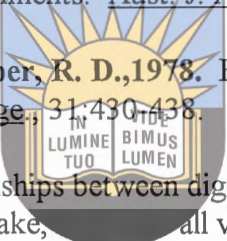
browsing during the early days of occupation of a plot compared to the latter part of occupation. Based on this evidence, it is important that oesophageal fistula samples be collected throughout the day. Therefore, the fistula valve technique provides a more representative sample of the diet selected by free ranging goats as it takes into account the variation in diet selection through out the day.



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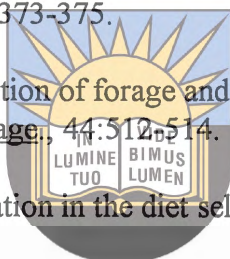
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Appendix

Appendix table 1 (a) Grass component - veld condition score

Appendix table 1 (b) Bush component- tree equivalent/ha, browsing units/ha
and stocking rate

Appendix table 1 (c) Percentage available and acceptable bush species

Appendix table 1 (d) Percentage available and unacceptable bush species

Appendix table 1 (e) Number and percentage of available bush species that are
acceptable and those that are unacceptable

The logo of the University of Fort Hare, featuring a shield with a sunburst at the top, an open book in the center with the Latin motto 'IN LUMINE BIVIS', and a banner at the bottom.

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VELD CONDITION ASSESSMENT FOR EXPERIMENTAL AREA

Appendix Table 1(a) : Grass component (points 40000 m²). Veld condition score:

SPECIES	PLOT 1		PLOT 3		PLOT 4	
	HSR	LSR	HSR	LSR	HSR	LSR
DECREASER	%	%	%	%	%	%
Panicum stapfianum	6	6	8	13	5	7
Setaria neglecta						2
Themeda triandra	4	13	1	6	1	6
INCREASER						
Aristida congesta						1
Cymbopogon plurinodis	7	16	16	16		4
Cynodon dactylon	3	5	5	3	13	8
Digitaria eriantha	40	21	30	24	28	26
Eragrostis chloromelas				2	6	2
Eragrostis curvula			3		2	
Eragrostis obtusa			1	2		
Forbs	3	3	3	2		1
Karoochloa curva		1		1		
Karroid species			1			
Microchloa caffra			1			2
Sporobolus africanus				3		1
Sporobolus fimbriatus	30	34	37	27	16	23

Appendix Table 1(b) : Bush component - Tree Equivalents/ha, browsing units/ha and stocking rate (ha/SSU)

SPECIES	PLOT 1		PLOT 2		PLOT 3		PLOT 4	
	HSR	LSR	HSR	LSR	HSR	LSR	HSR	LSR
Tree equivalent per ha : current	2519	2213	2817	3495	3147	1148	945	1658
Browsing units per ha : current	1379	1316	1639	2089	1977	979	540	1392
Stocking rate (ha/ssu) : current	1.5	1.5	1.2	1.0	1.0	2.0	3.7	1.4

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Appendix Table 1(c) : Percentage available and acceptable bush species

SPECIES	PLOT 1		PLOT 2		PLOT 3		PLOT 4	
	HSR	LSR	HSR	LSR	HSR	LSR	HSR	LSR
Acacia karroo	19.2	23.9	16.2	18.6	9.9	24.2	5.0	34.5
Coddia rudis	13.7	12.7	20.8	20.6	44.4	18.2	15.0	
Ehretia rigida	6.3	5.6	3.9	4.1	4.9	3.0		3.6
Grewia occidentalis	3.2	3.9	13.2	14.2	7.4	15.2	12.5	25.5
Lippa javanica	4.4		6.0	5.1		6.1	5.0	1.8
Maytenus heterophylla	5.6	1.3	1.6	1.5	7.4		7.5	10.9
Olea europea	10.7	15.9	0.2	0.2	2.5			9.10
Rhus longispina	12.4	13.1	8.3	4.9	6.2	15.2	10.0	1.8
Rhus refracta	1.5	4.6	2.1	2.6	1.2	6.1	2.5	1.8
Scutia myrtina	14.2	11.9	10.3	8.6	12.3	9.1	15.0	1.8

Appendix Table 1(d) : Percentage available and unacceptable bush species

SPECIES	PLOT 1		PLOT 2		PLOT 3		PLOT 4	
	HSR	LSR	HSR	LSR	HSR	LSR	HSR	LSR
Aloe ferox			1.1	0.3				
Diospyros lycioides	8.3	6.9	4.5	5.1	2.5		10.0	9.1
Diogyalis caffra		0.1				3.0		
Jasman angulare			2.1	1.1				
Protasparagus			8.6	8.1		0.60		
Rhus andulata			0.3	0.2				
Rhus dentata			0.1	1.2				

**Appendix Table 1(e) : Number and percentage of available bush species that are acceptable and those that are unacceptable**

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Stocking rate	PLOT 1		PLOT 2		PLOT 3		PLOT 4	
	HSR	LSR	HSR	LSR	HSR	LSR	HSR	LSR
Available\acceptable								
No :	1441	1402	1816	2362	78	32	29	50
% :	91.4	93.0	83.2	84.0	96.3	97.0	72.5	90.9
Available\Unacceptable								
No :	135	105	367	449	2.0	1.0	11.0	5.0
% :	8.6	7.0	16.8	16.0	2.5	3.0	27.5	9.1
TOTAL	1576	1507	2183	2811	81	33	40	55

Veld condition assessment was done according to the methods described by Trollope (1980) and Foran, Tainton and Booysen (1978), adapted for the False Thornveld of the Eastern Cape (Danckwerts, 1981).

