DIETARY FIBRE REQUIREMENTS OF FEEDLOT LAMBS

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by

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Dissertation submitted in partial fulfilment of the requirements for the degree

MAGISTER SCIENTIAE AGRICULTURAE

to the

Faculty of Natural and Agricultural Sciences
Department of Animal, Wildlife and Grassland Sciences
University of the Free State
Bloemfontein

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Bloemfontein
May, 2008

DECLARATION

I hereby declare that this dissertation submitted by me to the University of the Free State for the degree, **Magister Scientiae Agriculturae**, is my own independent work and has not previously been submitted by me at another university/faculty. I further cede copyright of the dissertation in favour of the University of the Free State.

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Bloemfontein
May, 2008

ACKNOWLEGEMENTS

The author hereby wishes to express his sincere appreciation and gratitude to the following persons and institutions that made this study possible:

My supervisor, Prof. H.J. van der Merwe, for his guidance, advice and constructive criticism during the study and writing of this dissertation.

My co-supervisor, Dr. A.V. Ferreira, from Molatek for his support during this study, formulation of the experimental diets and sponsoring of the high protein concentrate used.

The Chairman of the Department Animal, Wildlife and Grassland Sciences, Prof. J.P.C. Greyling, for his support and encouragement during the trial.

Dr. L.M.J. Schwalbach, from the Department of Animal, Wildlife and Grassland Sciences for his advice and assistance in animal health.

Mr. M.D. Fair, from the Department of Animal, Wildlife and Grassland Sciences for the statistical analysis of the data.

Mr. W.J. Combrink, from the Department of Animal, Wildlife and Grassland Sciences for his assistance in the technical preparations for the trial, collection of ruminal fluid and the chemical analysis of the samples.

Mr. A. Troskie, for his valuable assistance and support with the collection of data and the health of the animals for the study.

Mr. S. Boshoff and Mr. I. van Zyl, for their assistance during the processing of the animals and collection of pH and chewing activity data.

Mr. F. de Witt, from the Department of Animal, Wildlife and Grassland Sciences for his advice, support and assistance in acquiring suitable trial animals and during the carcass evaluations.

Dr. A. Hugo and Mr. O. Einkamerer, from the Department of Animal, Wildlife and Grassland Sciences for their assistance to evaluate the carcasses.

The National Research Foundation (NRF) for the bursary received.

Mss. H. Linde and R.Barnard, for all their administrative support.

My parents, Gert and Magda Smith, for all their encouragement, support and guidance during my studies and for giving me the opportunity to attend university in the first place.

My wife Anja, for all your assistance, encouragement and patience during the study, and writing of this dissertation which would not have realised if not for all your support.

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ACRONYMS AND ABBREVIATIONS

ADF	acid detergent fibre
ADG	average daily gain
ADL	acid detergent lignin
ad lib	ad libitum
aNDF	amylase treated neutral detergent fibre
Ca	calcium
CF	crude fibre
CO_2	carbon dioxide
CP	crude protein
D	digestibility
D_a	apparent digestibility of dry matter
DDM	digestible dry matter
DM	dry matter
DMI	dry matter intake
eNDF	effective neutral detergent fibre
FCR	feed conversion ratio
GE	gross energy
k_d	rate of digestion
kg	kilogram
KOH	potassium hydroxide
k_P	rate of passage
MRT	mean retention time
ME	metabolizable energy
MECR	metabolizable energy conversion ratio
MEI	metabolizable energy intake
N	nitrogen
NDF	neutral detergent fibre
NDP	non-degradable protein
NDR	neutral detergent residue
NDS	neutral detergent solubles
NE	net energy
NPN	non-protein nitrogen
OM	organic matter
P	phosphorus
pef	physical effectiveness factor

peNDF	physical effective neutral detergent fibre
PDNDF	potentially digestible neutral detergent fibre
RDP	rumen non-degradable protein
RVI	roughage value index
RVU	roughage value unit
SD	standard deviation
TBA	trenbolone acetate
tdNDF	truly digestible neutral detergent fibre
VFA	volatile fatty acid

CHAPTER 1

GENERAL INTRODUCTION

In recent years, finishing lambs in feedlot systems has become a common practice on South African commercial farms and feedlots alike. In order for feedlot production systems to be economical and viable enterprises, the objective is to maximize performance and efficiency, while minimizing production costs which results in a positive/increased profit margin. Feed costs and additional costs and losses associated directly with nutrition are major factors adding to these production costs. This highlights the importance of feedlot diets which must be of the lowest possible cost but still maximizing gain in the feeding period without hampering production by causing metabolic disorders that decrease intake along with production and profit.

Different from other animal species, ruminants such as cattle and sheep has the ability to utilize large quantities of roughages such as forages and cereal straws (Sudweeks *et al.*, 1981). The cell walls of plants cannot be digested by animals and must be fermented by various micro-organisms to volatile fatty acids (VFA) in the rumen. The VFA can then be absorbed to provide the necessary nutrients needed for maintenance, growth, and production. Nutritionists measure these cell walls of plants as fibre (Mertens, 2002). The degradation of the cell walls in the rumen is slow and incomplete. This is a major factor attributing to the limited value of forages to animals (Ahmad & Wilman, 2001). Wilson & Mertens (1995) reported that the proportion of cell wall material and the resistance of fibrous structures breakdown to small particles during mastication and digestion influence both the intake and digestibility of forage dry matter. To improve the fermentation and digestion of roughages, ruminants regurgitate and re-masticate large particles (rumination). Diets high in roughage increase rumination time and mastication in turn, stimulate the salivary glands to produce and secrete saliva. Saliva contains buffers which maintain the pH in the rumen (Mertens, 2002).

An increase in the energy densities of finishing diets is necessary in order to attain higher levels of production. However, the inclusion of high amounts of highly fermentable carbohydrates increases the risk of ruminal acidosis (Krause & Combs, 2003). Ruminal acidosis varies from acute (life-threatening) to sub-acute (chronic), resulting in reduced feed intake and weight gain. Major physiological and economical costs result from chronic acidosis that goes undetected in large groups where feed intake and weight gain of the affected animals is only revealed when the group is slaughtered and abscessed livers reveal the deleterious effects of acidosis (Huntington, 1988).

Feedlot research has been focusing on reducing the forage levels in finishing diets as a mean of reducing the energetic cost of gain (Fimbres *et al.*, 2002). The lower digestibility and available energy of forages or roughages in comparison with that of grains and concentrates also contribute to reducing fibre to a minimum in finishing diets (Mertens, 2002). However, Bartle & Preston (1992) reported that small quantities of forage are necessary in finishing diets to maintain the normal function of the rumen. Feeds which are high in fibre are also included in diets fed to early post weaning animals to prevent excessive fat deposition during the growth period and in high energy finishing diets to control acidosis (Fox & Tedeschi, 2002). In the available literature, no research results on the fibre requirements of finishing lambs could be detected.

Neutral detergent fibre (NDF) is the only fibre determining method that isolates all of the insoluble fibre components in plants (cellulose, hemicellulose and lignin) with some protein. However, NDF is not an ideal nutritive entity because the digestibility varies with lignin concentration and other factors which affect the availability to the animal (Mertens, 2002). In the absence of a more accurate method to quantify fibre within feedstuffs, the purpose of this study was to determine the NDF requirements of lambs fed high energy feedlot diets with a healthy and productive rumen environment and accordingly high intake, gain and feed efficiency as the main objective. This study was however limited to only two dietary sources of NDF namely, *Medicago sativa* (lucerne) and *Eragrostis curvula* (weeping lovegrass) which are the roughage sources most commonly used in South African finishing diets for lambs. The effect of physical form of roughage (effective fibre) on utilization was addressed by using the particle size most commonly used in South African feedlot diets.

This dissertation is presented in the form of six chapters. Firstly the study is introduced by a general introduction (Chapter 1) followed by a literature review (Chapter 2). Chapter 3 outlines the materials and methods used in the digestibility and production studies of the two dietary sources of NDF with the results and discussion thereof presented in Chapters 4 and 5 for *Medicago sativa* and *Eragrostis curvula* respectively. The study is concluded within Chapter 6.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Fibre requirements for cattle, especially dairy cattle, fed high concentrate diets have been extensively documented (NRC, 1996; Mertens, 1997; NRC, 2001; Fox & Tedeschi, 2002; Mertens, 2002), but there are little information in the literature on the fibre requirements of lambs fed such diets. The objective of this chapter is to review the literature on the fibre requirements of finishing lambs fed high concentrate diets and the effect of fibre on production. However, the literature available regarding this topic is limited and most of the principles in this review were derived from research done with cattle. The principles in this review may have applicability in meeting the fibre requirements of feedlot lambs and/or assist in better understanding the fibre needs of finishing lambs in the feedlot.

2.2 Measurement of dietary fibre

Determining the nutritional value of feeds that have high amounts of structural carbohydrates (dietary fibre) is of great significance as it affects both the digestibility and intake of the diet (Church, 1988). The plant cell wall, which is measured as fibre, is a complex structure composed of lignin, cellulose, hemicellulose, pectin, some protein, lignified nitrogenous substances, waxes, cutin and mineral components. Fibre composition is important from a nutritional point of view and varies with the type of cell wall (Van Soest, 1994).

2.2.1 Fibre analysis

In order to isolate the different chemical constitutes in feed (Figure 2.1), chemical analysis methods were developed. The classical methods used for the analysis of structural carbohydrates (crude fibre) did not represent a nutritionally realistic separation of structural carbohydrates (Church, 1988). This led to the development of alternative procedures for fibre analysis by Van Soest. The residue that remains after extraction with boiling neutral solutions (sodium lauryl sulphate and ethylenediamine-tetraacetic acid, EDTA), consists mainly of lignin, cellulose and hemicellulose and is known as neutral detergent fibre (NDF). Acid detergent fibre (ADF) results after refluxing with acid solutions (0.5 M sulphuric acid and cetyltrimethyl-ammonium bromide) and represents the crude lignin and cellulose fractions, including silica. Additional treatment of ADF with 72% sulphuric acid to dissolve cellulose and ashing of the residue determines the acid-detergent lignin (ADL) which consists of crude lignin, including cutin (Van Soest, 1967, as cited by McDonald *et al.,* 2002). Neutral detergent fibre (NDF) is the only method that isolates all of the insoluble fibre components in plants (cellulose, hemicellulose, and lignin) with some protein. ADF is not an accurate estimate of fibre in feeds as it does not contain hemicellulose. However, NDF is not an ideal nutritive entity because the digestibility varies with lignin concentration and other factors which affect the availability to the animal (Mertens, 2002).

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CHEMICAL FRACTIONS:

Moisture| ------------------------------------------------------ Dry Matter ---------------------------------------------------------- |
          |Ash| -------------------------------------------------- Organic Matter -------------------------------------------------- |
               | Lipid | Protein | ----------------- Carbohydrates, Organic Acids, Complex Polymers --------------------- |
                                  |  Sugars |  Starches  |  Org.Acids[a] | Pectins[b] |  Hemicellulose  |  Lignin+[c]  |  Cellulose |

NUTRITIONAL FRACTIONS – Incompletely Digested:
                                                                  | ------------------------ Cell Walls --  ----------------- |
                                                                           | --------- Neutral Detergent Fibre ---- --- |
                                                                                          |Acid Detergent Fibre[d] |
                                                                                                  |  Crude Fibre  |

