# SUPPLEMENTAL DEGRADABLE PROTEIN SOURCES FOR BEEF CATTLE CONSUMING LOW QUALITY ROUGHAGE

**by**

HENRY LUBBE JACOBS

**Dissertation submitted to the Faculty of Animal, Wildlife and Grass Science, University of the Free State**

**In partial fulfillment of the requirements for the degree**

**MAGISTER SCIENTIAE AGRICULTURAE**

Supervisor: Prof. H.J. van der Merwe
Co-supervisor: Dr. C.H.M. de Brouwer
Dr. H.P. Spangenberg

BLOEMFONTEIN

May 2005

# DEDICATION

I dedicate this thesis to my wife, Alida and children, Lambert, Heleen and Rina. Their love, support and encouragement have inspired me to overcome the long stay away from home. They always believe in me and made me believe that my dream will come true. We sacrificed a lot in the past three years, but now we can enjoy one another again. Thanks to you Alida, for your support and looking after the children while I was away.

# Preface

This thesis is presented in the form two of separate articles, augmented by a general introduction and conclusions in an effort to create a single unit. Although care has been taken to avoid unnecessary repetition, some repetition has been inevitable.

The author hereby wishes to express sincere thanks to the following establishments and persons who contributed to this study:

Molatek Animal Feeds for the financing of the study.

Heinri Spangenberg for your support from the start and help whenever I asked for it.

Fanie du Plessis for your support and understanding.

The Department of Animal Sciences, North West Agricultural Development Institute, Potchefstroom for the use of the cattle and facilities.

The following persons put in a great deal of work to make a success of the study. Thanks to you all, you need pad on the back. They are KJ Moeng, TJ Segotso, KJ Kgobe, OP Mankwe, BJ Menoe, AM Sebakeng, TL Mokoena and MG Takatayo.

Thanks a lot to my co-researcher, MA Mothlabane, for all you did to make the study a success and help me to be at home some times.

My supervisor, Prof H.J. van der Merwe for his guidance and constructive criticism and a willing ear whenever there was a problem.

My co-supervisors, Dr. C.H.M. de Brouwer and Dr. H.P. Spangenberg, for there special interest in the study and valuable assistance, advice and guidance during the study.

Mr. M. Fair of the Department of Biometry, University of the Free State for the support with the statistical analysis of the data.

The Pasture Science Division of the NW ADI, Potchefstroom for the cut and bale of the winter pasture.

The Soil Science Division of the NW ADI for the chemical analysis of some of the samples.

The ARC-Irene Analytical Services for the analysis of the plant, feed and faeces samples.

My colleagues at Molatek Feeds for you're understanding and support.

My parents, parents-in-law, brother and sisters for their sustained interest, support and help during the study.

My wife, Alida, and children, Lambert, Heleen and Rina, for your love, help, understanding and extreme patience.

To our Heavenly Father, thankfulness and gratitude for mercy received and the granting of the opportunity, health and endurance to complete the work.

I hereby declare that the thesis hereby presented for the degree MSc., at the University of the Free State, is my independent work and has not been previously presented by me for a degree at another university of faculty.

HL Jacobs
Vryheid
May, 2005

# Contents

# Chapter 1

## General Introduction

Low quality roughages and natural pastures are important sources of nutrients used to maintain beef cattle throughout the world. Approximately 80% or approximately 68 million hectares (ha) of the land area in South Africa are not arable and can only be utilized effectively by grazing ruminants. The South African veld types are extremely diverse in terms of botanical composition (Acocks, 1975) and therefore, also dry matter (DM) production potential and quality of the available DM (De Waal, 1994). These diversities are further exacerbated by erratic and highly seasonal rainfall, with droughts being experienced on an irregular basis. This variation in rainfall and the quantity of veld is characteristic of the arid and semi arid regions of South Africa. It occurs at any specific site between years and invariably is reflected in animal performance (Van Niekerk, 1965). The grazing ruminants, therefore, exists in a highly dynamic environment situation where its performance in terms of production and reproduction, is determined not only by changes in nutrient requirements, but also by the physical environment, including the quantity and quality of the available grazing.

It is generally desirable to enhance intake and digestion *via* the provision of supplemental nutrients to optimize the utilization of these forages and maintain acceptable animal performance. However, to be economically justifiable, provision of supplementary feeding must be practiced judiciously. The primary nutrient sources in low quality roughages are structural carbohydrates in the cell walls, i.e. cellulose, hemicelluloses and pectin. Another cell wall component, lignin, is not digestible by rumen microbes. Low quality roughages normally available in winter are usually high in cell wall contents and deficient in nitrogen (N). These roughages have a low crude protein (CP) content (< 70 g/kg DM), low digestibility and low rumen microbial activity (Brand, 1996). Therefore these roughages and pastures cannot maintain body weight of non-producing animals or nearly provide in the nutrient requirements of producing animals.

The primary nutritional requirements of the rumen microbes are nitrogen and energy (Henning, 1990). The provision of energy supplements to ruminants on low quality roughages does not address the problem, because these forages already contain considerable amounts of metabolizable energy, primarily in cellulose. Although cellulose is not easily fermented, the cellulolytic rumen bacteria can metabolize the relatively unavailable cellulolytic energy if there is no N deficiency in the rumen. It is thus clear that energy is not the first limiting nutrient in low quality roughages. Elliot & Topps (1963) concluded that when cattle are fed protein sufficient for maintenance, they would eat enough roughage of low quality to satisfy their energy requirements for maintenance. In these low quality roughages and pastures N is usually considered to be the first limiting nutrient (Freeman *et al.*, 1992; Mawuenyegah *et al.*, 1997). Therefore the provision of energy supplements is ineffective in enhancing the energy status of cattle consuming low quality roughages (Kartchner, 1980; Sanson *et al.*, 1990). On the other hand CP supplementation improves the energy status of the animal by promoting greater dry matter intake (DMI) and digestion and/or the rate of passage to the small intestine. (Del Curto *et al.*, 1990; Matejovsky & Sanson, 1995). Owens *et al.* (1991) reported that improved animal performance as a result of CP supplementation was due to either an increased digestible organic matter intake (DOMI) and / or an enhanced efficiency of metabolisible energy (ME) utilization. Owens *et al.* (1991) also stated that most research showed that an increased digestible organic matter intake (DOMI) was primarily due to crude protein supplementation.

According to Köster (1996) the rumen degradable fraction of crude protein is actually the first limiting dietary component for efficient utilization of low quality roughages. Therefore providing supplements with adequate amounts of rumen degradable protein (RDP) to ruminants fed low quality roughages promotes increased forage intake and flow of nutrients to the small intestines (Hannah *et al.*, 1991; Lintzenich *et al.*, 1995). Because of the critical role RDP plays in enhancing the use of low quality roughages and because protein supplementation can be costly, it is important to identify the precise amount of RDP required to maximize digestible organic matter intake and duodenal protein flow. Furthermore, such information should be used to develop supplementation strategies with the aim to optimizing the utilization of low quality roughages.