NUTRITIONAL FRACTIONS – Readily Digested:
                                  | ---------------------------- Nitrogen-Free Extract[e] ------------------------- |
               | ----------------- Neutral Detergent Solubles ------------------ |
                                  | ------------------- NFC[f] ---------------------- |
                                  | -- TNC or NSC[g] -- |
                                          |  Starches  |
```

Figure 2.1 Partitioning of feeds into chemical and nutritional fractions (Mertens, 2002).

[a] Organic acids which include the volatile fatty acids in silages and other fermented feeds.
[b] Includes other soluble fibre such as beta-glucans and fructans.
[c] Polymeric lignins and phenolic acid complexes (some may be soluble).
[d] Some phenolic complexes and lignins with low molecular weight may be solubilised by acid detergent.
[e] Was supposed to represent readily available carbohydrate in feeds, but does not as it contains some lignins, phenolic, and hemicellulose, especially in forages.
[f] Non-fibrous carbohydrates determined by difference (100 – ash – lipid – protein – neural detergent fibre).
[g] Total non-structural carbohydrates or non-structural carbohydrates determined analytically.

The original Van Soest procedure (NDF method) did not adequately remove starch from feeds which contained grains. For more accurate fibre analysis of high grain feeds such as concentrates and silages, Van Soest *et al.* (1991) developed the neutral detergent residue (NDR) method, which used heat- and detergent-stable amylase to assist in starch removal and also eliminated the use of sodium sulphate that might remove phenolic compounds thought to be lignin. Another variation, amylase-treated NDF ($_{a}$NDF), was suggested by Undersander *et al.* (1993) and this method differs from the original NDF method because it uses amylase. It also differs from the NDR method as it uses sodium sulphate to remove protein contamination (Undersander *et al.*, 1993 as cited by Mertens, 2002). Values derived from the different methods (NDF, NDR and $_{a}$NDF) can be quite different even though the results are often called NDF. Therefore, it is important to know which method was used to determine the NDF values, as some of the discrepancies among laboratories may be due to differences in methods. There are high correlations among fibre methods within a feed type and this may indicate that it does not matter which fibre analysis/method is used to develop feeding recommendations. However, NDF is the only method that measures the differences within and among feed types and has the potential for developing a system of general feeding recommendations across all feeds (Mertens, 2002).

2.2.2 Digestibility of fibre

An interaction of animal and plant factors effect the physical degradation of forages, thereby promoting the passage of plant residues through the intestinal tract of the animal and influencing forage intake (Atkin, 1989). The fibre fraction of forages has the greatest influence on the digestibility, and both the amount and chemical composition of the fibre are important (McDonald *et al.*, 2002). Neutral detergent fibre, as an estimate of the proportion cell wall in the diet, is likely to affect both the digestibility and intake of roughage (Van Soest, 1994). The lignification of the cell walls is also a factor restricting the digestion of fibre (Van Soest, 1994; McDonald *et al.*, 2002). The degree of lignification is expressed per kg of NDF as well as per kg dry matter (DM).

Digestibility of fibre is defined as the proportion which is not excreted in the faeces and is, therefore, assumed to be absorbed by the animal. It is expressed in terms of dry matter and as a coefficient or a percentage (McDonald *et al.*, 2002). The faeces contain the undigested as well as metabolic products including bacteria and endogenous wastes from animal metabolism. Consequently, apparent digestibility can be considered to be the balance between the feed minus the faeces, but the true digestibility is the balance between the diet and the respective feed residues from the diet escaping digestion and arriving in the faeces exclusive of metabolic products. Therefore, the coefficient of true digestibility is always higher than the coefficient of apparent digestibility if there is a metabolic loss in the faeces (Van Soest, 1994). The apparent digestibility of dry matter (D_a) is algebraically expressed as:

$$D_a = (F_i - P_r)/F_i \qquad (2.1)$$

where, F_i (feed) = average daily dry matter intake and
P_r (passage) = average quantity of undigested dry matter voided daily.

When total diets is considered, protein and lipids always have a metabolic loss in the faeces, but for fibre and carbohydrates there is no metabolic loss in the faeces and apparent coefficients equal true digestibility (Van Soest, 1994).

2.2.2.1 Estimating digestibility of fibre

The effects of growing conditions and post-harvest factors results in ever changing feedstuffs and no individual feed that is currently utilized has truly been represented in a population collected previously. Different equations are needed for each feedstuff class and classification is difficult, especially for forage mixtures. In an attempt to reduce some of these problems, different types of models have been developed (Weiss, 1993). A theoretically sound equation was developed to estimate the digestible dry matter (DDM) of feeds (Goering & Van Soest, 1970 as cited by Weiss, 1993).

$$DDM = 0.98 \times NDS + dNDF - M \qquad (2.2)$$

where, NDS = neutral detergent solubles,
dNDF = digestible NDF and
M = metabolic faecal losses (approx. 12.9).

All the values are expressed as a percentage of DM and 0.98 is the true digestibility of the NDS fraction of the feed.

The limitation of equation (2.2) is that the digestibility of NDF must be known. However, the NDF digestibility is not constant across or within feeds and several different constants are needed. Therefore, an equation was developed to estimate the digestibility of NDF based on the logarithm of the lignin:ADF ratio. Equation (2.2) produced accurate values for forages and roughages, but not for concentrates (Weiss, 1993). Conrad *et al.* (1984) derived an equation (2.3) using the surface law of a geometric object to predict the proportion of NDF available for digestion from the NDF and lignin (L) values of the feed.

$$\text{Available NDF} = 1 - [L^{0.67}/(NDF)^{0.67}] \qquad (2.3)$$

Using equation (2.3), a second correction for lignin was made to predict values for the potentially digestible NDF (PDNDF). Because of the indigestibility of lignin, it was subtracted from NDF to yield a lignin-free NDF value and this resulted in equation (2.4) to estimate PDNDF values (Weiss, 1993).

$$PDNDF = (NDF - L)(1 - [L/NDF]^{0.67}) \qquad (2.4)$$

According to the NRC (2001), estimating truly digestible NDF (tdNDF) is then represented by equation (2.5).

$$tdNDF = 0.75 \times (NDFn - L) \times [1 - (L/NDFn)^{0.667}] \quad (2.5)$$

where, NDFn = NDF – NDICP,
NDICP = neutral detergent insoluble crude protein (N × 6.25) and
0.75 is the true digestibility of lignin-free NDFn fraction.

2.2.2.2 Other factors affecting fibre digestibility

Digestibility is not only affected by the chemical composition, but also by the physical characteristics of the feed, animal factors and associative effects (Weiss, 1993). A series of experiments was conducted by Fadlalla *et al.* (1987) to examine the influence of the particle size of hay on its digestibility in terms of rate of digestion in the rumen, retention of solids and fluids in the rumen, large intestine and whole gut and of rumen fermentation characteristics in sheep. Results indicated a more rapid disappearance of rumen DM from hay milled through a 5 mm screen compared to coarser hays (20 and 40 mm). This effect was more pronounced *in vivo* than *in vitro*. A reduction in the rumen pH to 6.2 was noted for 2 and 5 mm hays, which was likely to have decreased fibre digestion in the rumen. Mould *et al.* (1983) reported inhibited digestion of cellulose when the rumen pH falls below 6.3, with total inhibition of cellulolysis when the pH fell below 6.0. They concluded that the depression of DM degradation is partly due to a decrease in the rumen pH. This finding was in consensus with the results found by Hoover (1986). Fadlalla *et al.* (1987) also reported a reduced digestibility of the finer milled hays (2 and 5 mm) by sheep which was associated with the relatively short mean retention time (MRT). This indicated that the increase of potential digestibility caused by the milling of the hay was insufficient to over-ride the decrease in DM degradation caused by reduced retention time and lowered pH in the rumen.

The major animal factor that affects digestibility of fibre is the dry matter intake (DMI). As ruminants consume more DM, the efficiency of digestion decreases (Tyrrell & Moe, 1981 as cited by Weiss, 1993). Variation and competition among sheep may significantly affect the utilization and daily intake of individual sheep (NRC, 1985). Colucci *et al.* (1982) found that depression in the digestibility of DM, NDF, hemicellulose, cellulose, energy and cell solubles per unit of intake was greater on low forage diets. The retention time of concentrates only increased by 0.44 units for each unit increase in the retention time of forages. The interaction between fibre digestibility (D) and the rates of digestion (k_d) and passage (k_p) is indicated in equation (2.6). However, accurate rates of digestion and passage are needed, which are difficult to obtain and are variable (Waldo & Smith, 1972, as cited by Weiss, 1993).

$$D = k_d/(k_d + k_p) \qquad (2.6)$$

Longer retention time associated with lower DMI allow for extended fermentation in the rumen and thus feed degradation, and most likely allows more time for mastication and rumination of the feed. This accounts for the larger depression in digestibility of diets low in forage with a shorter retention time (Colucci *et al.*, 1982). Fimbres *et al.* (2002) reported a contradictory result to the normal depression of DMI at increasing forage levels and found that the intake increased linearly with the forage level in the finishing diet of lambs. This was attributed to the dilution of the energy densities in the diets and the fine physical form of the forage, which might have minimized the effect of physical fill. However, the DM digestibility showed the same trend as reported by other researchers with a decrease in the DM digestibility when DMI increased. The same decrease in the digestibility of NDF was reported considering the higher forage levels.

Associative effects are defined as the synergistic or antagonistic effects of two or more feedstuffs on the utilization of a diet or the productive performance of animals (Moore *et al.*, 1990). These associative effects have been observed by Mould *et al.* (1983) when the effect of various levels and types of concentrate supplementation of roughage based diets was hypothesized. They found that the extent of DM degradation and cellulolysis are not only influenced by the already mentioned rumen pH, but also by the rate of solubilisation of the concentrate supplement and the degradability of the roughage. The percentage reduction of cellulolysis was the greatest when roughages had a low DM degradability. Moore *et al.* (1990) reported an improved digestibility of lucerne hay and milo when wheat straw was included in mixed diets, but the inclusion of cotton seed hulls did not have the same effect. This was attributed to the associative effects between different roughage sources influencing the digestibility of other ingredients in a mixed diet.

2.2.3 Effectiveness of fibre

The NDF methods (NDF, NDR, $_a$NDF) used to measure fibre only measures the important chemical characteristics of fibre for ruminants. It does not measure the physical properties, such as particle size, which influence the effectiveness of fibre in meeting ruminant minimum fibre requirements. NDF is less effective in formulating minimum fibre diets when finely chopped forages or ground non-forage fibre sources (by-product feeds) are used (Mertens, 2002). Hadjigeorgiou *et al.* (2003) concluded that as the forage staple length declined, the voluntary intake of sheep increased, while the digestibility and mean retention time decreased. The results of Welch (1986) indicated that particle size, density, and hydration rate, affect chewing and rumination time. Ruminants require adequate amounts of coarse textured feeds, which contribute to maintaining the proper muscle tone in the digestive system as well as the rumen pH, and thus help to avoid metabolic disorders (Sudweeks *et al.*, 1981). Salivary buffers are required to neutralize the fermentation acids in the rumen. However, there are a relationship between the flow of the salivary buffers and the chewing activity, which are stimulated by the roughages in the diet (Bailey & Balch, 1961 as cited by Allen, 1997). This led to the development of an index of roughage value which proposed that chewing activity per unit of DM could be a biological measure of the physical properties of a feed (Balch, 1971 as cited by Mertens, 2002). On the basis of the observation of Balch (1971), Sudweeks *et al.* (1981) developed a roughage value index (RVI) that is expressed as minutes of chewing (eating and ruminating) per kilogram of dietary DM. The RVI was partitioned for feed ingredients from regression equations and an equation (2.7) was developed that predicts RVI from sieving and chemical data.

$$RVI = 10.86 + PS(21.59) - DMI(1.91) + NDF(0.451) \qquad (2.7)$$

where, RVI = minute/kilogram,
PS = particle size in diameter,
DMI = dry matter intake in kilograms, and
NDF = neutral detergent fibre percentage.

Similar systems as cited by Mertens (2002) have been developed to relate the roughage in the diet to chewing activity. Norgaard (1986) based his system on the type of feed (physical structure group) and particle size. Mertens (1986) proposed a roughage value unit (RVU) system based on a chemical measure of NDF and a physical measure of particle size. Sauvant *et al.* (1990) observed a relationship between crude fibre (CF) and chewing activity, which they called the fibrosity index. The major limitation of these systems is the variability of chewing activity per kilogram of DM that is related to animal differences and this limits the usefulness of these systems as feed attributes.