It is generally accepted that true RDP will enhance fibre digestion and microbial growth efficiency in comparison to ammonia ($NH_3$) alone (Rooke & Armstrong, 1989; Merry *et al* ., 1990; McAllan, 1991) Proteolytic and de-aminative enzymes or rumen microorganisms degrade dietary protein to volatile fatty acids (VFA's), peptides, amino acids and $NH_3$ (Kang-Meznarich & Broderick, 1981). A part of the dietary protein can escape rumen fermentation to provide essential amino acids in the duodenum, while the peptides and the amino acids can be directly incorporated into microbial crude protein (MCP), with the subsequent lower energy cost than $NH_3$ (Nolan *et al.*, 1976).

According to Kang-Meznarich & Broderick, (1981) and Argyle & Baldwin, (1989) the growth rate of rumen bacteria is highly influenced by the availability of $NH_3$, peptides and amino acids. Allison, (1970), Bryant, (1973), Nolan (1975); and Aharoni *et al.* (1991) found that $NH_3$ is the primary nitrogen source for the growth of rumen microorganisms and is essential for the existence of several species of rumen bacteria. Bryant & Robinson (1962) stated that 82% of rumen bacteria can grow with $NH_3$ as the sole N source, 25% would not grow unless $NH_3$ was present and 56% could utilize either $NH_3$ or amino acids. Balch (1967) found that the effect on rumen microbial growth is limited if energy deficient diets are fed. The energy released during fermentation is first used for maintenance of the microbial population and the excess energy is then used for microbial growth (Henning *et al.*, 1993). When carbohydrate availability allows growth, 66% of the nonstructural carbohydrate microbial protein originates from peptides and 34% from ammonia. Russell *et al.* (1992) is of opinion that sugar and starch degrading bacteria needs ammonia and amino acids or peptides for growth, while cellulolytic bacteria use ammonia as the primary source of N (Russell *et al.*, 1992). In contrast, Carro & Miller (1999) reported that both structural and non-structural carbohydrates fermenting bacteria could utilize ammonia as well as pre-formed amino acids as an N source. Nolan (1975) and Aharoni et al. (1991) found that amino acids also play an important role in the N supply to rumen microorganisms.

Stimulating rumen bacterial growth *via* urea supplementation holds considerable financial benefits in terms of the cost of the protein supplement, but may be inferior to natural protein in terms of animal performance (Helmer & Bartley, 1971).

From the limited data available it seems that non-protein nitrogen (NPN) supplements support the same amount of microbial N flowing to the duodenum, as well as similar levels of microbial N synthesis (Kropp *et al.*, 1977; Redman *et al.*, 1980; Petersen *et al.*, 1985). Several studies (Nelson & Waller, 1962; Williams *et al.*, 1963; Rush & Totusek, 1976) however indicated that when supplementing low quality roughages with NPN the performance of livestock is generally lower than with true protein supplementation. Although body condition changes, body weight changes and reproductive measures of cows are improved there is no difference in calf weaning weights between NPN and true protein supplementation (Nelson & Waller, 1962; Rush & Totusek, 1973; Rush *et al.*, 1976).

When NPN was compared to true protein in growth studies the weight gain was generally greater when true protein were fed (Nelson & Waller, 1962; Raleigh & Wallace, 1963; Tollet *et al.*, 1969; Clanton, 1978). The positive weight gain in growing ruminants has led scientists to believe that the poorer performance with NPN is due to the decreased supply of metabolizable protein to the lower intestine. This could be because of a depression on microbial N production of limiting growth factors such as peptides, amino acids and branched VFA (Hume, 1970).

The RDP requirements of beef cows consuming low quality roughages were determined by Köster (1996). Accordingly it was found that urea could provide up to 50 –75 % of the supplemental RDP-intake. The rest should be provided as true protein that could be achieved with the use of an oilcake meal. Oilcakes however differ in protein degradability and amino acid content, which could influence the results. From the available literature it is not clear whether these differences could influence the performance of beef cattle on low quality roughages. Furthermore a linear relationship occurred which suggest that independent of rumen conditions; voluntary intake of low quality roughages may be increased further by undegradable intake protein (UIP).

It is clear that some questions still remains unanswered regarding the practical use of these results under South African conditions. Investigations are necessary, primarily because of the cost implications and the soundness of on farm supplementary feeding recommendations. Therefore, a study was conducted in Chapter 3 to determine which one of the oilcakes available in South Africa would be the best natural source of RDP not provided by urea to maximize the digestible organic matter intake of South African winter pasture hay (Chapter 3).

In a second study (Chapter 4) the optimum ratio of supplemented urea to the most available oilcake (cotton oilcake) was investigated.

References

Acocks, J.P.H. 1975., Veld types of South Africa (2nd Ed.). Mem. Bot. Surv. S. Afr. 40, Govt. Printer, Pretoria.

Aharoni, Y., Tagari, H. & Boston, R.C. 1991. A new approach to the quantitative estimation of nitrogen metabolic pathways in the rumen. *Br. J. Nutr.* 66, 407 – 422.

Allison, M.J., 1970. Nitrogen metabolism of ruminal microorganisms. In: Physiology of Digestion and Metabolism in the Ruminant. Ed. Phillipson, A.T., Oriel Press, Newcastle.

Argyle , J.L. & Baldwin, R.L., 1989. Effects of amino acids and peptides on rumen microbial growth yields. *J. Dairy Sci.* 72, 2017 – 2027.

Balch, C.C., 1967. Problems in predicting the value of non-protein nitrogen as a substitute for protein in rations for farm ruminants. *World Rev. Anim. Prod.* 3, 84-91.

Brand, T.S., 1996. The nutritional status and feeding practices of sheep grazing cultivated pasture and crop residue in a Mediterranean environment. Ph.D.Agric-thesis, Stellenbosch University, Stellenbosch, South Africa.

Bryant, M.P., 1973. Nutritional requirements of the predominant rumen cellulolytic bacteria. *Fed. Proc.* 32, 1809 – 1816.

Bryant, M.P. & Robinson, I.P., 1962. Some nutritional characteristics of predominant culturable rumen bacteria. *J. Bacteriol.* 84, 605-614.

Carro, M.D. & Miller, E.L., 1999. Effect of supplementing a fibre basal diet with different nitrogen forms on ruminal fermentation and microbial growth in an *in vitro* semi-continuous culture system (RUSITEC). *Br. J. Nutr.* 82, 149-157

Clanton, D.C., 1978. Non-protein nitrogen in range supplements. *J. Anim. Sci.* 47, 765(*Abstr*).