Both the amount and effectiveness of fibre can affect ruminal fermentation and animal metabolism. The traditional definition of effective fibre referred to the ability of fibre to maintain milk fat production and animal health effectively. To clarify different concepts, separate definitions for NDF were proposed by Mertens (1997). Physical effective NDF (peNDF) is related to physical characteristics of fibre, primarily particle size, that influence chewing activity and the biphasic nature of ruminal contents (floating mat of large particles on a pool of liquid and small particles). Effective NDF (eNDF) is related to the sum total ability of a feed to replace forage or roughage in a diet so that the percentage fat in milk produced is effectively maintained. Mertens (1986) as cited by Fox & Tedeschi (2002) found that peNDF could be quantified by determining the percentage of the NDF remaining on a 1.18 mm screen after vertical shaking of the dry feed. Particles smaller than this readily pass out of the rumen and provide little stimulus for chewing (Mertens, 1997). The peNDF is a more restricted term and concept because it only relates to the physical properties of fibre and will always be less than NDF, whereas eNDF can be less or greater than the NDF concentration in a feed (Mertens, 2002). The relationship between these concepts is illustrated in Figure 2.2.

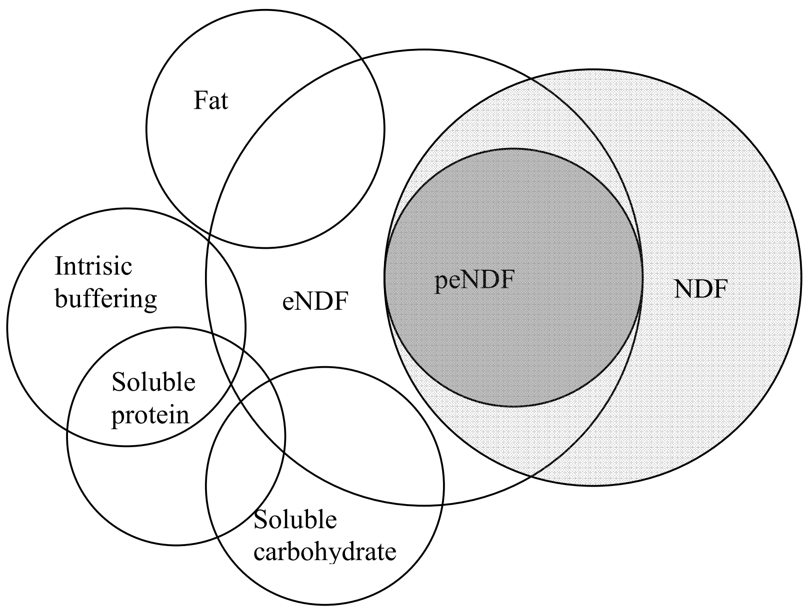

Figure 2.2 Illustration of the relationships among NDF, peNDF and eNDF (Mertens, 2002).

The animal response associated with peNDF is chewing activity and the peNDF of a feed is the product of its NDF concentration and its physical effectiveness factor (pef). The pef value varies from 0, when NDF is not effective in stimulating chewing activity, to 1, when NDF is fully effective in promoting chewing. The peNDF concept differs from those roughage concepts mentioned above (RVI, physical structure, fibrosity index) in that the feed attribute (peNDF) is based on the NDF concentration and the relative effectiveness of the NDF in promoting chewing activity rather than being expressed as minutes of chewing activity per kilogram of DM (Mertens, 1997). The variations due to animal and experimental differences are minimized in the NDF concept because pef are fractions in which the animal effects in the numerator and denominator cancel each other as shown in equation (2.8).

pef = [min. of chewing per kg of NDF in the test feed] / [min. of chewing per kg of NDF in long grass hay] (2.8)

The peNDF is a constant for feed and is additive in feed formulation systems. The variation due to animal is attributed to the peNDF requirements and not arbitrarily partitioned between feed characteristics and animal requirements. This implies a difference in the peNDF requirements of animals (dairy, feedlot), but an accurate peNDF for each feed represents the proportional response of each animal type to the diet they consume (Mertens, 2002). Factors for converting NDF to peNDF can be derived from chewing activities associated with the intake of NDF from various sources. Using this approach, the requirement for peNDF of dairy cows was determined to be 22% of diet DM to maintain an average ruminal pH of 6.0. This system distinguishes between the physical effectiveness of NDF to stimulate chewing activity and the overall effectiveness of NDF in maintaining milk fat percentage (Mertens, 1997). Beauchemin *et al.* (2003) concluded that peNDF was a reliable indication of chewing activity and sub-clinical ruminal acidosis and their results for the peNDF requirement of dairy cows was the same as found by Mertens (1997), when using particles retained on a 1.18 mm screen to determine the peNDF level. This peNDF system may be very useful for meeting the fibre requirements of feedlot lambs, being an indicator of the effectiveness of fibre to maintain the rumen environment at optimal conditions.

2.2.3.1 Determining minimum peNDF requirements

The NRC (1996) suggested that as much as 25% eNDF may be required by beef cattle to maintain an adequate ruminal pH for maximum forage digestion and microbial growth. The eNDF required in high energy diets is 8%, which is considered to be the concentration necessary to keep the rumen pH above 5.7, below which cattle have been shown to dramatically reduce DMI. Increased passage rates are also associated with low levels of eNDF, reducing the predicted net energy (NE) value. However, Owens *et al.* (1997) reported that the effects of eNDF on DMI and ME of grain are neither large nor consistent. Although Owens *et al.* (1997) indicted a poor relationship between eNDF and feedlot cattle performance, Mertens (2002) found a good relationship between peNDF and average daily gain (ADG) in another database.

$$ADG = 1.19 + 0.0269 \times peNDF - 0.000883peNDF^2 \quad (2.9)$$

where, $R^2 = 0.95$, and

reg. s.e. = ±0.06 kg/d.

By taking the first derivative of equation (2.9), the peNDF that maximizes ADG of feedlot cattle was determined as 15.3%, but there was little difference in the ADG when the peNDF in the diet was between 12 and 18%. The optimum peNDF in the diet to minimize liver abscesses was 22%, and the peNDF that maximized intake was 25%. The acceptable peNDF range (12 to 18% of diet DM) suggests that recommendations can be modified to match multiple objectives (reduce abscesses, reduce feed per gain, etc.) and account for other factors that may influence minimum peNDF requirements. Fox & Tedeschi (2002) recommended the peNDF requirements of feedlot cattle to be 7 to 10% in the DM for high energy diets. This was based on the eNDF prediction by the equation of Pitt *et al.* (1996) required to keep the rumen pH above 5.7, which is the threshold below which cattle reduce intake. The recommendations for fibre requirements of ruminants can be improved by adjusting fibre for its effectiveness in maintaining chewing activity and ruminal pH (Mertens, 1997). The lack of standard and validated methods to measure effective fibre of feeds or to establish requirements for effective fibre limits the application of the peNDF concept at the present time (NRC, 2001).

2.3 Ruminal acidosis and dietary fibre

Huntington (1988) defines acidosis as a condition of pathologically high acidity in the blood, and in ruminant animals the term includes acidic conditions in the rumen (ruminal acidosis). The condition can be acute (life threatening), or sub-acute (chronic or sub-clinical). Acute acidosis is exhibited as an overt illness following consumption of readily fermented carbohydrates in amounts sufficient to reduce ingesta pH. With sub-acute acidosis, feed intake and performance are reduced, but animals may not appear sick (Owens *et al.*, 1998; Henning, 2004). Calsamiglia *et al.* (2002) found that a ruminal pH kept constant at 5.7 had a negative impact on digestibility of apparent DM, NDF and ADF, lower total and branch-chained VFA concentrations and lower acetate and higher propionate proportions than a ruminal pH kept constant at 6.4. The etiology of acidosis has been described in an review by Huntington (1988).

2.3.1 Control of ruminal pH

Increased ruminal input of buffers, such as bicarbonate from the diet or saliva, or feeds that yield buffers, such as ammonia from degraded protein or non-protein N, will help prevent a depression in the ruminal pH. In addition to buffers, absorption of VFA, by removing un-ionized acid and by the exchange of ionized VFA for bicarbonate during the absorption process, also aids in maintaining the pH near neutral in the rumen (Owens *et al.*, 1998). The ruminal pH is very responsive to chewing behaviour and the pH decreases following meals and increases during rumination (Allen, 1997). Approximately half the bicarbonate entering the rumen comes from saliva during eating and rumination (Owens *et al.*, 1998). The rate of ruminal pH decline is faster as meal size increases and dietary NDF concentration decreases (Dado & Allen, 1993 as cited by Allen, 1997). The dietary NDF is related to total chewing time (Beauchemin, 1991; Mertens 1997) and therefore, salivary buffer flow into the rumen but not to ruminal degradation of organic matter (OM). Fimbres *et al.* (2002) found that the concentration of acetate and the ruminal pH increased, while propionate concentration decreased as the hay in the diet of finishing lambs increased. Increased ruminal degradation is desirable to maximize microbial protein production and energy intake, but the increase of fermentation acids must be compensated for by either increasing the dietary NDF or by increasing the physically effectiveness of the NDF to maintain the ruminal pH by stimulating salivary buffer secretion. However, increased NDF concentration might decrease the DMI because of constraints on ruminal fill. Increasing the physical effectiveness of NDF might be a more desirable alternative to maintain ruminal pH because it would result in greater ruminal fermentation and production of microbial protein (Allen, 1997). Krause *et al.* (2002) found no correlation between intake of NDF to ruminal pH and chewing activity in dairy cows, but intake of eNDF tended to correlate positively with time spend ruminating and chewing.

2.3.2 Prediction of ruminal pH

The prediction of the ruminal pH from the eNDF values of the diet is indicated by equation (2.10). However, the eNDF of this equation is described as the percent of the NDF remaining on a 1.18 mm screen after dry sieving (NRC, 1996). This equation was derived by Pitt *et al.* (1996), before Mertens (1997) differentiated between eNDF and peNDF, which defined peNDF as the way eNDF is described above.

$$\text{Ruminal pH} = 5.425 + 0.04299\ (\%\text{eNDF}) \qquad (2.10)$$

where, $\%\text{eNDF} < 35\%$ in DM, and
$R^2 = 0.52$

2.4 Effect of source and level of roughage

The roughage sources commonly used in feedlot diets have different physical and chemical characteristics. Defoor *et al.* (2002) found that much of the variation in the net energy intake of beef heifers could be attributed to the concentration of NDF in the roughages, and those roughages with higher NDF concentrations had greater roughage value and would be needed at lower concentrations in finishing diets. Galyean & Defoor (2003) suggested that much of the effect of roughage source and level on DMI by feedlot cattle could be accounted for by changes in the dietary NDF supplied by the roughage. Results from a study on the effect of roughage source on the performance of finishing beef cattle indicated that roughage source did not affect performance when the diets were balanced for the percentage of NDF supplied by the roughage (Rivera *et al.*, 2004).

Bartle & Preston (1991; 1992) indicated that decreasing the roughage content of finishing diets below 8 to 10% during the mid-finishing period could reduce roughage use and diet cost with no negative effect on steer performance. This is accomplished by reducing the roughage of the diet to 2% for 60 days during the middle of the feeding period. However, the group of steers fed 2% roughage had numerically more liver abscesses than the group fed 10% of roughage throughout the feeding period.

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CHAPTER 3

GENERAL MATERIALS AND METHODS

3.1 Introduction

This study was conducted on the experimental farm of the University of the Free State situated 20 km south from Bloemfontein, South Africa. The collection period of the digestibility study was undertaken between 15 and 24 October 2006 (10 days), and the production study between 27 October and 12 December 2006 (47 days). The climate during the study period was the normal seasonal occurrence for the end of spring and the onset of the South African summer. The maximum temperature fluctuation during the duration of the study was between a minimum of 14°C and a maximum of 32°C.

3.2 Experimental animals

The experimental animals consisted of approximately four month old South African Mutton Merino ram lambs with an average initial body weight of 36.4 kg and standard deviation (SD) of ±4.67. Animals were selected on live weight in order to reduce initial weight variation and insure the most homogenous group of study animals possible. All the trial animals received a vaccine for the active immunisation against the *Clostridium* strains causing pulpy kidney disease, malignant oedema, blackquarter and tetanus. In addition, the animals were vaccinated against pasteurellosis and treated with an antiparasitic injectable solution as well as an oral treatment against tapeworms. Animals used for the production study received additional feedlot processing treatments that included an oral vitamin A and D supplement and a trenbolone acetate (TBA)/β-oestradiol combination growth promoter.

The digestibility study was conducted with a total of 15 animals for each of two neutral detergent fibre (NDF) sources (*Medicago sativa* and *Eragrostis curvula* hay). The 15 animals were allocated at random to each of three treatments (NDF levels). Although the animals were grouped by the diet and housed together, the allocation to specific pens was done at random and animals being fed the same diet were not necessarily penned next to one another. This random allocation to the specific diets and pens was not only done between the diets of one NDF source, but also between the animals and pens of the other NDF source studied in this trial. The method of random allocation used in this study reduced the probability of animals of the same diet being penned next to one another and thus decreased the probability that a specific diet may have been affected either positively or negatively by environmental factors due to pen location.

The production study was conducted with 27 animals for each of the NDF sources. The animals were allocated in exactly the same way as discussed above in the digestibility study. However, the animals were penned in groups of three per treatment and each of the three experimental diets was replicated with three pens in total. All the animals in this study were weighed on the first day prior to feeding and the morning of slaughter after a 12 hour fasting period. In addition to the empty stomach weights, the animals were weighed on a weekly basis without being fasted.

3.3 Housing

The animals of both the studies were housed in a well ventilated building with a slatted floor (Figure 3.1). This allows urine and faeces to accumulate on a concrete floor below as the wooden floor is elevated above the bottom concrete floor. The individual animals of the digestibility study and the group animals of the production study were separated from one another by partitions build from steel pipes (Figure 3.2).

Figure 3.1 Slatted floor of trial pens.

Figure 3.2 Digestibility study pens.

The measurements of the digestibility study pens were 184 cm in length and 82 cm in width (15088 cm^2/1.5088 m^2). The pens were placed in a double, back to back, row with a common centre partitioning. The feed and water troughs was on opposite ends of the double row, resulting in animals facing away from each another while feeding. Fresh water was provided on an *ad libitum* (*ad lib*) basis by means of fixed water troughs that were located in the left corner of each pen. Feed troughs were secured to avoid water contamination.

The pens of the production study (Figure 3.3), which housed 3 animals, measured 184 cm in length and 156 cm in width, resulting in a surface area of 28704 cm^2/2.8704 m^2. The pens were placed in exactly the same manner as for the digestibility study. However, due to the increased size of the feed troughs, pen measurements and the placing of the access gate, the feed troughs were placed along the common centre partitioning and the animals faced one another while feeding. The centre partitioning was reinforced to prevent animals from reaching for feed from the opposite pen. Water troughs were located on the opposite side from the feed troughs and were also fixed to the side of each pen.

Figure 3.3 Production study pens.

3.4 Feeding and experimental diets

3.4.1 Feeding troughs

The feed troughs for the individually fed animals of the digestibility study measured 30 cm in length, 30 cm in width and 15 cm in depth. This provided more than sufficient space to feed the totally mixed high energy diets fed in this study, as high energy diets are less bulky compared to diets with a higher roughage concentration.

In order to provide feedlot comparable feeding space for the animals of the production study and allow competition at the feeding troughs, single extended feed troughs were build (Figure 3.4).

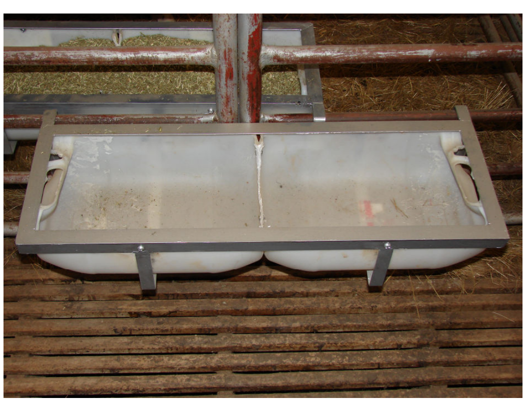

Figure 3.4 Production study feed trough.

These troughs measured 83 cm in length, 24.2 cm in width and 14 cm in depth. This provided each of the three animals with 27.7 cm of feeding space. The feed troughs were also framed to prevent the animals from scraping feed over the side of the trough and thus reduce wastage of the diets.

3.4.2 Feeding of the animals

The animals in both of the studies conducted were fed twice daily, not only to reduce the wastage of the diets, but also to increase the frequency that the animals feed at the troughs, thus increasing the dry matter intake (DMI) of the animals. The first feeding was at 07:00 in the morning and the second at 16:00 in the afternoon. The feeding times was followed precisely to accommodate the animals as creatures of habit and to ensure a healthy constant rumen environment. The animals of the digestibility study were pre-adapted to the high energy diets, while the adaptation of the production study occurred as part of the study to correspond with normal feedlot practice. The adaptation program is explained under paragraph 3.4.2.1.

The animals of the digestibility study all received 1.8 kg (as fed) of their specific diet at the 07:00 feeding of the first day. Additional feed was then allocated at the 16:00 feeding time to pens where animals indicated a higher intake than predicted, ensuring refusals the next morning and thus establishing the intake of the specific animal. Feed allocation for the following days was then calculated from the average intake of the previous three days (except Day 2 and 3 where that average was not available), allocating 15% more feed than the average to allow for refusal by the animal. In order to calculate actual intake and digestibility, the refusals was collected every morning before the 07:00 feeding time and the intake (as fed) of the animal was calculated and recorded for future use in feed allocation. The calculated feed required by each animal was then fed by supplying 50% of the allocation at the 07:00 and 16:00 feeding periods respectively.

First day feed allocation for the production study mimicked the procedure followed during the digestibility study, except that the feed was allocated for three animals per pen. The main differences from the procedure described above were that production study animals received feed *ad lib* and the refusals of each pen was collected on a weekly basis in order to calculate the DMI of each pen. The lambs were fed less near the end of the week according to the feed status of their troughs and DMI in order to clear the majority of the feed before refusal collection.

3.4.2.1 Adaptation of the animals

The animals of both the digestibility and production studies were adapted to high energy diets over a 14 day period. Totally mixed final diets were fed on top of additional roughage (the roughage of the specific diet the animals was to receive during the study). The amount of the diet was increased and the additional roughage decreased with the same amount every second day. The total amount of feed allocated was determined by the daily intake of the animal. An example of the program used is explained below. The amount of feed supplied after the first day (1.8 kg/animal/day) was however adapted to higher and lower intake for individual digestibility study animals and grouped production study animals. The method of calculation however remained exactly the same. If the intake of the animal(s) was/were 1.8 kg/animal/day, the feed allocated on day one consists of 0.225 kg (1.8 kg divided by 8) of diet and 1.575 kg of additional roughage (per lamb). The amount of diet is then increased by 0.225 kg every second day and the additional roughage decreased by the same amount. This result in the same amount (0.9 kg) of diet and roughage fed on days seven to eight and 1.575 kg of diet and 0.225 kg of additional roughage fed on Days 13 to 14 of the adaptation period. On Day 15 the diet was fed without any additional roughage. These procedures ensure that the animals were less prone to metabolic disorders caused by high energy diets containing feedstuffs with crushed maize and molasses that are easily fermentable in the rumen.

3.4.3 Composition of the experimental diets

The composition of the experimental diets are shown in Table 3.1 for *Medicago sativa* and in Table 3.2 for *Eragrostis curvula* hay. Three different diets for a specific NDF source was formulated according to the NRC (1985) feeding standards for finishing lambs. Diets with a specific roughage source were formulated with different NDF levels. In an effort to investigate the effect of NDF levels, the diets were formulated on a metabolizable energy (ME), crude protein (CP), rumen degradable protein (RDP), non-degradable protein (NDP), non-protein nitrogen (NPN), calcium (Ca) and phosphorus (P) equivalent basis. The feedstuff specifications used to formulate the diets were obtained from a commercial animal nutrition company based on South African analysis of feedstuffs. The true values of each diet determined by means of wet chemistry are indicated in the results (Chapter 4 and 5) of this study.

Table 3.1 Calculated physical and chemical composition of experimental diets containing neutral detergent fibre from *Medicago sativa* hay.

	Diets		
Parameter	**1**	**2**	**3**
Physical composition (as fed):			
Medicago sativa hay (%)	8.00	14.00	20.00
Crushed maize (%)	68.50	64.50	60.00
Protein concentrate[1] (%)	20.00	20.00	20.00
Cottonseed oilcake (%)	3.50	1.50	0.00
Chemical composition (dry matter basis):			
Dry matter (%)	89.84	89.63	89.42
Crude protein (%)	16.00	15.83	15.83
Neutral detergent fibre (%)	13.60	14.86	16.22
Metabolizable energy (MJ/kg)	12.64	12.43	12.20
Calcium (%)	0.75	0.80	0.85
Phosphorous (%)	0.37	0.36	0.35
Effective fibre (%)	10.40	16.45	22.52
Fat (%)	4.54	4.41	4.28
Molasses (%)	10.91	10.93	10.96
Ionophore (mg/kg)	16.25	16.29	16.33
Rumen degradable protein (%)	10.81	10.91	11.11
Non-degradable protein (%)	5.19	4.93	4.72
Non-protein nitrogen (%)	1.67	1.67	1.68

[1]Specifications of the commercial protein concentrate was 90.72% DM, 30% crude protein, 2.48% calcium, 0.6% phosphorous and 72 mg/kg monensin.

Table 3.2 Calculated physical and chemical composition of experimental diets containing neutral detergent fibre from *Eragrostis curvula* hay.

	Diets		
Parameter	**1**	**2**	**3**
Physical composition (as fed):			
Eragrostis curvula hay (%)	3.00	6.00	9.00
Crushed maize (%)	71.00	68.00	64.50
Protein concentrate[1] (%)	20.00	20.00	20.00
Cottonseed oilcake (%)	6.00	6.00	6.50
Chemical composition (dry matter basis):			
Dry matter (%)	90.27	90.41	90.57
Crude protein (%)	16.06	15.96	16.02
Neutral detergent fibre (%)	13.94	15.98	18.12
Metabolizable energy (MJ/kg)	12.74	12.55	12.33
Calcium (%)	0.68	0.68	0.68
Phosphorous (%)	0.38	0.38	0.38
Effective fibre (%)	5.36	8.34	11.31
Fat (%)	4.62	4.52	4.43
Molasses (%)	10.86	10.84	10.82
Ionophore (mg/kg)	16.17	16.15	16.12
Rumen degradable protein (%)	10.62	10.61	10.69
Non degradable protein (%)	5.44	5.35	5.32
Non protein nitrogen (%)	1.66	1.66	1.66

[1]Specifications of the commercial protein concentrate was 90.72% DM, 30% crude protein, 2.48% calcium, 0.6% phosphorous and 72 mg/kg monensin.

3.4.4 Preparation of the experimental diet

The roughage was ground through a 12.5 mm screen using a Drosky hammer mill. The crushed maize, protein concentrate and cottonseed oilcake was obtained from a commercial feed merchant. Feed components of the individual diets were accurately weighed and mixed thoroughly with the aid of a stationary mechanical mixer. The batch size of every mix differed according to the amount of roughage required for the specific diet, as the capacity of the mixer was limited when bulky feeds were mixed.

3.5 Digestibility study

3.5.1 Adaptation

The adaptation of the digestibility study animals occurred for a period of 14 days with the method described in paragraph 3.4.2.1. The animals were fed the complete diet without any additional roughage for another three days before the faecal bags were fitted. Animals were then allowed another three days to adapt to the faecal bags before the collection period commenced.

3.5.2 Collection period

A 10 day collection period followed the adaptation period to determine the digestibility coefficients and digestible nutrients of the diets. The animals were allocated to the different treatments as explained in paragraph 3.2 and feed allocation in paragraph 3.4.2 of this chapter. A representative sample of each of the diets was taken on a daily basis, sealed and kept for later milling and chemical analysis. All the animals were fitted with faecal collecting bags and the faeces voided was collected twice daily to avoid over accumulation of faeces inside the bag. The first collection of faeces occurred 24 hours after the first feeding and collection continued 24 hours after the last feed was allocated. Collected faeces was weighed, placed in marked paper bags and dried for 12 hours at 100 °C. Dried faeces was weighed, sealed and kept for later milling and chemical analysis. The feed refused from each animal was also collected on a daily basis and kept in sealed marked bags. At the end of the 10 day collection period, the daily collected feed, refusals and faeces were respectively mixed together and milled through a 1 mm screen. Representative samples of each were taken using the quartering method and these samples were used for chemical analysis.

3.5.3 Effective fibre

A representative sample of each experimental diet was vertically shaken on a 1.18 mm screen to determine the physical effective NDF (peNDF) values of the diets. Physical effective NDF is expressed as the percentage of NDF remaining on the 1.18 mm screen (Mertens, 1986, as cited by Fox & Tedeschi, 2002).

3.5.4 Ruminal pH and faecal score

Ruminal pH and faecal score data was also gathered during the digestibility study. Rumen fluid was collected at the end of the collection period by means of a stomach tube, three hours after the morning feeding. Each individual sample was immediately tested using a pH meter.

Faecal scores were awarded daily after all the faeces were collected. These scores were documented to each animal and treatment. The faecal scores were defined as follows:

1 - Diarrhoea
2 – No visible separation, high moisture (soft faeces)
3 – No visible separation, normal moisture
4 – Some separation visible, normal moisture
5 – Completely separated, normal moisture

3.5.5 Chemical analysis

The representative feed, refusal and faecal samples were milled through a 1 mm screen and analysed in duplicate for dry matter (DM), crude protein (CP), gross energy (GE), ash, organic matter (OM), neutral detergent fibre (NDF) and lignin content using standard laboratory procedures. All the chemical analysis were done in duplicate and repeated if the difference between the two values exceeded more than 3%.

3.5.5.1 Dry matter (DM)

Approximately 2 g of each milled sample was weighed accurately in a 30 ml porcelain crucible and dried in a oven at 100 °C for a minimum period of 16 hours (over night) to a constant mass (AOAC, 2000). After drying, the samples was placed in a desiccator to cool down and weighed immediately afterwards.

DM was calculated as follows:

% Moisture = [(weight loss on drying, g) / (weight of test sample, g)] × 100
% Dry matter = 100 - % Moisture

The weight of the individual crucibles were deducted to determine the weight loss of drying and the weight of the test sample as all the crucibles did not have exactly the same weight.

3.5.5.2 Crude protein (CP)

The crude protein of the samples (feed, refusals and faeces) was determined using the Dumas method of nitrogen combustion, using a Leco FP-528 instrument for analysis. The principle of the Dumas method is that nitrogen (N_2), freed by pyrolysis and subsequent combustions, is swept by a carbon dioxide (CO_2) carrier into a nitrometer. The CO_2 is absorbed in potassium hydroxide (KOH) and volume residual N_2 is measured. The nitrogen content is then converted to the protein equivalent by multiplying the percentage nitrogen with the factor of 6.25 (AOAC, 2000).