Del Curto, T., Cochran, R.C., Harman, D.L., Beharka, A.A., Jacques, K.A., Towne, G. & Vanzant, E.S., 1990. Supplementation of dormant tallgrass-prairie forage: 1. Influence of varying supplemental protein and (or) energy levels on forage utilization characteristics of beef steers in confinement. *J. Anim. Sci.* 68, 515-531

De Waal, H.O., 1994. *In sacco* dry matter disappearance of herbage and maize meal from the rumen of lactating Dorper and Merino ewes supplemented with protein and energy on native pasture. *S.Afr. J. Anim. Sci.* 25, 1-5.

Elliot, R.C. & Topps, L.H., 1963. Studies of protein requirements of Ruminants. *Br. J. Nutr.* 17, 539(*Abstr*).

Freeman, A.S., Galyean, M.L. & Caton, J.S., 1992. Effects of supplemental protein percentage and feeding level on intake, ruminal fermentation and digesta passage in beef steers fed prairie hay. *J. Anim. Sci.* 70, 1562(*Abstr*).

Hannah, S.M., Cochran, R.C., Vanzant, E.S. & Harmon, D.L., 1991. Influence of protein supplementation on site and extent of digestion, forage intake and nutrient flow characteristics in steers consuming bluestem-range forage. *J. Anim. Sci.* 69, 2624-2630.

Helmer, L.G. & Bartley, E.E., 1971. Progress in the utilization of urea as a protein replacer for ruminants. A Review. *J. Dairy Sci.* 54, 25(*Abstr*).

Henning, P.H., 1990. The role of rumen microbial growth efficiency in protein nutrition of ruminants. Technical Communication 223, 21-29.

Henning, P.H., Steyn, D.G. & Meissner, H.H., 1993. Effect of synchronzation of energy and nitrogen supply on ruminal characteristics and microbial growth. *J. Anim. Sci.* 71, 2516-2528

Hume, I.D., 1970. Synthesis of microbial protein in the rumen. III. The effect of dietary protein. *Aust. J. Agric.* Res. 21, 305 - 308.

Kartchner, R.J., 1980. Effects of protein and energy supplementation of cows grazing native winter range forage on intake and digestibility. *J. Anim.Sci.* 51, 432-438.

Kang-Meznarich, J.H. & Broderick, G.A., 1981. Effects of incremental urea supplementation on ruminal ammonia concentration and bacterial protein formation. *J. Anim. Sci.* 51(2), 422-431.

Köster,H.H., Cochran, R.C., Titgemeyer, E.C., Vanzant, E.S., Abdelgadir,I. & St Jean, G., 1996. Effect of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. *J. Anim. Sci.* 74, 2473-2481.

Kropp, J.R., Johnson, R.R., Males, J.R. & Owens, F.N., 1977. Microbial protein synthesis with low-quality roughage rations: Level and source of nitrogen. *J. Anim. Sci.* 46, 844-854.

Lintzenich, B.A., Vanzant, E.S., Cochran, R.C., Beaty, J.L., Brandt Jr, T & St. Jean., 1995. Influence of processing supplemental alfalfa on intake and digestion of dormant bluestem-range forage by steers. *J.Anim. Sci.* 73, 1187 - 1191.

Mawuenyegah, P.O., Shem, M.N., Warly, L. & Fujihara, T., 1997. Effect of supplementary feeding with protein and energy on digestion and rumination behaviour of sheep consuming straw diets. *J. Agric Sci.* (Camb.) 129, 479-484.

Matejovsky, K.M. &Sanson, D.W., 1995. Intake and digestion of low-, medium-, and high quality grass hays by lambs receiving increasing levels of corn supplementation. *J. Anim. Sci.* 73, 2156-2163.

McAllan, A.B., 1991. Carbohydrate and nitrogen metabolism in the forestomach of steers given untreated or ammonia treated barley straw diets supplemented with urea or urea plus fishmeal. *Anim. Feed Sci. Technol.* 31, 195-208.

Merry, R.J., McAllan, A.B. & Smith, R.H., 1990. *In vitro* continuous culture studies on the effect of nitrogen source on rumen microbial growth and fiber digestion. *Anim. Feed Sci. Technol.* 31, 55(*Abstr*).

Nelson, A.B. & Waller, G.R., 1962. Urea in winter supplements for range beef cattle. *J. Anim.Sci.* 21, 387(Abstr.).

Nolan, J., 1975. Quantitative models of nitrogen metabolism in sheep. In. Digestion and Metabolism in the ruminant. Eds. McDonald, I.W. & Warner, A.C.I., University of New England Publishing Unit, Armidale, Australia.

Nolan, J., Norton, B.W. & Leng, R.A., 1976. Further studies of the dynamics of nitrogen metabolism in sheep. *Br. J. Nutr.* 35, 127-147.

Owens, F.N., Garza, J. & Dubeski, P., 1991. Advances in amino acid and Nutrition in grazing ruminants. In proceedings of the 2$^{nd}$ Grazing Livestock Nutrition Conference, 2 to 3 August 1991, Steamboat Springs, CO p,109. MP-133, Oklahoma State Univ. Agr. Exp. Sta.

Peterson, M.K., Clanton, D.C. & Britton, R., 1985. Influence of protein degradability in range supplements on abomasal nitrogen flow, nitrogen balance and nutrient digestibility. *J. Anim. Sci.* 60, 1324-1335.

Raleigh, R.J & Wallace, J.D., 1963. Effect of urea at different nitrogen 1 levels on digestibility and on performance of growing steers fed low quality flood meadow roughage. *J. Anim. Sci.* 22, 330-339.

Redman, R.G., Kellaway, R.C. & Leibholz, J.,1980. Utilization of low quality roughages: Effects of urea and protein supplements of differing solubility on digesta flows, intake and growth rate of cattle eating oat chaff. *Br. J. Nutr.* 44, 343-359.

Rooke , J.A. & Armstrong, D.G., 1989. The importance of the form of nitrogen on microbial protein synthesis in the rumen of cattle receiving grass silage and continuous intrarumen infusions of sucrose. *Br. J. Nutr.* 61, 113-121.

Russell, J.B., O'Connor, J.D., Fox, D.G., Van Soest, P.J. & Sniffen, C.J., 1992. A net carbohydrate and protein system for evaluating cattle diets. I. Ruminal fermentation. *J. Anim. Sci.* 70, 3551-3561.

Rush, I. & Totusek, R., 1973. Urea and biuret in range cow supplements. *J. Anim. Sci.* 37, 355(*Abstr*).

Rush, I. & Totusek, R., 1976. Supplemental value of feed grade biuret and urea-molasses for cows on dry winter grass. *J. Anim. Sci.* 42, 497- 491.

Rush, I.G., Johnson, R.R. & Totusek, R., 1976. Evaluation of beef cattle range supplements containing urea and biuret. *J. Anim. Sci.* 42, 1297(*Abstr*).

Sanson, D.W., Clanton, D.C. & Rush, I.G., 1990. Intake and digestion of low-quality meadow hay by steers and performance of cows on native range when fed protein supplements containing various levels of corn. *J. Anim. Sci.* 68, 595-602.