Approximately 0.12 g of each sample (as fed) was accurately weighed into aluminium foil cups that was sealed and placed on the carousel of the instrument which did sample analysis continuously. Protein values were recorded on a computer which was connected to the scale as well as the analysing instrument. The protein equivalent was calculated by the computer program from the numerical factor as described above. The protein equivalent on a DM basis was then calculated as follows:

% Protein (DM) = % Protein (as fed) / % DM of test sample

3.5.5.3 Gross energy (GE)

A Gallencamp adiabatic bomb calorimeter (CP 400) standardised using benzoic acid was used in the determination of the GE values of all the samples. Approximately 0.7 g of each sample (feed, refusals and faeces) was weighed accurately and placed in a steel crucible. A platinum wire (5 cm) was connected to the electrodes of the bomb, the sample carefully placed inside and the bomb was filled with oxygen to a pressure of 3000 Kpa. The temperature of the bomb was then reduced to equal the temperature of the instrument by means of water cooling. The bomb was then placed inside the instrument, the weight of the sample entered and the GE was determined by the combustion method. Gross energy is expressed as megajoules per kilogram (MJ/kg).

3.5.5.4 Ash and organic matter (OM)

The ash content of the samples was determined using a Heraew furnace. The 2 g DM samples weighed into porcelain crucibles used to determine the DM of the samples, was also utilised for ash determination. The furnace was pre-heated to a temperature of 600 °C and the samples were kept at this temperature for two hours. The samples were then transferred to a desiccator to cool down and weighed immediately afterwards (AOAC, 2000). The ash and organic matter content was calculated as follows:

% Ash = [(weight of ash, g) / (weight of test sample, g)] × 100

% Organic matter (OM) = 100 - % Ash

The weight of the individual crucibles were deducted to determine the weight of the ash and the weight of the test sample, as all the crucibles did not have exactly the same weight.

3.5.5.5 Neutral detergent fibre (NDF) and lignin

The NDF and lignin determination was done by Cumberland Valley Analytical Services, in the United States of America. The NDF was determined by the procedure recommended by Van Soest *et al.* (1991). The only modification to the NDF method was that the samples were filtered through a Whatman 934-AH glass micro-fibre filter with 1.5 µm particle retention.

The lignin content of the samples was determined by the method described by Goering & Van Soest (1970). Modifications to the method were that the fibre residue from the ADF step was recovered on a 1.5 µm particle retention 7 cm Whatman glass fibre filter instead of a Gooch crucible. The fibre residue and filter was transferred to a capped glass tube and approximately 45 ml of 72% sulphuric acid was added. Tubes were agitated for two hours to insure constant washing with the acid. The contents were filtered onto a second filter which was then dried and weighed. The filters and lignin was then ashed for two hours to remove lignin organic matter. The filter and ash residue was weighed and subtracted from the original weight to determine the grams of lignin.

3.6 Production study

The production study was conducted over a period of 47 days to determine the DMI, average daily gain (ADG), feed conversion ratio (FCR) and carcass characteristics of animals fed in penned conditions. The animals were allocated to the different treatments and weighed as explained in paragraph 3.2. The feed allocation occurred as described in paragraph 3.4.2.

3.6.1 Chewing activity

A 24 hour observation was done to determine the time animals spend eating and ruminating within a 24 h period. One animal from each pen (three replications per treatment) was selected at random to be observed every five minutes and the activity was documented. Observations included eating, ruminating and no activity. This was done under the assumption that that activity will continue for the entire five minute period as described by Beauchemin *et al.* (2003). The combined eating and ruminating activity data form the chewing activity values.

3.6.2 Carcass characteristics

All the animals were slaughtered at a commercial abattoir and the carcass characteristics was recorded. Parameters used in carcass evaluation were cold carcass weight, dressing percentage, carcass length, shoulder circumference, buttock circumference and fat thickness. Carcass measurements and weights were taken 24 hours after refrigeration according to the methods described by Fisher & De Boer (1993). The fat thickness was measured on the left flank of the carcass between the 12^{th} and 13^{th} rib of the *M. longissimus thoracis* at three different points

(Edwards *et al.*, 1989). Carcasses were independently classified at a commercial abattoir according to the official sheep carcass classification system as described by the South African Government Notice No. R 863 (2006).

3.7 Experimental design

The experimental layout for both the digestibility and production studies was a complete random design. The digestibility data had five replications per treatment (diet) for each of the NDF sources and the same animals were used for ruminal pH collection. The production study had three replications per treatment for dry matter intake and feed conversion ratio and nine replications for average daily gain and carcass characteristics. Chewing and ruminating activity observations done during the production study was replicated three times per NDF source.

3.8 Statistical analysis

Data were statistically analysed using PROC GLM procedures of SAS (1995). The treatments were compared using the one-way ANOVA for all the data collected. Tukey's method of multiple comparisons was also used to determine which means differed, if significant differences were indicated for a specific parameter.

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CHAPTER 4

THE DIETARY FIBRE REQUIREMENTS OF LAMBS FED FINISHING DIETS WITH *MEDICAGO SATIVA* HAY

4.1 Introduction

Medicago sativa (lucerne) is one of the most important hay crops in South Africa and 90% is produced under irrigation. Grönum *et al.* (2000) reported that between 208,000 and 240,000 ha are used for the production of hay and the average annual production was approximately 3.8 million tons. The area cultivated for the production of this crop has remained more or less constant during past years.

Compared to grasses cultivated for hay production, *Medicago sativa* has a moderate neutral detergent fibre (NDF) content with a higher cell wall density that leads to higher intakes. The hay also has a high buffering capacity with a moderately fast rate of fermentation in the rumen. In addition, *Medicago sativa* contains a higher concentration of pectin compared to grasses which has some very desirable nutritional characteristics even though a component of cell walls (Van Soest, 1987). Hall (1994) noted that pectin is a highly digestible and fermentable carbohydrate energy source. The nutritional characteristics of *Medicago sativa* hay makes it an excellent and popular roughage source in the finishing diets of lambs in South African feedlots.

Neutral detergent fibre limits dry matter intake (DMI) by the animals due to the “bulk” or “fill” it gives to a diet and because NDF can be used to predict intake by the animals, it is an important consideration when formulating diets (Mertens, 1992). Ruminants require adequate amounts of coarse textured feeds, which contribute to maintaining the proper muscle tone in the digestive system as well as the rumen pH, and thus help to avoid metabolic disorders (Sudweeks *et al.*, 1981). The NDF physical effectiveness is correlated to ruminal pH as it stimulates rumination when the particle size is large enough (Allen, 1997). NDF is less effective in formulating minimum fibre diets when finely chopped forages or ground non-forage fibre sources (by-product feeds) are used (Mertens, 2002). This is important when formulating finishing diets with high concentrations of easily fermentable carbohydrates that cause clinical and sub-clinical acidosis which results in animal losses and hampers production in the feedlot. NDF is the only fibre quantifying method that measures the differences within and among feed types and has the potential for developing a system of general feeding recommendations across all feeds (Mertens, 2002). NDF requirements should however be combined with the physical form of the fibre (effective fibre). This has been addressed in the present study by using the particle size commonly applied in South Africa.

No information regarding the fibre requirements (NDF) of lambs fed high energy finishing diets with *Medicago sativa* hay as roughage source could be detected in the available literature. The aim of this study was to determine the NDF requirements of lambs fed finishing diets containing *Medicago sativa* hay with a specific particle size as roughage source.

4.2 Materials and Methods

The materials and methods used in the digestibility and production study have been described in Chapter 3.

4.3 Results and Discussion

4.3.1 Digestibility study

4.3.1.1 Chemical composition of the experimental diets

The chemical composition of the experimental diets containing *Medicago sativa* hay as fibre source is presented in Table 4.1. Chemical analysis of the diets indicated higher values than calculated in Table 3.1 for NDF and crude protein (CP). The NDF values differed from the calculated values with 15.2%, 3.2% and 24.4% for the diets containing 8, 14 and 20% hay respectively. Calculated values for the CP fraction of the diets did not indicate large differences compared to the analysed values except for the diet containing 20% NDF which was 11.2% higher than calculated. The differences from the calculated values for the remaining diets were 1.5% and 0.9% for the diets containing 16 and 15% NDF respectively.

Table 4.1 Chemical composition of diets containing neutral detergent fibre from *Medicago sativa* hay on a dry matter basis.

	***Medicago sativa* hay in diets**		
Parameter	**8%**	**14%**	**20%**
Chemical composition (dry matter basis)			
Dry matter (%)	90.54	90.48	91.55
Organic matter (%)	95.42	94.79	94.08
Crude protein (%)	16.24	15.98	17.60
Neutral detergent fibre (%)	15.67	15.34	20.17
Physical effective NDF (%)	13.45	12.92	15.14

The different actual and calculated CP and NDF values of the experimental diets could be attributed to the fact that it was not practically possible to determine the nutrient concentrations of the feed ingredients, especially *Medicago sativa* by means of chemical analysis before diet formulation. The *Medicago sativa* hay used in the present study had an average NDF content of 39.94% and a lignin content of 6.23%. These values were lower than the average of 44.06 and 7.37% found for NDF and lignin respectively by Scholtz (2008, unpublished data) for South Africa lucerne hay.

Roughage sources contribute the most to nutrient variation as there are large differences found in nutrient densities between the same roughage due to various factors such as locality, climate, soil and production practices. Scholtz (2001) indicated a variation in the NDF content of 26.70 to 69.82% for *Medicago sativa* hay cultivated in South Africa. *Medicago sativa* has also been reported to contain between 15 to 22% CP (Hanson *et al*., 1988). This variation in nutrient densities different from the average used in diet formulation explains the higher values indicted in the experimental diets.

The NDF values of the diets did not indicate the expected increase with an increase in the roughage percentage of the diets. However, a large increase in the NDF content occured when the roughage content was increased from 14 to 20%. This may probably be attributed to variation within the baled *Medicago sativa* hay load (lot) that was used during the mixing of the different diets. Premixing of all the hay before mixing the individual diets did not occur for practical and mechanical reasons and the quality of the hay may have differed between the different bales used. However, the hay was obtained from a single source and baled at one location.

The peNDF values of all the diets were between the 12 to 18% recommended by Mertens (2002) as the acceptable range for cattle. According to data of this particular study a peNDF value of 15.3% was the most desirable for an optimum average daily gain (ADG). The peNDF values in the present study were however above the requirements recommended by Fox & Tedeschi (2002). These researchers are of the opinion that 7 to 10% peNDF are sufficient to keep the ruminal pH above 5.7, the threshold when cattle start to reduce intake. The commercial concentrate used in the diets might have been a contributing factor to the peNDF values found in the experimental diets as it contained a by-product (bagasse) of the sugarcane industry which increased the fibre content of the concentrate. The physical structure of the by-product might have contributed more to the peNDF of the diets than initially expected. The NDF and peNDF concentrations differed between the diets. However, the effects of the different fibre concentrations are only applicable between the concentrations of 15 to 20%

NDF and 13 to 15% peNDF. Crude protein provided was sufficient for finishing lambs with a body weight of between 30 to 50 kg if the daily DMI is equal or above 1.20 kg as recommended by the NRC (1985).

4.3.1.2 Apparent digestibility coefficients and digestible nutrients

The DMI, apparent digestibility coefficients and digestible nutrients of the experimental diets are summarised in Table 4.2. The DMI of the lambs did not differ significantly (P>0.05) between the experimental diets. Therefore, feeding level was not a factor that could have influenced apparent digestibility of the diets. Dado & Allen (1995) found that the DMI of cows fed 25% NDF were not affected, but a reduction in DMI was noted when the dietary NDF was increased to 35% due to increased rumen fill caused by the "bulk" or "fill" of NDF. This might explain the non significant (P>0.05) DMI differences between the diets of the present study. The NDF in the experimental diets might have been to low too affect the DMI of the lambs.

Table 4.2 Dry matter intake and digestion of diets containing neutral detergent fibre from *Medicago sativa* hay (Mean±s.e.).

	Dietary neutral detergent fibre				
Parameter	**16%**	**15%**	**20%**	**P[1]**	**CV[2]**
Dry matter intake (kg/lamb/day)	1.32±0.061	1.32±0.079	1.27±0.127	0.9369	15.90
Apparent digestibility coefficients:					
Dry matter (%)	82.08±0.005	81.59±0.015	80.49±0.008	0.4537	2.43
Organic matter (%)	83.26±0.005	83.25±0.013	82.14±0.007	0.5798	2.25
Crude protein (%)	77.12±0.006	74.93±0.025	76.98±0.011	0.5219	4.01
Neutral detergent fibre (%)	39.60±0.025[a]	33.99±0.044[a]	55.23±0.046[b]	0.0072	19.25
Gross energy (%)	65.28±0.005	65.28±0.013	63.87±0.009	0.3518	2.57
Apparent digestible nutrients:					
Organic matter (%)	79.93±0.465	79.82±1.321	77.87±0.736	0.1819	2.29
Crude protein (%)	12.20±0.213[a]	11.15±0.400[a]	13.40±0.230[b]	0.0006	4.82
Neutral detergent fibre (%)	6.04±0.481[a]	4.84±0.629[a]	11.15±0.923[b]	0.0001	20.60
Metabolizable energy (MJ/kg)[3]	11.53±0.095	11.58±0.259	11.13±0.167	0.0805	2.63

[1](P>0.05 = non significant).

[2]Coefficient of variation (%).

[3]Metabolizable energy = digestible energy × 0.8 (McDonald *et al.*, 2002).

[a,b]Means in a row with different superscripts differ significantly (P<0.05).

Apart from NDF, the apparent digestibility coefficients results of dry matter (DM), organic matter (OM), CP and gross energy (GE) indicated no significant (P>0.05) differences between the three experimental diets. Apparent digestible nutrients showed the same results with the exception of CP. The apparent digestible CP content of the diet containing 20% NDF was significantly (P<0.05) higher than those with 16 and 15% NDF. The digestibility coefficients and digestible nutrients of NDF indicated the same differences as CP. The significantly different result of the apparent digestible CP content and the non significant apparent digestibility coefficient of CP between the diets may be explained by the DMI used in the calculation of the apparent digestible nutrient compared to the nutrient intake used in the apparent digestibility coefficient calculation as the denominator for the digested nutrient. As indicated in Table 4.2 the DMI (non significant) of the lambs fed the diet containing 20% NDF was lower than the DMI of the lambs fed diets containing 15 and 16% NDF. This explains the significantly higher apparent digestible CP of this diet. The apparent digestibility coefficients indicate non significance (P>0.05) with the lower DMI, but the higher CP concentration in the diet containing 20% NDF explains the higher CP intake of the animals with a lower DMI.

As already mentioned, the expected increase in the NDF concentration of the calculated values with an increased roughage percentage did not realise when the diets was practically mixed. The same results were reflected in the apparent digestibility coefficients and apparent digestible NDF values. It seems that these values were positively related to the NDF content of the diets. This result may be attributed to reduced fibre digestibility with an increase in the concentrate (crushed maize) content of the diets. Reduction in fibre digestibility with a concentrate increase in mixed diets was also found by Miller & Muntifering (1985) and Dixon (1986). The reduced NDF digestibility may be attributed to associative effects of feeds due to the increase of easily fermentable carbohydrates (starch in crushed maize). Rapid fermentation of starch to volatile fatty acids (VFA) occurs in the rumen which depresses the ruminal pH to 6 or lower. This lower pH inhibits cellulolytic micro-organisms which results in the depression of fibre digestibility (McDonald *et al.,* 2002). Mould *et al.* (1983) reported inhibited digestion of cellulose if the rumen pH falls below 6.3 with total inhibition when the pH fell below 6.0. The extent of DM degradation and cellulolysis are, however, not only influenced by the ruminal pH, but also by the rate of solubilisation of the concentrate supplement and the degradability of the roughage. These findings were also supported by Hoover (1986).

The results from this study (Table 4.2) indicated that an inclusion level of 15 to 20% NDF in a finishing diet for lambs with *Medicago sativa* hay as fibre source did not influence the metabolizable energy (ME) content of the diet. Accordingly, it should be reflected in the production performance of the lambs.

4.3.2 Production study

4.3.2.1 Intake

The DMI and metabolizable energy intake (MEI) of the lambs is shown in Table 4.3 and Figure 4.1. The results in Table 4.3 and Figure 4.1 illustrates with the exception of Week 6, that no significant (P>0.05) differences occurred in the DMI and MEI of the lambs in the different treatments during the feeding period.

Table 4.3 Dry matter and metabolizable energy intake of lambs fed diets containing neutral detergent fibre from *Medicago sativa* hay (Mean±s.e.).

	Dietary neutral detergent fibre				
Parameter	**16%**	**15%**	**20%**	**P[1]**	**CV[2]**
DMI: Week 1 (kg/lamb/day)	1.47±0.033	1.40±0.100	1.43±0.033	0.7703	7.71
DMI: Week 2 (kg/lamb/day)	1.53±0.120	1.50±0.115	1.63±0.067	0.6585	11.53
DMI: Week 3 (kg/lamb/day)	1.16±0.033	1.40±0.058	1.40±0.200	0.3580	15.94
DMI: Week 4 (kg/lamb/day)	1.47±0.067	1.53±0.120	1.53±0.067	0.8314	10.11
DMI: Week 5 (kg/lamb/day)	1.60±0.115	1.70±0.115	1.77±0.089	0.5725	10.99
DMI: Week 6 (kg/lamb/day)	1.60±0.058^{a}	1.90±0.100^{b}	1.67±0.033^{a}	0.0498	6.98
DMI: Week 7 (kg/lamb/day)	1.73±0.067	1.93±0.067	1.83±0.067	0.1866	6.30
DMI: Feeding period (kg/lamb/day)	1.50±0.058	1.60±0.058	1.60±0.100	0.5787	8.24
Metbolizable energy intake (MJ/lamb/day)	17.2±0.7479	18.5±0.7363	17.9±0.948	0.5499	7.92

[1](P>0.05 = non significant).

[2]Coefficient of variation (%).

[a,b]Means in a row with different superscripts differ significantly (P<0.05).

Animals fed the 16% NDF diet tended to have a lower DMI for the majority of the feeding period compared to the other treatments. This might be attributed to a non significant lower live weight of this group from the start of the trial as set out in Figure 4.2 and Table 4.4. As already mentioned in paragraph 4.3.1.2, the NDF content of the experimental diets may have been to low to affect the DMI between the different treatments due to rumen fill. This was also indicated by other researchers (Dado & Allen, 1995). From the present study it was however clear that feedlot diets containing NDF of 15 to 20% and/or peNDF of 13 to 15% did not influence the DMI of lambs. However, it is probably important that the particle size of the feed ingredients and especially roughage was of such a nature (not to large) as to avoid selective feeding by the lambs.

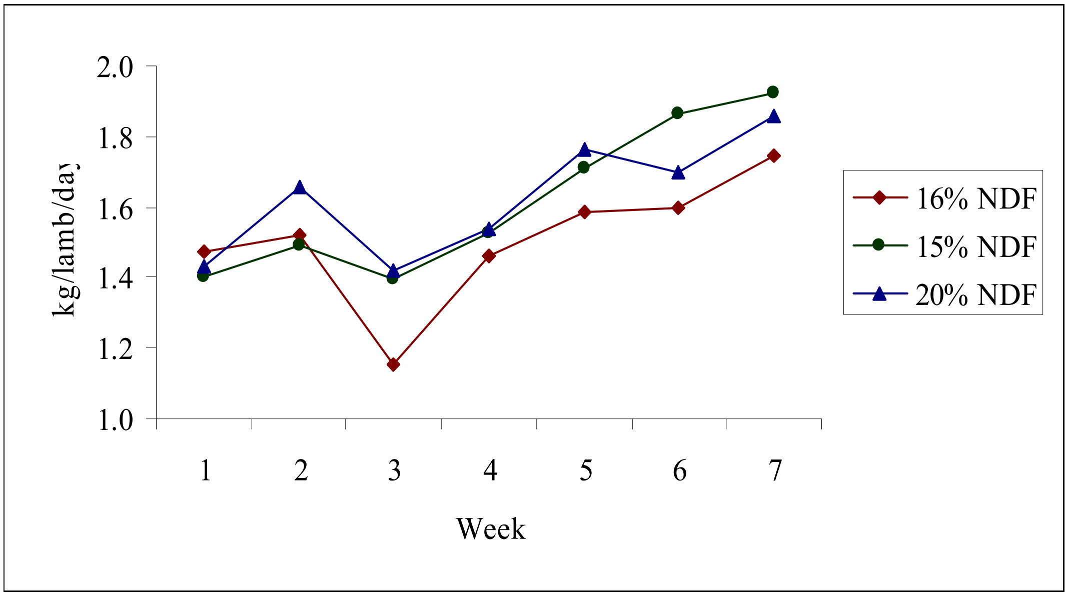

Figure 4.1 Dry matter intake of lambs fed diets containing neutral detergent fibre from *Medicago sativa* hay.

4.3.2.2 Weight gain and conversion ratios

The live weight, average daily gain (ADG), feed conversion ratio (FCR) and metabolizable energy conversion ratio (MECR) results is shown in Figure 4.2 and Table 4.4.

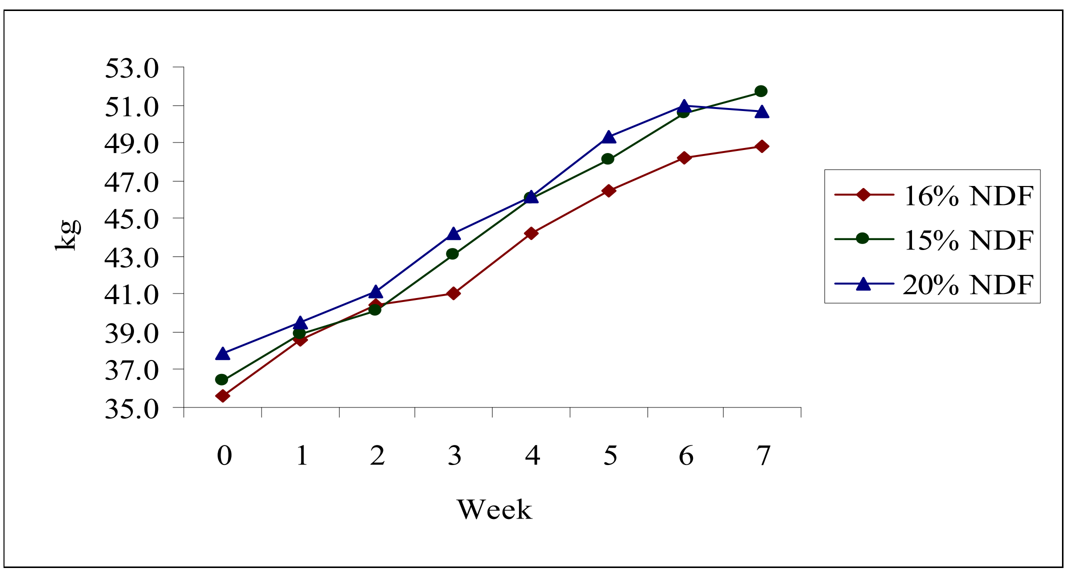

Figure 4.2 Live weight of lambs fed diets containing neutral detergent fibre from *Medicago sativa* hay.

Table 4.4 Live weight and conversion ratios of lambs fed diets containing neutral detergent fibre from *Medicago sativa* hay (Mean±s.e.).

Parameter	Dietary neutral detergent fibre 16%	15%	20%	P[1]	CV[2]
Live weight: Week 0 (kg)[3]	35.6±1.240	36.4±2.394	37.9±1.164	0.6346	13.88
Live weight: Week 1 (kg)	38.6±1.016	38.8±2.632	39.5±1.078	0.9340	13.24
Live weight: Week 2 (kg)	40.5±1.355	40.1±2.853	41.1±1.501	0.9363	14.93
Live weight: Week 3 (kg)	41.0±1.007	43.1±2.910	44.2±1.334	0.5240	13.59
Live weight: Week 4 (kg)	44.2±0.941	46.0±2.860	46.2±1.515	0.7243	12.84
Live weight: Week 5 (kg)	46.5±1.331	48.0±2.848	49.3±1.789	0.6375	13.07
Live weight: Week 6 (kg)	48.2±1.249	50.5±2.825	50.9±2.005	0.6252	12.79
Live weight: Week 7 (kg)[3]	48.8±1.044	51.7±2.600	50.7±1.938	0.5722	11.71
Average daily gain (kg/lamb/day)	0.280±0.013	0.326±0.023	0.272±0.022	0.1404	20.53
Feed conversion ratio (kg DM/kg gain)[4]	5.37±0.318	4.93±0.410	6.00±0.231	0.1474	10.45
Metabolizable energy conversion ratio (MJ/kg gain)	61.6±3.7413	57.4±4.7996	66.4±2.639	0.3166	10.73

[1](P>0.05 = non significant).

[2]Coefficient of variation (%).

[3]Empty stomach weight.

[4]DM = dry matter.

[a,b]Means in a row with different superscripts differ significantly (P<0.05).

The live weights of Weeks 0 and 7 indicated in both Figure 4.2 and Table 4.4 were empty stomach weights after a 12 hour over night fasting of the animals. As with the DMI and MEI results, no significant (P>0.05) differences in live weight occurred either at one particular week or for the entire feeding period. Accordingly, no differences in feed or energy conversion ratios could be expected. From Table 4.4 it is clear that the NDF and/or peNDF levels applied in the present study with *Medicago sativa* hay as NDF source did not influence the efficiency of feed and energy utilization. Mertens (2002) suggested that the peNDF can be altered in cattle diets to either aid FCR or reduce liver abscesses by reducing or increasing the peNDF of the diet between 12 and 18% respectively. However, the FCR did not differ between the different actual NDF and peNDF levels and liver abscess data was not collected for this particular study.

4.3.2.3 Carcass characteristics

The carcass characteristics of the slaughtered lambs are presented in Table 4.5. None of the parameters used in the carcass evaluation indicated any significant (P>0.05) differences. No distinct differences which might be attributed to any of the specific treatments could be identified within this particular data set. All the carcasses were awarded the A2 classification at a commercial abattoir. Thus, no statistical analysis was carried out. Furthermore, no significant (P = 0.3081) differences were observed in the fat thickness of the lambs in the different NDF dietary treatments.

Table 4.5 Carcass characteristics of lambs fed diets containing neutral detergent fibre from *Medicago sativa* hay (Mean±s.e.).

	Dietary neutral detergent fibre				
Parameter	**16%**	**15%**	**20%**	**P[1]**	**CV[2]**
Cold carcass weight (kg)	24.0±0.760	25.5±1.433	25.4±0.929	0.5520	12.95
Dressing (%)	49.2±0.851	49.3±0.578	50.2±0.448	0.4830	3.92
Carcass length (cm)	60.1±0.632	60.9±1.053	61.8±0.717	0.3491	4.04
Shoulder circumference (cm)	79.0±0.583	80.4±1.344	81.5±0.820	0.5268	3.62
Buttock circumference (cm)	66.4±0.674	68.5±1.242	68.1±0.705	0.2625	4.04
Fat thickness (mm)	3.5±0.318	3.0±0.125	3.5±0.236	0.3081	21.53

[1](P>0.05 = non significant).

[2]Coefficient of variation (%).

[a,b]Means in a row with different superscripts differ significantly (P<0.05).

4.3.3 Rumen health characteristics

The chewing activity, ruminal pH and faecal scores of the lambs are summarised in Table 4.6. No significant (P>0.05) differences between the treatments was found for any of the parameters. These findings were in accordance with the performance of the lambs regarding dry matter intake, growth, feed conversion and carcass characteristics.

Chewing activity as a total value for the eating and ruminating activity is an indication of efficiency of production. These results however did not support that of Fimbres *et al.* (2002) who found a linear increase in total chewing activity with an increase in forage level in the diets of lambs. The length of the chopped hay and the peNDF values of the diets used in their study were however not indicated by these researchers. Both these factors can affect the chewing activity of the lambs.

Table 4.6 Rumen health characteristics of lambs fed diets containing neutral detergent fibre from *Medicago sativa* hay (Mean±s.e.).

	Dietary neutral detergent fibre				
Parameter	**16%**	**15%**	**20%**	**P[1]**	**CV[2]**
Chewing activity (h/day)[3]	7.9±1.003	8.6±1.058	6.8±0.751	0.4471	21.09
Eating activity (h/day)	2.7±0.333	3.3±0.333	3.3±0.333	0.3318	18.56
Ruminating activity (h/day)	5.3±0.882	5.0±0.577	3.7±0.333	0.2282	23.69
Ruminal pH	6.42±0.084	6.47±0.036	6.40±0.134	0.8857	3.36
Faecal score (1 - 5)	5±0.143	4±0.393	4±0.179	0.1109	11.87

[1](P>0.05 = non significant).

[2]Coefficient of variation (%).

[3]Combined eating and ruminating activity.

[a,b]Means in a row with different superscripts differ significantly (P<0.05).

The ruminal pH value of above 6 for all the diets indicates a healthy rumen environment that was also reflected in the faecal scores. This may be attributed to sufficient fibre in the diets that was effective in stimulating chewing activity which in turn produced adequate saliva to buffer the rumen pH and ensure a healthy rumen environment. However, the ruminal pH did not contribute to the difference in NDF digestibility as discussed in paragraph 4.3.1.2 of the digestibility study. As previously mentioned, rate of solubilisation of the concentrate supplement and degradability of the roughage could also attribute to the extent of cellulolysis (paragraph 4.3.1.2). The lower degradability of *Medicago sativa* hay and high buffering capacity as well as the high solubility of the molasses based protein concentrate might have been contributing factors to this result. Mould *et al*. (1983) reported that molasses as carbohydrate source depressed DM degradation to a greater extent than grains. It seems from the results of the present study that peNDF values that varied from 13 to 15% in the finishing diets of lambs did not influence chewing activity, ruminal pH and faecal scores.

4.4 Conclusions

From the results of the present study it seems that the inclusion of 15 to 20% NDF (13 to 15% peNDF) in the finishing diets for lambs with *Medicago sativa* hay as roughage source did not influence the DMI and ME intake and accordingly growth and feed conversion performance as well as carcass characteristics. These results were supported by rumen health measurements like chewing activity, ruminal pH and faecal scores that were also not influenced by the mentioned NDF and peNDF percentages in the finishing diets. These results were obtained despite of the fact that a lower NDF and/or peNDF content in the diet resulted in a lower fibre digestibility. The influence of a wider range of NDF percentages in finishing diets for lambs with *Medicago sativa* hay as roughage source as well as different particle sizes of the hay on rumen health, digestibility and lamb performance warrants further investigation. The inclusion of 15 to 20% NDF (13 to 15% peNDF) provided in the NDF requirements of lambs fed finishing diets with *Medicago sativa* hay as roughage source milled through a 12.5 mm screen.

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CHAPTER 5

THE DIETARY FIBRE REQUIREMENTS OF LAMBS FED FINISHING DIETS WITH *ERAGROSTIS CURVULA* HAY

5.1 Introduction