Tollet, J.T., Swart, R.W., Loset, R. M. & Templeton, J.A., 1969. Biuret as a nitrogen source for wintering steers. *J.Anim. Sci.* 28, 862(Abstr.).

Williams, D.L., Whiteman, J.V. & Tillman, A. D., 1963. Urea utilization in protein supplements for cattle consuming poor quality roughages on the range. *J. Anim. Sci.* 28, 807-815.

Van Niekerk, A.I., 1965. Aspects of nitrogen metabolism of sheep with special reference to the rumen. MSc-thesis. University of Stellenbosch.

# Chapter 2

## Literature review

### 1. Factors influencing roughage intake

#### 1.1 Retention time

Campling *et al.,* (1962) found, in cows, that voluntary intakes of hay, oat straw and oat straw with urea, were inversely related to the mean retention times of feed residues in the reticulo-rumen. Therefore it seems likely that factors affecting the rate at which feed particles are reduced to a size suitable for transfer to the omasum will largely determine their mean retention time in the reticulo-rumen, the mean organic matter (OM) flow rate from the reticulo-rumen and hence the voluntary intake of roughage diets (Freer *et al.,* 1962).

The two competitive processes of reduction in particle size and passage of small particles determine fermentation time and are modulated by the animal through ingestive chewing, ruminative chewing and passage from the rumen (Wilson & Kennedy, 1996). Under marginal conditions when availability of food is limited, a ruminant reduces the force or frequency of its ruminal contractions, which prolongs the retention time of feed particles in the rumen and thereby maximises the digestive recovery of nutrients per weight of food. In contrast, ruminants fed on adequate amounts of low-quality fibrous diets maximise nutrient yield by increasing rumination and rate of passage, as cited by Mawuenyegah, (1997). In support of this view, Merchen *et al.* (1986) have shown that wethers fed at a high intake level, apparently digested a greater quantity (g/d) of OM than when fed at a lower intake. These authors also found that the proportion of total OM digested (% of digestible OM) decreased with increasing intake levels, presumably as a result of an increased passage rate, since the OM flow at the duodenum was increased at higher intake levels.

It is important to realize that an increased feed intake will result in a faster passage rate, which in turn will lead to a decreased rumen retention time and a consequent depression in ruminal digestion of OM and fibre (Firkins *et al.*, 1986). For this reason, maximizing intake will not necessarily maximize animal performance. However, an increased intake will stimulate microbial population growth in the rumen because of higher substrate availability and consequently improve rumen fermentation, which in turn will lead to more microbial protein (MP) being synthesized. The additional MP plus increased amount of dietary protein that escapes rumen fermentation due to a faster passage rate, supply more digestible protein in the small intestine and should improve the nitrogen (N) status of the animal, which would enhance voluntary feed intake. An increased feed intake will result in an increased production of volatile fatty acids (VFA`s) and absorption of nutrients from the digestive tract (Kempton & Leng, 1979). It is important, however, not to increase intake to such an extent that retention time in the rumen and/or intestine is too short to thoroughly ferment and digest the substrate, but to determine the optimum balance between an increased voluntary feed intake, rumen fermentation rate and N status of the animal.

## 1. 2 Crude protein supplementation

It is essential to distinguish between the different crude protein (CP) fractions, i.e. rumen degradable protein (RDP) and rumen undegradable protein (RUP). Rumen undegradable protein is particularly effective in improving livestock performance because it is not fermented in the rumen, but catabolised in the lower tract to form amino acids, which are then absorbed and incorporated into muscle, milk and wool. Rumen degradable protein, on the other hand, is fermented in the rumen and is broken down to amino acids, peptides and ammonia ($NH_3$), which serve as nutrients for the rumen microbes. Peptides and amino acids can be directly incorporated into MP (Nolan *et al.*, 1976), which increases the efficiency of MP production, as well as production rate.

### 1.2.1 Pasture crude protein content

In South Africa veld types are extremely diverse in terms of botanical composition (Acocks,1975) and therefore, also dry matter (DM) production and CP content. In most natural pastures in the world the N content of low quality roughages are the first limiting nutrients for ruminants (Kempton & Leng, 1979; Freeman *et al.*, 1992; Mawuenyegah *et al.*, 1997). According to Moore & Kunkle (1995) there are close relationships between forage intake and forage CP, when forage CP was less than 7% of DM. At CP levels above 7% there was low relationship between CP and intake. As a result of these observations the need for supplemental protein seems to be at its greatest at CP levels lower than 7% (McCollum & Horn, 1990). This is typical of natural pastures during winter in most parts of South Africa (Van der Merwe & Smith, 1991.)

Intensive research was conducted over years to evaluate the effect of different levels of supplementation of protein and also the different sources of N on the intake and utilization of low quality roughages. The results of the some of the studies are summarized in Table 1.

**Table 1 A summary of the literature on protein supplementation to low quality forages consumed by beef cattle.**

| References | Forage | Supplement | FOMI $g/kgW^{0.75}$ | DOMI $g/kgW^{0.75}$ | TDIP $g/kgW^{0.75}$ |
|---|---|---|---|---|---|
| Hennessy *et al* (1978) | Pasture 3.6% CP | Control | 52.6 | 26.2 | 0.57 |
| | | 56 g Urea | 60.0 | 31.2 | 4.29 |
| | | 56g Urea/395g Molasses | 65.5 | 45.2 | 4.63 |
| | | 112g Urea/395g Molasses | 51.9 | 41.2 | 8.12 |
| | | 112g Urea/790g Molasses | 60.1 | 46.8 | 8.49 |
| Hunter & Siebert (1980) | Spear grass 4.8% CP | Control | 30.2 | 16.9 | 0.43 |
| | | Urea + Sulfur | 38.5 | 21.7 | 2.05 |
| | | Cottonseed meal | 41.6 | 26.0 | 1.79 |
| McCollum & Galyean (1985) | Prairie Hay 6.1 % CP | Control | 58.2 | 30.4 | 1.06 |
| | | 800g Cottonseed meal | 74.0 | 45.5 | 4.30 |
| Guthrie & Wagner, (1988) (Trail 2) | Prairie Hay 5.2% CP | Control | 77.2 | 31.7 | 1.50 |
| | | 121 g Soya Meal | 83.1 | 37.3 | 2.30 |
| | | 241 g Soya Meal | 97.2 | 49.9 | 3.20 |
| | | 362 g Soya Meal | 100.8 | 53.3 | 4.00 |
| | | 603 g Soya Meal | 111.6 | 64.1 | 5.50 |
| Köster *et al.*, (1994) | Prairie Hay 1.9% CP | Control | 29.3 | 13.1 | 0.18 |
| | | 180 g DIP/day | 48.1 | 27.0 | 1.81 |
| | | 360 g DIP/day | 57.3 | 32.8 | 3.39 |
| | | 540 g DIP/day | 64.7 | 35.7 | 4.95 |
| | | 720 g DIP/day | 61.0 | 36.6 | 6.45 |

FOMI = Forage organic matter intake

DOMI = Digestible organic matter intake

TDIP = Total digestible intake protein

CP = Crude protein

DIP = Degradable intake protein

As can be seen from Table 1 all the studies recorded a remarkable increase in forage organic matter intake (FOMI) and digestible organic matter intake (DOMI) when crude protein was supplemented. This suggests that inadequate protein/N is the first limiting factor in low quality roughage.
A higher forage intake and higher total DOMI is commonly associated with protein supplementation. Protein supplementation generally improves animal performance and the reason is the higher forage intake and digestion (Nolte *et al.*, 2003).