Eragrostis curvula (weeping lovegrass) hay is produced throughout South Africa. The crop is normally cultivated without the need to irrigate which contributes to its popularity amongst South African farmers as the majority of agricultural land does not have sufficient water for irrigation purposes. Meissner & Paulsmeier (1995) analysed different forages commonly found in South Africa. The results indicated a variation of between 77 to 87% in the neutral detergent fibre (NDF) content of *Eragrostis curvula* hay. These high NDF concentration allows for a reduced content of the hay in finishing diets due to its greater roughage value (Defoor *et al.* 2002).

The importance of particle size and accordingly effective fibre in finishing diets is described in paragraph 4.1 of Chapter 4. A particle size that is small enough to avoid selective feeding by the lambs is however of critical importance as the palatability of *Eragrostis curvula* hay is lower than that of *Medicago sativa* hay. On the other hand, *Eragrostis curvula* is an important roughage and/or fibre source at South African locations where irrigation crops can not be cultivated and is thus an alternative for use in the finishing diets of lambs.

The results of Chapter 4 indicated that the inclusion of 15 to 20% NDF (13 to 15% peNDF) in finishing diets containing *Medicago sativa* hay as roughage source did not influence intake, performance and the rumen health of lambs. The NDF composition (cellulose, hemicellulose and lignin) of legumes and grasses however varies. Accordingly, the fibre requirements for grasses could be different in the finishing diets for lambs. The aim of this study was to determine the NDF requirements of lambs fed finishing diets containing *Eragrostis curvula* hay with a specific particle size as roughage source.

5.2 Materials and Methods

The materials and methods used in the digestibility and production study have been described in Chapter 3.

5.3 Results and Discussion

5.3.1 Digestibility study

5.3.1.1 Chemical composition of the experimental diets

The chemical composition of experimental diets containing *Eragrostis curvula* hay is presented in Table 5.1. As with *Medicago sativa* hay as roughage source, the result of higher than calculated values of NDF and crude protein (CP) in the actual experimental diets was also apparent in this study. The reasons therefore and importance of NDF in diet formulation is described in paragraphs 4.1 and 4.3.1.1 of Chapter 4, discussing the results of *Medicago sativa* hay as NDF source. The variation in NDF content from 77 to 87% of South African *Eragrostis curvula* hay reported by Meissner & Paulsmeier (1995) stressed the importance of chemical analysis before diet formulation. The NDF values differed from the calculated values with 13.7, 16.7 and 16.3% for diets containing 3, 6 and 9% hay respectively. Calculated values for the CP fraction of the diets did not indicate large differences compared to the values showed in Table 5.1. Crude protein values differed from the calculated values with 1.2, 4.1 and 1.2% for the diets containing 16, 19 and 21% NDF respectively.

Table 5.1 Chemical composition of diets containing neutral detergent fibre from *Eragrostis curvula* hay on a dry matter basis.

	***Eragrostis curvula* hay in diets**		
Parameter	**3%**	**6%**	**9%**
Chemical composition (dry matter basis)			
Dry matter (%)	91.02	91.17	91.34
Organic matter (%)	96.33	95.66	95.70
Crude protein (%)	16.26	16.61	16.22
Neutral detergent fibre (%)	15.85	18.65	21.07
Physical effective NDF (%)	12.92	16.47	17.02

In the present study the *Eragrostis curvula* hay had a NDF content of 77.97% with a lignin content of 3.56%. The physical effective NDF (peNDF) values of all the diets were within the peNDF range of 12 to 18% recommended by Mertens (2002) and above the required peNDF of 7 to 10% recommended by Fox & Tedeschi (2002) for optimum average daily gain (ADG) and a healthy rumen pH. As already mentioned in Chapter 4, the commercial concentrate used in the diets might have been a contributing factor to the high peNDF values observed in the experimental diets (paragraph 4.3.1.1). The NDF and peNDF concentrations did, however, differ between the experimental diets. The different NDF levels are applicable between a NDF range of 16 to 21% and peNDF of between 13 to 17% with *Eragrostis curvula* as roughage source. Crude protein provided was sufficient as recommended by the NRC (1985) for finishing lambs with a body weight of between 30 to 50 kg if the daily dry matter intake (DMI) is equal or above 1.20 kg.

5.3.1.2 Apparent digestibility coefficients and digestible nutrients

The dry matter intake, apparent digestibility coefficients and digestible nutrients of the experimental diets are shown in Table 5.2. No significant (P = 0.5749) differences occurred in the DMI of lambs fed the different diets. Therefore, feeding level was not a factor that could influence apparent digestibility. With the exception of NDF, the apparent digestibility coefficients and digestible nutrients indicated no significant (P>0.05) differences between the diets for dry matter (DM), organic matter (OM), CP, gross energy (GE) and metabolizable energy (ME).

Table 5.2 Dry matter intake and digestion of diets containing neutral detergent fibre from *Eragrostis curvula* hay (Mean±s.e.).

	Dietary neutral detergent fibre				
Parameter	**16%**	**19%**	**21%**	**P[1]**	**CV[2]**
Dry matter intake (kg/lamb/day)	1.27±0.079	1.11±0.176	1.27±0.079	0.5749	22.05
Apparent digestibility coefficients:					
Dry matter (%)	73.79±0.027	77.19±0.005	75.63±0.013	0.4212	5.21
Organic matter (%)	75.62±0.027	78.70±0.005	77.00±0.013	0.4782	5.05
Crude protein (%)	67.72±0.032	71.52±0.009	71.52±0.017	0.3796	6.81
Neutral detergent fibre (%)	19.95±0.039[a]	31.93±0.011[b]	35.99±0.026[b]	0.0056	21.39
Gross energy (%)	58.42±0.026	60.90±0.006	59.57±0.013	0.4718	5.20
Apparent digestible nutrients:					
Organic matter (%)	74.05±2.367	76.05±0.681	74.39±1.267	0.6499	4.78
Crude protein (%)	10.40±0.665	11.47±0.345	10.74±0.293	0.2895	9.56
Neutral detergent fibre (%)	3.07±0.601[a]	5.76±0.094[b]	7.19±0.551[b]	0.0002	19.99
Metabolizable energy (MJ/kg)[3]	10.31±0.446	10.68±0.117	10.49±0.252	0.5841	5.17

[1](P>0.05 = non significant).

[2]Coefficient of variation (%).

[3]Metabolizable energy = digestible energy × 0.8 (McDonald *et al.*, 2002).

[a,b]Means in a row with different superscripts differ significantly (P<0.05).

Compared to the results of *Medicago sativa* hay (15 to 20% NDF) as roughage source, similar results was found in this study with the exception of CP. The DMI of the lambs was not affected by the NDF content of the different diets which might be attributed to a NDF level not high enough to reduce DMI as explained in paragraph 4.3.1.2 of Chapter 4. The digestible ME of the diet when 16% NDF was included from both sources did, however, show a reduction (P>0.05) when *Eragrostis curvula* was used. This might indicate that the structural carbohydrates (NDF) from *Eragrostis curvula* hay might not be as digestible compared to NDF from *Medicago sativa* hay. The apparent NDF digestibility coefficients of 39.6 and 20.0% for *Medicago sativa* and *Eragrostis curvula* hay diets respectively at 16% NDF (Tables 4.2 and 5.2) did confirm this result.

The digestibility of NDF did not differ significantly (P>0.05) between 19 and 21% dietary NDF. However, the inclusion of 16% NDF from *Eragrostis curvula* hay did however indicated a significantly (P<0.05) reduced NDF digestibility. This positive relationship between the NDF content of the diet and NDF digestibility was also found in the study with *Medicago sativa* hay as NDF source. The higher concentrate content of the diet reduced digestibility of NDF and this could be attributed to associative effects of feed due to an increase of easily fermentable carbohydrates (crushed maize) in the diet as discussed in Chapter 4 (paragraph 4.3.1.2).

Results from this study indicated that an inclusion level of 16 to 21% NDF in a finishing diet for lambs with *Eragrostis curvula* hay as fibre source did not influence (P>0.05) the metabolizable energy (ME) content of the diet. Accordingly, it should be reflected in the production performance of the lambs.

5.3.2 Production study

5.3.2.1 Intake

The DMI and metabolizable energy intake (MEI) of the lambs is shown in Table 5.3 and Figure 5.1. The results indicates a significantly (P<0.05) higher DMI during Week 4 of the feeding period for the lambs fed the diet containing 19% NDF compared to the animals fed the diet containing 16% NDF. Apart from week 4, no significant (P>0.05) differences in DMI of lambs for the rest of the experimental period occurred. The lambs fed the diet containing 19% NDF tended to have a higher (P>0.05) DMI for the majority of the feeding period. The DMI of the lambs are reflected in their live weights (Table 5.4) with the lambs fed the 19% NDF diet having a non significant higher live weight over the feeding period. The non significant (P = 0.0723) higher DMI of these lambs during the feeding period may also be attributed to the

NDF content of the diets being below the level where DMI is affected due to rumen fill as explained in paragraph 4.3.2.1 of Chapter 4. These results indicate that feedlot diets containing 16 to 21% NDF and/or 13 to 17% peNDF did not influence the DMI of lambs over the feeding period.

Table 5.3 Dry matter and metabolizable energy intake of lambs fed diets containing neutral detergent fibre from *Eragrostis curvula* hay (Mean±s.e.).

	Dietary neutral detergent fibre				
Parameter	**16%**	**19%**	**21%**	**P[1]**	**CV[2]**
DMI: Week 1 (kg/lamb/day)	0.93±0.088	0.97±0.033	0.93±0.088	0.9362	13.67
DMI: Week 2 (kg/lamb/day)	1.03±0.088	1.20±0.058	1.07±0.033	0.2282	10.05
DMI: Week 3 (kg/lamb/day)	1.03±0.033	1.23±0.088	1.17±0.088	0.2342	11.28
DMI: Week 4 (kg/lamb/day)	1.07±0.033[a]	1.33±0.067[b]	1.17±0.033[ab]	0.0194	6.87
DMI: Week 5 (kg/lamb/day)	1.30±0.000	1.53±0.088	1.33±0.088	0.1206	8.98
DMI: Week 6 (kg/lamb/day)	1.43±0.088	1.70±0.100	1.43±0.067	0.1133	9.79
DMI: Week 7 (kg/lamb/day)	1.70±0.000	1.77±0.067	1.60±0.115	0.3677	7.89
DMI: Feeding period (kg/lamb/day)	1.20±0.000	1.37±0.067	1.23±0.033	0.0723	5.88
Metabolizable energy intake (MJ/lamb/day)	12.3±0.1829[a]	14.6±0.4978[b]	12.8±0.409[a]	0.0136	5.05

[1](P>0.05 = non significant).

[2]Coefficient of variation (%).

[a,b]Means in a row with different superscripts differ significantly (P<0.05).

The MEI of the lambs fed the 19% NDF diet was significantly (P<0.05) higher than the lambs which received diets containing 16 and 21% dietary NDF. This may be attributed to the non significant (P>0.05) higher ME content (Table 5.2) and DMI of lambs consuming this diet.

Compared to the results of *Medicago sativa* hay as roughage source, the lambs fed diets with *Eragrostis curvula* hay had lower DM, as well as ME intakes. This could be attributed to a lower palatability of *Eragrostis curvula* hay compared to *Medicago sativa*. In addition, the lower NDF digestibility of the *Eragrostis curvula* hay could also negatively affect the mean retention time (MRT) and DMI of the lambs.

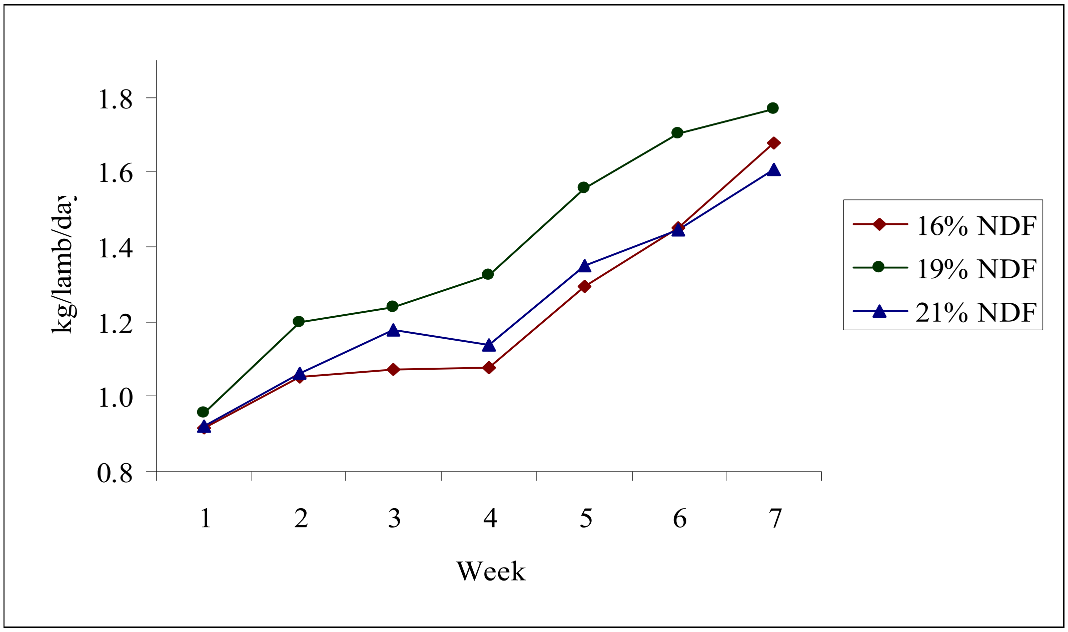

Figure 5.1 Dry matter intake of lambs fed diets containing neutral detergent fibre from *Eragrostis curvula* hay.

5.3.2.2 Weight gain and conversion ratios

The live weight, average daily gain (ADG), feed conversion ratio (FCR) and metabolizable energy conversion ratio (MECR) results is shown in Table 5.4 and Figure 5.2.

The live weights of weeks 0 and 7 were empty stomach weights after a 12 hour over night fasting of the animals. No significant ($P>0.05$) differences were observed for live weight at any of the particular weeks or for the entire feeding period. The average daily gain of the lambs consuming the diet with 19% NDF tended to be higher compared to other treatments. This is partly in accordance with the MEI results (Table 5.3). Accordingly, no differences in the feed or metabolizable energy conversion ratios could be detected.

From the results presented in Table 5.4 it is clear that the NDF and/or peNDF levels applied in this study with *Eragrostis curvula* hay as NDF source did not influence the efficiency of either feed or energy utilization by the lambs. Results from the present study with *Eragrostis curvula* hay as roughage source indicated lower ADG and higher FCR compared to the lambs consuming diets with *Medicago sativa* as roughage source. Again, this could be attributed to the lower DMI and NDF digestibility of the lambs fed *Eragrostis curvula* containing diets. Palatability as already discussed (paragraph 5.3.2.1) could also be a contributing factor.

Table 5.4 Live weight and conversion ratios of lambs fed diets containing neutral detergent fibre from *Eragrostis curvula* hay (Mean±s.e.).

Parameter	Dietary neutral detergent fibre			P[1]	CV[2]
	16%	**19%**	**21%**		
Live weight: Week 0 (kg)[3]	34.9±1.965	37.7±1.501	35.5±0.959	0.3895	12.19
Live weight: Week 1 (kg)	35.4±2.258	37.9±1.628	36.0±1.158	0.5725	13.69
Live weight: Week 2 (kg)	36.5±2.092	39.1±1.769	37.0±1.154	0.4977	13.21
Live weight: Week 3 (kg)	37.3±2.090	40.7±2.117	37.8±1.378	0.3980	14.31
Live weight: Week 4 (kg)	38.6±2.083	42.8±2.076	39.7±1.807	0.3153	14.48
Live weight: Week 5 (kg)	40.6±1.892	45.2±2.306	41.9±1.685	0.2707	13.73
Live weight: Week 6 (kg)	43.2±2.110	47.8±2.252	43.8±1.620	0.2236	13.14
Live weight: Week 7 (kg)[3]	42.9±2.079	47.5±2.274	43.6±1.763	0.2505	13.50
Average daily gain (kg/lamb/day)	0.170±0.017	0.208±0.019	0.173±0.027	0.3969	35.12
Feed conversion ratio (kg DM/kg gain)[4]	7.27±0.970	6.67±0.448	7.10±0.231	0.7933	15.60
Metabolizable energy conversion ratio (MJ/kg gain)	75.1±10.215	71.2±4.647	74.5±2.329	0.9044	15.57

[1](P>0.05 = non significant).

[2]Coefficient of variation (%).

[3]Empty stomach weight.

[4]DM = dry matter.

[a,b]Means in a row with different superscripts differ significantly (P<0.05).

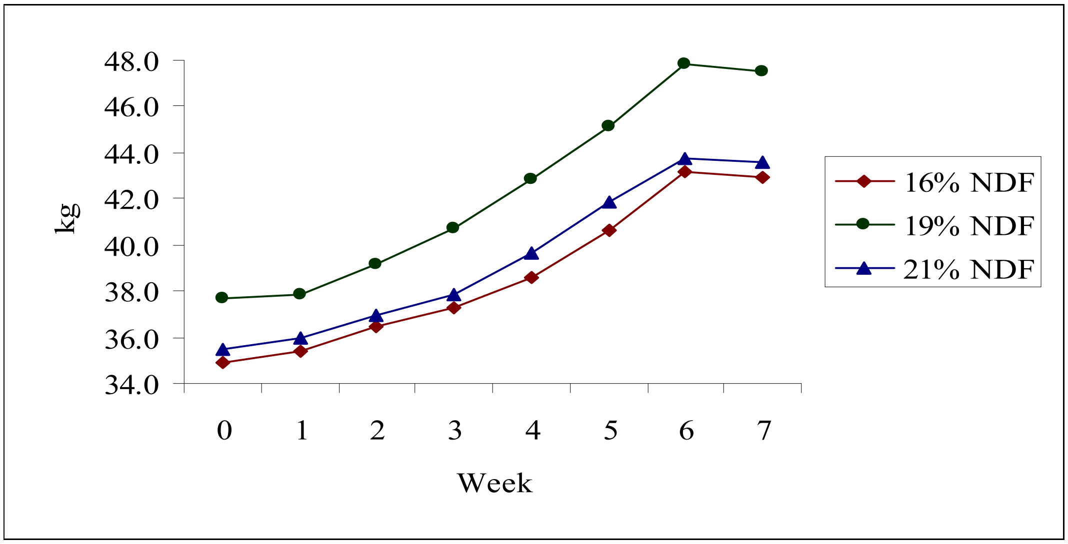

Figure 5.2 Live weight of lambs fed diets containing neutral detergent fibre from *Eragrostis curvula* hay.

5.3.2.3 Carcass characteristics