According to Owens *et al.* (1991) it must be emphasized that forage quality plays an important role on intake response when protein supplements are provided. If we look closely at Table 1 there is an increase of 47% in forage intake of low quality forage with a CP less than 7% as response to protein supplementation. This compares well to Minson (1990) who reported an increase of 40% in forage intake when protein supplements were supplied on low quality forage with CP of 4.5%. Lee *et al.* (1987) compared forages of similar origin and observed a bigger increase in forage intake on the lower quality hay. Köster (1996) also confirmed that the response to protein supplementation was much greater when the CP content of the forage was less than 3% than when it was between 3 and 6%.

### 1.2.2 Degradable protein

Van Soest (1982) supported by Hennessy *et al.*, (1978), Hunter & Siebert (1980), Guthrie & Wagner (1988), Stokes *et al.*, (1988) and Köster *et al.*, (1994) noted that feed intake might be increased by protein supplementation to top up the provision of ruminal N. In this regard Church & Santos (1981), Scott & Hibberd (1990) and Köster *et al.* (1994) reported that as the total amount of N and/or degradable intake protein (DIP) increased, a plateau or decline occur after the initial increase in intake. The same occurred when Basurto-Gutierrez *et al.*, (2003) fed low quality forage to steers and the source of degradable protein did not play a role. This is an indication that the amount of DIP needed to maximize DOMI has been met or exceeded and that a further increase in DIP would result in wastage of N. This would lessen the potential cost benefit. Accordingly wastage of expensive N may result in an increase in energetic cost associated with ammonia detoxification in the liver.

In contrast with these findings the same plateau wasn't observed when the relationship of total CP intake to total DOMI was evaluated. A linear relationship occurred which suggest that independent of rumen conditions, voluntary intake of low quality roughages may be increased further by undegradable intake protein (UIP). These results related well to studies of Egan (1965) and Garza & Owens (1991), who concluded that metabolic effects play an important role in the control of voluntary intake. In contrast, it appears from the study of Jones *et al.* (1994) that when sufficient DIP was offered *via* feedstuffs (e.g. soybean meal and sorghum grain) to maximize intake and forage utilization, additional UIP had no further beneficial effect on the forage intake.

Previous works, Stokes *et al.*, (1988), Scott & Hibberd (1990); Hannah *et al.* (1991) showed that there was an increase in organic matter digestibility (OMD) with N supplementation when low quality roughages were consumed. It was also noted that once the initial increment of N to stimulate ruminal fermentation was provided, additional RDP appeared to have little effect on OMD. Although N supplementation may enhance forage digestion

(Guthrie & Wagner 1988, Scott & Hibberd, 1990 and Hannah *et al.*, 1991), it may also reduce ruminal retention time.

### 1.2.2.1 Degradable protein source

According to Hannah *et al.*, (1991) and Lintzenich *et al.*, (1995) the DIP fraction of CP is the first limiting dietary component for the efficient utilization of low quality roughages. Another source of N to the rumen microbes is non-protein nitrogen (NPN), primarily urea, which only provides ammonia ($NH_3$) to the rumen microbes. Non-protein nitrogen is the cheapest source of protein and is therefore commonly used in protein supplements (Fonnesbeck *et al.*, 1975). If dietary NPN is substituting true protein sources, the cost of protein supplementation is lowered. Urea and biuret contain an N concentration of 5 to 7 fold that of commonly used plant proteins, but the plant proteins also supply energy, vitamins and minerals. Because these nutrients can contribute to animal performance and, thus have a cost associated to them, they must be considered in the evaluation of supplements that contain NPN (Owens & Zinn, 1993). A nutrient of particular concern in NPN-based supplements is sulfur (S). A ratio of 10:1 (NRC, 2000) has generally been suggested to be adequate.

Urea is fermented very quickly, which may lead to excessive amounts of $NH_3$ being released in the rumen immediately after consumption of the supplement. This would decrease the efficiency of urea supplements, because the rumen microbes cannot utilize part of the available $NH_3$ quickly enough and is absorbed through the rumen wall. This $NH_3$ is transported to the liver where it is converted to urea and recycled to the rumen, mainly by means of saliva (Doyle *et al.*, 1982) where it serves as a source of $NH_3$ and is utilized by the microbes. However, because of the inverse relationship between the level of protein intake and blood urea-N entry into the rumen (Bunting *et al.*, 1987), a great deal of thus absorbed $NH_3$ will be excreted in the urine as urea. Energy is used for excretion of additional $NH_3$, which increases the maintenance requirement of the animal.

In contrast, RDP is fermented more slowly in the rumen and provides nutrients to the rumen microbes on a more regular and continuous basis than NPN. For these reasons RDP is more efficient in improving the utilization of low quality roughages than NPN. However, NPN is less expensive than RDP per unit N and according to Campling *et al.*, (1962) it increases digestibility and voluntary intake of oat straw by cows, due to an improved carbohydrate digestibility. Therefore, it is important to determine to what extend urea can substitute RDP in protein supplements.

True protein sources readily available in South Africa such as cotton oilcake, soybean oilcake and sunflower oilcake also provide rumen degradable protein (RDP) as a percentage of the total protein. Erasmus *et al.*, (1988; 1990) determined the rumen degradability percentage and crude protein content of cotton oilcake, soybean oilcake and sunflower oilcake (Table 2).

Soybean oilcake has the highest CP content and between cotton oilcake and sunflower oilcake there was almost no difference. Sunflower oilcake has the highest CP degradability and there are also differences between soybean oilcake and cotton oilcake with cotton oilcake the lowest. These oilcakes also differ in amino acid content and this may influence the forage intake, digestibility and animal performance.

**Table 2 The CP-content (DM-basis) and rumen degradability (%) of cotton oilcake, soybean oilcake and sunflower oilcake. (Erasmus *et al.*, 1988; 1990).**

| Item | CP % | Degradability % |
|---|---|---|
| Cotton oilcake meal | 40.2 | 72.0 |
| Soybean oilcake meal | 44.1 | 79.5 |
| Sunflower oilcake meal | 40.3 | 93.5 |

CP = Crude protein

Morrison (1961) determined the amino acid content of cotton oilcake, soybean oilcake and sunflower oilcake. Table 3 reveals that there are considerable differences between the oilcakes' amino acid content.

**Table 3 The amino acid content of cotton oilcake, soybean oilcake and sunflower oilcake (Morrison, 1961).**

| Feeding stuff | Lysine | Methionine | Phenyl-alanine | Threo-nine | Trypto-phan | Tyro-sine | Valine |
|---|---|---|---|---|---|---|---|
| Cotton oilcake | 3.9 | 1.2 | 4.6 | 2.6 | 1.2 | 2.5 | 4.3 |
| Soybean oilcake | 6.4 | 1.3 | 4.8 | 3.7 | 1.3 | 3.1 | 5.3 |
| Sunflower Oilcake | 3.6 | 3.2 | | | 1.2 | | |

As observed with true protein supplements, urea- based supplements have been shown to stimulate intake and digestibility of low quality forages. Minson (1990) reported that the magnitude of the increase to a negative control was 34%.

According to Redman *et al.*, (1980), Kellaway & Liebholz, (1983) and Egan & Doyle (1985) urea supplementation may enhance the consumption of low quality forages *via* increased microbial production, microbial flow and subsequent intestinal absorption of microbial amino acids. A summary of studies comparing intake response of NPN-based supplements with true protein supplements are shown in Table 4. Little difference in forage intake was observed when true protein supplements were compared to urea-based supplements. The differences in forage intake were less than 10% when true protein was fully replaced by urea N, (Oh *et al.*, 1969; Hunter & Siebert, 1980; Lee *et al.*, 1987).

**Table 4 A summary of studies comparing intake response of non-protein nitrogen supplements with negative controls and true protein supplements.**

| References | Intake % response of non-protein nitrogen over | |
|---|---|---|
| | Control | True protein |
| Campling *et al.*, (1962) | 38.7 | |
| Coombe & Tribe (1962) | 14.5 | |
| Oh *et al.*, (1969) | 48.0 | -5.7 |
| Ammerman *et al.*, (1972) | 20.1 | -4.5 |
| Swingle *et al.*, (1977) | 28.0 | -3.1 |
| Hunter & Siebert (1980) | 27.5 | -7.4 |
| Kellaway & Leibholz (1983) | 23.5 | |
| Lee *et al.*, (1987) | 194.4 | -8.3 |

In several studies (Raleigh & Wallace, 1963: Oh et al., 1969, Hunter & Siebert, 1980; Lee *et al.*, 1987) indicated that true protein could be completely replaced by urea without significantly affecting organic matter (OM) and fibre digestibility. Urea substantially improved digestibility to a negative control and also compared well when replacing true protein. Coombe & Tribe (1962) suggested that urea had a more pronounced effect on retention time than on digestibility. They argued that for low-quality forages, which normally move slowly through the gut, a high proportion of the digestible material is broken down in a relative short time, compared to the time the material spend in the rumen. In contrast, Maeng *et al.* (1976) suggested an optimum ratio of NPN to amino acid N of 75:25 for maximum microbial growth. A summary of studies comparing digestibility response of NPN supplements with a negative control and true protein supplements is shown in Table 5.

**Table 5: A summary of studies comparing digestibility response of non-protein nitrogen supplements with negative controls and true protein supplements.**

| References | Digestibility % response of non-protein nitrogen over: | |
|---|---|---|
| | Control | True protein |
| Campling *et al.*, (1962) | 28.9 | |
| Coombe & Tribe (1962) | 8.2 | |
| Raleigh & Wallace (1963) | 23.6 | -1.0 |
| Kropp *et al.*, (1977) | | -14.1 |
| Hennesey *et al.*, (1978) | 4.4 | |
| Peterson *et al.*, (1985) | | 1.7 |
| Lee *et al.*, (1987) | 41.4 | 7.7 |

Several studies, (Redman *et al.*, 1980; Kropp *et al.*, 1977 and Peterson *et al.*, 1985) indicates a substantial improvement in microbial N production (48%) and efficiency of microbial CP synthesis (23%) when NPN was supplemented compared with a non- supplemented control.

An additional item of significant concern is the palatability of NPN-based products to animals (Köster *et al.*, 1996). If an animal refuses to eat products that contain specific ingredients, its inclusion in the feed is of little value. Therefore the ingredient is not completely evaluated unless the feed is consumed in adequate amounts by the animal (Fonnesbeck *et al.*, 1975). Huber & Cook (1969) showed that cows refusal to eat high-urea rations were due to undesirable taste and not ruminal or post ruminal effects. Tollet *et al.*, (1969) compared intakes of supplements containing different proportions of cottonseed meal, urea and/or biuret. They observed that consumption was lower on urea-based supplements due to palatability. Fonnesbeck *et al.* (1975) suggested that the low acceptability of urea and the potential danger of toxicity from ammonia limit its substitution potential to approximately 30% of the diet protein.

Many of the studies that evaluated urea-based supplements chose the levels of urea inclusion arbitrarily. Information regarding the effect of different levels of NPN in range supplements is currently lacking. This implies that there is a need to evaluate the optimum level of NPN inclusion in supplements fed to cattle consuming low quality forages. The need is also there to evaluate the ratio between NPN and true protein in the supplements fed to cattle consuming low quality forages.

Köster *et al.* (1996) determined the optimal use of NPN as DIP source and also the optimal ratio between natural DIP sources and NPN as DIP source on low quality prairie hay (CP 1.9%). He found that a RDP of 4,01g/kg $W^{0.75}$ was sufficient to maintain body weight of mature pregnant beef cows and optimize the DOMI of these cows. He also determines that the ratio of natural RDP: NPN should be between 50 –75% of total RDP supplied.

### 1.3 Protein/energy ratio

Egan (1972) found that the protein/energy (P/E) ratio (g digestible protein/MJ energy) was much more dominant in regulating voluntary intake of roughages, than digestibility of OM. Where P/E ratios in digestion are less than 5.5g digestible protein/MJ digestible energy (DE), responses in voluntary intake of roughage diets due to supplemental protein digested in the intestine may be expected. The reason for this is that increases in voluntary intake are usually the result of rectifying a deficiency in the availability of nitrogen to the micro-organisms in the reticulo-rumen, with a consequent increase in the rate of removal of digesta by fermentation and outflow (Egan & Doyle, 1985). If the P/E value is greater than 7.5, the limitation to intake lies in factors other than protein inadequacy, probably physical factors such as space-occupying effects of the digesta load associated with a low fibre digestion rate. In this regard Crampton *et al.*, (1957) have found that voluntary intake of fodders is a better index of their nutritive value than either chemical composition or total digestible nutrient (TDN) content.