The carcass characteristics of the lambs fed the different experimental diets are shown in Table 5.5. None of the parameters differed significantly (P>0.05) except for the dressing percentage where the diet containing 16% NDF had a significantly (P<0.05) higher dressing percentage compared to the lambs fed the diet containing 21% NDF. This might indicate that the fasting period of 12 hours was insufficient to clear the stomach contents and the longer mean retention time (MRT) of the higher roughage content of the diet containing 21% NDF resulted in a lower dressing percentage compared to the diet with 16% NDF with less roughage and a shorter MRT. The same results were however not observed with *Medicago sativa* hay in Chapter 4 (paragraph 4.3.2.3). These differences could probably be attributed to a higher degradation rate and shorter MRT of *Medicago sativa* hay.

Table 5.5 Carcass characteristics of lambs fed diets containing neutral detergent fibre from *Eragrostis curvula* hay (Mean±s.e.).

	Dietary neutral detergent fibre				
Parameter	**16%**	**19%**	**21%**	**P[1]**	**CV[2]**
Cold carcass weight (kg)	21.3±1.020	23.3±1.278	20.8±0.968	0.2564	14.91
Dressing (%)	49.6±0.320^{b}	48.9±0.406^{bc}	47.7±0.379^{c}	0.0087	2.26
Carcass length (cm)	59.1±0.890	60.2±1.191	58.6±0.549	0.4278	4.56
Shoulder circumference (cm)	75.4±2.150	79.2±1.131	76.6±0.849	0.1727	5.43
Buttock circumference (cm)	65.2±1.184	67.1±0.944	65.1±1.179	0.3612	4.63
Fat thickness (mm)	3.0±0.274	3.3±0.345	3.0±0.230	0.6131	27.33

[1](P>0.05 = non significant).

[2]Coefficient of variation (%).

[a,b]Means in a row with different superscripts differ significantly (P<0.05).

All the carcasses were awarded the A2 classification. From Table 5.5 it is, however, clear that the fat thickness of the carcasses was not influenced by different NDF levels from *Eragrostis curvula* hay in the diet. This result is in accordance with the results found in the study with *Medicago sativa* hay as roughage source. Higher carcass weights and fat thickness values resulted for lambs fed *Medicago sativa* diets compared to the *Eragrostis curvula* diets (Tables 4.5 and 5.5).

5.3.3 Rumen health characteristics

The chewing activity, ruminal pH and faecal scores of the lambs are summarised in Table 5.6. Results did not indicate any significant (P>0.05) differences between any of the diets for the parameters mentioned. As with the study using *Medicago sativa* hay as NDF source, the rumen health measurements were in accordance with the other performance parameters of this study. The same result of a non linear increase in chewing activity discussed in paragraph 4.3.3 of Chapter 4 is also evident in this study with *Eragrostis curvula* hay. The diet with the highest NDF content (20%) did not stimulate the highest chewing activity.

Accordingly, ruminal pH values indicate a healthy rumen environment for all the diets. The pH value of the present study does not explain the reduced NDF digestibility indicated in Table 5.2. This might rather be explained by the other factors contributing to NDF digestibility such as solubilisation of the concentrate and roughage degradability as discussed in Chapter 4 (paragraph 4.3.3). The faecal scores (non significant) of the lambs fed the diets with less NDF did tend (P = 0.1100) to be lower compared to the other diets.

Results from this study indicates that a peNDF between 13 to 17% from *Eragrostis curvula* hay in finishing diets of lambs did not influence chewing activity, ruminal pH and faecal scores.

Table 5.6 Rumen health characteristics of lambs fed diets containing neutral detergent fibre from *Eragrostis curvula* hay (Mean±s.e.).

	Dietary neutral detergent fibre				
Parameter	**16%**	**19%**	**21%**	**P[1]**	**CV[2]**
Chewing activity (h/day)[3]	6.2±0.529	8.9±0.557	8.1±1.298	0.1576	19.47
Eating activity (h/day)	2.4±0.285	2.5±0.285	2.6±0.987	0.8246	21.01
Ruminating activity (h/day)	3.8±0.296	6.4±0.410	5.5±0.987	0.0713	21.09
Ruminal pH	6.34±0.096	6.33±0.099	6.33±0.165	0.9990	4.38
Faecal score (1 - 5)	3±0.350	4±0.236	5±0.105	0.1100	12.81

[1](P>0.05 = non significant).

[2]Coefficient of variation (%).

[3]Combined eating and ruminating activity.

[a,b]Means in a row with different superscripts differ significantly (P<0.05).

The NDF range (15 to 20%) with *Medicago sativa* hay as roughage source discussed in Chapter 4 and the present study with similar NDF contents (16 to 21%) both indicated no significant (P>0.05) differences with regard to rumen health characteristics. Average chewing activity for the diets containing 20% *Medicago sativa* hay and 21% *Eragrostis curvula* hay does tend to be higher for the latter (Tables 4.6 and 5.6). The linear increase in chewing activity with an increase in dietary NDF, found by other researchers (Fimbres *et al.,* 2002), was not observed in either of the studies. In fact, the rumen health measurements were in general similar in both studies. The results of this two studies do not support the statement of Van Soest (1987) that *Medicago sativa* hay has a higher buffering capacity. Only slightly higher ruminal pH was measured for *Medicago sativa* hay (6.4) compared to *Eragrostis curvula* hay (6.3).

5.4 Conclusions

The results of the present study indicated that the inclusion of 16 to 21% NDF (13 to 17% peNDF) in finishing diets of lambs with *Eragrostis curvula* hay as NDF source did not influence the DMI of the lambs. Metabolizable energy intake was increased in the diet containing 19% NDF compared to the other experimental diets (16 and 21% NDF). However, this increase in energy intake of the mentioned diet did not manifested in an increased growth rate or decreased feed conversion ratio. Accordingly, the carcass characteristics were not influenced by different levels of dietary fibre from *Eragrostis curvula* hay. These performance results was supported by rumen health measurements like chewing activity, ruminal pH and faecal scores that was also not influenced by the NDF percentages in the finishing diets. Digestibility of the NDF fraction of the diet was reduced with the reduction of NDF content of the diet. The influence of a wider range of NDF percentage with *Eragrostis curvula* as roughage source, as well as different particle sizes of the hay, on rumen health, digestibility and lamb performance warrants further investigation. The inclusion of 16 to 21% NDF (13 to 17% peNDF) provided in the NDF requirements of lambs fed finishing diets with *Eragrostis curvula* hay as roughage source milled through a 12.5 mm screen.

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CHAPTER 6

GENERAL CONCLUSIONS

The results of this study indicates that the inclusion of 15 to 20 % neutral detergent fibre (NDF) and/or 13 to 15% physical effective neutral detergent fibre (peNDF) from *Medicago sativa* hay and 16 to 21% NDF and/or 13 to 17% peNDF from *Eragrostis curvula* hay provided in the NDF requirements of lambs fed finishing diets when the hay was milled through a 12.5 mm screen. With the exception of NDF, dietary fibre content did not influence the apparent digestibility and metabolizable energy (ME) content. Accordingly, none of the performance parameters, namely dry matter intake (DMI) over the feeding period, average daily gain (ADG), feed conversion ratio (FCR) and metabolizable energy conversion ratio (MECR) were influenced by the mentioned NDF and peNDF percentages and/or NDF source in finishing diets of lambs. The metabolizable energy intake (MEI) was largely unaffected, except for the diet containing 19% NDF from *Eragrostis curvula* hay which indicated a significantly ($P<0.05$) higher MEI compared to the diets with more and less NDF from the same source. This result, however, was not reflected in the growth and conversion ratios of the lambs.

The carcass characteristics for each of the roughage sources were not influenced by the diet NDF content. The only exception was dressing percentage that decreased as the NDF content of the *Eragrostis curvula* diet increased. This could be attributed to more rumen fill caused by a longer mean retention time (MRT) of the higher NDF diets. Similar results were not observed with the *Medicago sativa* hay diets. The higher degradation rate and lower MRT of *Medicago sativa* hay probably resulted in less differences in rumen fill. Accordingly, rumen fill was not a factor influencing dressing percentage calculations with *Medicago sativa* hay diets.

In both studies the digestibility of NDF was reduced with a decrease in the NDF content of the diet. This was, however, not explained by the increase in diet concentrate as rumen pH was not reduced. Additional factors of concentrate solubility and dry matter (DM) degradation probably contributed to these results. All of the mentioned results were supported by rumen health measurements such as chewing activity, ruminal pH and faecal scores in both studies.

Although not statistical analysed, the comparison of the results of the two studies with *Medicago sativa* and *Eragrostis curvula* respectively, revealed interesting differences. The DMI and MEI for *Medicago sativa* hay was higher compared to *Eragrostis curvula* hay diets, which could be attributed to *Medicago sativa* being more palatable and NDF from *Eragrostis curvula* being less digestible with a longer MRT. An increased growth rate and better FCR for diets containing NDF from *Medicago sativa* was evident as the diets contained similar NDF concentrations of 15 to 20% (peNDF 13 to 15%) and 16 to 21% (peNDF 13 to 17%) for *Medicago sativa* and *Eragrostis curvula* hay respectively. These results were supported by higher carcass weights and fat thickness values for lambs fed *Medicago sativa* hay. The rumen health characteristics were, however, similar when *Medicago sativa* and *Eragrostis curvula* hay were included in the diets. According to these results, *Medicago sativa* and *Eragrostis curvula* hay have the same effective fibre characteristics. These comparisons between the two types of hay should however be interpreted with caution as no statistical analysis have been done. The inclusion levels of the roughages were however low and buffering effects could be more prominent at higher inclusion levels in the diets.

The influence of a wider range of NDF and peNDF percentages in the finishing diets of lambs with both *Medicago sativa* and *Eragrostis curvula* hay as NDF source, as well as different particle sizes of the hay on rumen health, digestibility and lamb performance warrants further investigation.

ABSTRACT

The aim of this study was to quantify the neutral detergent fibre (NDF) and physical effective neutral detergent fibre (peNDF) requirements of lambs fed finishing diets containing NDF from either *Medicago sativa* (lucerne) or *Eragrostis curvula* (weeping lovegrass) hay with a specific particle size (12.5 mm). A total of 84 South African Mutton Merino lambs (approximately four months of age) with a initial weight of 36.4 kg (SD±4.67) was used to conduct digestibility and production studies for each of the roughage sources. The digestibility study consisted of five replications for each of the six diets (three diets/roughage source) containing 15 to 20% NDF (13 to 15% peNDF) and 16 to 21% NDF (13 to 17% peNDF) for *Medicago sativa* and *Eragrostis curvula* hay respectively. The production study was conducted with three animals penned together replicated three times for each diet. The results of the digestibility and production studies with both roughage sources indicated no significant (P>0.05) differences for apparent digestibility coefficients, apparent digestible nutrients, dry matter intake (DMI), average daily gain (ADG), feed conversion ratio (FCR), metabolizable energy conversion ratio (MECR), carcass characteristics and rumen health characteristics with the exception of NDF digestibility. Metabolizable energy intake (MEI) was significantly (P = 0.0136) higher for the diet containing 19% NDF from *Eragrostis curvula* hay compared to the remaining two diets of the same roughage source. The MEI of *Medicago sativa* hay as roughage source indicated no significant (P>0.05) differences. NDF digestibility was reduced for both *Medicago sativa* and *Eragrostis curvula* hay when the NDF content of the diet was increased. Chewing activity did not increase when the NDF content of the diet was increased for either of the NDF sources and the rumen pH (>6.2) did not support the reduction in NDF digestibility found in both the studies. The inclusion of 15 to 20% NDF (13 to 15% peNDF) from *Medicago sativa* and 16 to 21% NDF (13 to 17% peNDF) from *Eragrostis curvula* hay in the finishing diets of lambs did not influence diet digestibility, animal performance or rumen health.

OPSOMMING

Die doel van die studie was die kwantifisering van neutraalbestande vesel (NBV) en fisiese effektiewe neutraalbestande vesel (feNBV) behoeftes van lammers wat afrondingsdiëte met NBV afkomstig van *Medicago sativa* (lusern) of *Eragrostis curvula* (oulandsgras) hooi ontvang het. ‘n Totaal van 84 Suid Afrikaanse Vleismerinolammers (ongeveer vier maande oud) met ‘n aanvangs massa van 36.4 kg (standaard afwyking ± 4.67) is in verterings- en produksiestudies met elk van die ruvoerbronne gebruik. Die verteringstudie het bestaan uit vyf herhalings vir elk van die ses diëte (drie diëte/ruvoerbron) wat onderskeidelik 15 tot 20% NBV (13 tot 15% feNBV) en 16 tot 21% NBV (13 tot 17% feNBV) vir *Medicago sativa* en *Eragrostis curvula* hooi bevat het. Die produksiestudie het bestaan uit drie lammers per hok met drie herhalings vir elke dieet. Met die uitsondering van NBV verteerbaarheid het geen betekenisvolle (P>0.05) verskille vir skynbare verteerbaarheidskoëffisiënte, skynbare verteerbare voedingstowwe, droëmateriaalinname (DMI), gemiddelde daaglikse massatoename (GDT), voeromsetverhouding (VOV), metaboliseerbare energieomsetverhouding (MEOV), karkaseienskappe en rumen gesondheidseienskappe voorgekom nie. Metaboliseerbare energie inname (MEI) was betekenisvol (P = 0.0136) hoër vir die dieet met 19% NBV afkomstig van *Eragrostis curvula* hooi in vergelyking met die oorblywende twee diëte van dieselfde ruvoerbron. Die MEI met *Medicago sativa* as ruvoerbron het geen betekenisvolle (P>0.05) verskille tussen die diete getoon nie. NBV verteerbaarheid het verlaag met ‘n verhoging in die NBV inhoud van die diete vir beide *Medicago sativa* en *Eragrostis curvula* hooi as ruvoerbron. Herkou aktiwiteite van die lammers in beide studies het nie verhoog met ‘n verhoging in die NBV-inhoud van die diëte nie en rumen pH (>6.2) het nie die verlaagde NBV verteerbaarheid ondersteun wat in beide studies waargeneem is nie. Die insluiting van 15 tot 20% NBV (13 tot 15% feNBV) afkomstig van *Medicago sativa* en 16 tot 21% NBV (13 tot 17% feNBV) afkomstig van *Eragrostis curvula* hooi in afrondingsdiëte vir lammers het nie dieet verteerbaarheid, diereprestasie of rumen gesondheid beïnvloed nie.