### 1.4 Particle size

A further contributing factor towards feed intake regulation is the particle size of the forage. Alwash & Thomas (1974) found depressions in ruminal digestion of OM and fibre due to decreased rumen retention times associated with greater feed intake or smaller forage particle size. Usually a faster passage rate will lead to an increased voluntary intake. However, Firkins *et al.,* (1986) found no differences in OM intake and duodenal OM flow between ground- and chopped hay diets, but apparent ruminal OM digestion and percentage of digestible OM disappearing in the rumen were greater for ground- than for chopped-hay diets. It was concluded that the greater surface area per gram DM of ground hay should allow more rapid colonization by rumen microbes and, subsequently more extensive fermentation of the ground *vs.* the chopped hay diet.

**2.0 Animal performance**

From previous discussion it appears that NPN may be used effectively as a substitute for RDP without significantly depressing voluntary intake and digestibility of low quality roughages. If ruminants graze low quality roughages the body weight decrease will be lower when supplementation is given. In Table 6 it is shown that the animal performance of livestock fed NPN supplements lags behind that supplemented with true protein. It is evident that with true protein supplementation the decrease of body weight is less (Nelson & Waller, 1962). According to Forero *et al.*, 1980 the pregnancy rate of cows fed true protein supplements were higher than those fed a supplement containing urea.

**Table 6: A summary of literature on performance of beef cows consuming low quality roughages and supplemented with different N sources (NPN or True protein)**

| Reference | Animal | Roughage | Supplement | SI (g/day) | Total BW change (kg) | Calf weaning weight (kg) | Pregnancy rate (%) |
|---|---|---|---|---|---|---|---|
| ielson & Waller, (1962) | Mature beef Cows | Dry range 2.5% CP | CSM/Corn 20% CP | | -174 | 157 | |
| | | | CSM 40% CP | | -150 | 184 | |
| | | | CSM/Urea 50% CP/Corn | | -168 | 173 | |
| ιond & Rumsey, (1973) | Angus x Hereford cows (Dry) | Timothy Hay | Control | 0 | -1 | | |
| | | | Molasses | 2100 | -11 | | |
| | | | Molasses/Urea | 2100 | -14 | | |
| | | | Molasses/ Buiret | 1800 | 7 | | |
| 'orero *et al.*, (1980) | Hereford cows Lactating | Dormant Native Range | Natural CP 15% CP | 1220 | -90 | | 44 |
| | | | Natural CP 40% CP | 1220 | -36 | | 94 |
| | | | Slow release urea 40 % CP | 1220 | -68 | | 75 |
| | | | Urea 40 % CP | 720 | -78 | | 88 |
| | | | Urea 20 % CP | 1540 | -78 | | 53 |

ꞁI = Supplement Intake
ꞁW = Body Weight
ꞁP = Crude protein

## References

Acocks, J.P.H., 1975. Veld types of South Africa (2nd Ed.). Mem. Bot. Surv. S. Afr. 40, Govt. Printer, Pretoria.

Alwash, A. H. & Thomas, P. C., 1974. Effect of the size of hay particles on digestion in the sheep. *J. Sci. Food Agr.* 25, 139(*Abstr*).

Ammerman, C.B., Gladys, J.V., Moore, J.E., Burns, W.C. & Chicco, C.F., 1972. Biuret, urea and natural proteins as nitrogen supplement for low quality roughage for sheep. *J. Anim. Sci.* 35, 121-131.

Basurto-Gutierrez, R., Purvis II, H.T., Horn, G.W., Krehbiel,C.R., Boine, T.W. & Weyers, J.S., 2003. Effect of degradable or undegradable intake protein on forage intake and digestibility in steers consuming low quality forage. Animal Science Research Report.

Bond, J.T. & Rumsey, S., 1973. Liquid molasses-urea or biuret (NPN) feed supplements for beef cattle: wintering performance, ruminal differences and feeding patterns. *J. Anim. Sci.* 37, 593-603.

Bunting, L. D., Boling, J. A., MacKown, C. T. & Muntifering, R. B., 1987. Effect of dietary protein level on nitrogen metabolism in lambs: Studies using $^{15}$N-Nitrogen. *J. Anim. Sci.* 64, 855-860.

Campling, R.C., Freer, M & Balch, C.C., 1962. Factors affecting the voluntary intake of food by cows. 3. The effect of urea on the voluntary intake of oat straw. *Br. J. Nutr.* 16, 115-122.

Church, D.C. & Santos, A., 1981. Effect of graded levels of soybean meal and of nonprotein nitrogen-molasses supplement on consumption and digestibility of wheat straw. *J. Anim. Sci.* 53, 1609-1616.

Coombe, J.B. & Tribe, D.E., 1962. The effects of urea supplements on the utilization of straw plus molasses diets by sheep. *Aust. J. Agric. Res.* 14, 70-92.

Crampton, E. W., Lister, E. E. & Lloyd, L. E., 1957. Voluntary intake of forage as a measure of its feeding value. *J. Anim. Sci.* 16, 1056-1065.

Doyle, P. T., Egan J. K. & Thalen A. J., 1982. Parotid saliva of sheep: 1. Effects of level of intake and type of roughage. *Aust. J. Agric. Res.* 33, 573-581.

Egan, A.R., 1965. Nutritional status and intake regulation in sheep. Ⅱ. The influence of sustained duodenal infusions of casein or urea upon voluntary intake of low quality protein roughages by sheep. *Aust. J. Agric.* Res. 16, 451-463.

Egan, A. R., 1972. Nutritional status and intake regulation in sheep: 8. Relationships between the voluntary intake of herbage by sheep and the protein/energy ratio in the digestion products. *Aust. J. Agric. Res.* 23, 247(*Abstr*).

Egan, A.R. & Doyle, P.T., 1985. Effects of intraruminal infusion of urea on the response in voluntary food intake by sheep. *Aust. J. Agric. Res.* 36, 483-495.

Erasmus, L.J., Prinsloo, J., Botha, P.M. & Meissner, H.H., 1988. The establishment of protein degradability database for dairy cattle using the nylon bag technique. I. Protein Sources. *S. Afr. J. Anim. Sci.* 18, 23(*Abstr*).

Firkins, J. L., Berger, L. L., Merchen, N. R. & Fahey Jr, G. C., 1986. Effect of forage particle size, level of feed intake and supplemental protein degradability on microbial protein synthesis and site of nutrient digestion in steers. *J. Anim. Sci.* 62, 1081-1090.

Fonnesbeck, P.V., Kearl, L.C. & Harris, L.E., 1975. Feed grade biuret as a protein replacement for ruminants: A Review. *J. Anim. Sci.* 40, 1150-1155.

Forero, O., Owens, F.N. & Lusby, K.S., 1980. Evaluation of slow- release urea for winter supplementation of lactating range cows. *J. Anim. Sci.* 50, 532-538.

Freeman, A.S., Galyean, M.L. & Caton, J.S., 1992. Effects of supplemental protein percentage and feeding level on intake, ruminal fermentation and digesta passage in beef steers fed prairie hay. *J. Anim. Sci.* 70, 1562-1572.

Freer, M., Campling, R. C. & Balch, C. C., 1962. Factors affecting the voluntary intake of food by cows: 4. The behavior and reticular motility of cows receiving diets of hay, oat straw and oat straw with urea. *Br. J. Nutr.* 16, 115-118.

Garza, F., & Owens, F.N., 1991. Duodenally infused casein or glucose-urea for steers fed a low quality roughage. Okla. Ag. Exp. Sta. Res. Rep. no. 129.

Guthrie, M.J., & Wagner, D.G., 1988. Influence of protein and grain supplementation and increasing levels of soybean meal on intake, utilization and passage rate of prairie hay in beef steers and heifers. *J. Anim. Sci.* 66, 1529-1535.

Hannah, S.M., Cochran, R.C., Vanzant, E.S., & Harmon, D.L., 1991. Influence of protein supplementation on site and extent of digestion, forage intake and nutrient flow characteristics in steers consuming bluestem-range forage. *J. Anim. Sci.* 69, 2624-2630.

Hennessy, D.W., Williamson, P.J., Nolan, J.V., Kempton,T.J., & Leng, R.A., 1978. The roles of energy- or protein-rich supplements in the subtropics for young cattle consuming basal diets that are low in digestible energy and protein. *J. Agric. Sci. (Camb.)* 100, 657(*Abstr*).

Huber, J.T. & Cook, R.M., 1969. Site intake depression on high urea diets. *J. Dairy Sci.* 52, 942(*Abstr*).

Hunter, R.A. & Siebert, B.D., 1980. The utilization of spear grass (*Heteropogon contortus*). IV. The nature and flow of digesta in cattle fed on spear grass alone and with protein or nitrogen or sulfur. *Aust. J. Agric. Res.* 31, 1037-1045.

Jones, T.J., Cochran, R.C., Olson, K.C., Köster, H.H., Vanzant, E.S. & Titgemeyer, E.C., 1994. Influence of post-ruminal protein supply on gain and forage intake of beef cows consuming dormant, tallgrass-prairie forage. *J. Anim. Sci.* 72(Suppl. 1), 353-365.

Kellaway, R.C. & Leibholz., 1983. Effects of nitrogen supplements on intake and utilization of low-quality forages. *World Anim. Rev.* 48, 33-36.

Kempton, T.J. & Leng, R.A., 1979. Protein nutrition of growing lambs: 1. Responses in growth and rumen function to supplementation of a low-protein-cellulosic diet with either urea, casein or formaldehyde-treated casein. *Br. J. Nutr.* 42, 289-302.

Köster, H.H., Cochran, R.C., Titgemeyer, E.C., Vanzant, E.S. & St Jean, G., 1994. Effect of increasing ruminal degradable protein on site and extent of digestion in beef cows fed dormant, tallgrass-prairie forage. *J. Anim. Sci.* 72(Suppl. 1), 387-396.

Köster,H.H., Cochran, R.C., Titgemeyer, E.C., Vanzant, E.S., Abdelgadir,I. & St Jean, G., 1996. Effect of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. *J. Anim. Sci.* 74, 2473-2481.

Kropp, J.R., Johnson, R.R., Males, J.R. & Owens, F.N., 1977. Microbial protein synthesis with low-quality roughage rations: Level and source of nitrogen. *J. Anim. Sci.* 46, 844-854.

Lee, G.J., Hennessy, D.W., Nolan, J.V. & Leng, R.A., 1987. Responses to nitrogen and maize supplements by young cattle offered a low-quality pasture hay. *Aust. J. Agric. Res.* 38, 195-205.

Lintzenich, B.A., Vanzant, E.S., Cochran, R.C., Beaty, J.L., Brandt Jr, R.T & St. Jean., 1995. Influence of processing supplemental alfalfa on intake and digestion of dormant bluestem-range forage by steers. *J.Anim. Sci.* 73, 1187-1191.

Maeng, W.J., Van Nevel,C.J., Baldwin, R.L. & Morris, J.G., 1976. Rumen microbial growth rates and yields: Effect of amino acids and protein. *J. Dairy Sci.* 59(1), 69-79.

Mawuenyegah, P.O., Shem, M.N., Warly, L. & Fujihara, T., 1997. Effect of supplementary feeding with protein and energy on digestion and rumination behaviour of sheep consuming straw diets. *J. Agric Sci. (Camb.)* 129, 479-484.

McCollum, F.T. & Gaylean, M.L., 1985. Influence of cottonseed meal supplementation on voluntary intake, rumen fermentation and rate of passage of prairie hay in beef steers. *J. Anim. Sci.* 60, 570(*Abstr*).

McCollum, F.T. & Horn, G.W., 1990. Protein supplementation of grazing Livestock: *A review. Prof. Anim. Sci.* 6(2), 1(*Abstr*).

Merchen, N. R, Firkins, J. L. & Berger, L. L., 1986. Effect of intake and forage level on ruminal turnover rates, bacterial protein synthesis and duodenal amino acid flows in sheep. *J. Anim. Sci.* 62, 216-225.

Minson, D.J.,1990. Forage in Ruminant Nutrition. 1st Ed. Academic Press, Inc. San Diego, CA.

Moore, J.E. & Kunkle, W.E., 1995. Improving forage supplementation programs for beef cattle. In: 6th Annual Florida Ruminant Nutrition Symposuim, Gainesville, Florida.

Morrison, F.B., 1961. Feeds and Feeding. 9th Ed. Claremont,Ontario, Canada: The Morrison publishing company.

Nelson, A.B. & Waller, G.R., 1962. Urea in winter supplements for range beef cattle. *J. Anim.Sci.* 21, 387(Abstr.).

Nolan, J., Norton, B.W. & Leng, R.A., 1976. Further studies of the dynamics of nitrogen metabolism in sheep. *Br. J. Nutr.* 35, 127-147.

Nolte, J. van E., Ferreira, A.V. & Köster, H.H., 2003. Effect of amount of rumen degradable protein on the utilization of wheat straw by Dohne Merino wethers. *J.Anim.Sci.* 76, 319-326.

NRC 2000. Nutrient Requirements of Dairy Cattle. 7th Ed. National Academy Press. Washington, D.C.

Oh, H.K., Longhurst, W.M. & Jones, M.B., 1969. Relation of nitrogen intake to rumen microbial activity and consumption of low-quality roughage by sheep. *J. Anim. Sci.* 28, 272-278.

Owens, F.N., Garza, J. & Dubeski, P., 1991. Advances in amino acid and N Nutrition in grazing ruminants. In proceedings of the 2nd Grazing Livestock Nutrition Conference, 2 to 3 August 1991, Steamboat Springs, CO p,109. MP-133, Okla Stat Univ. Agr. Exp. Sta.

Owens, F.N. & Zinn, R., 1993. Protein metabolism of ruminant animals. In. D. C. Church (Ed.) The Ruminant Animal. Digestive Physiology and Nutrition, Waveland Press Inc. Prospect Heights, IL.

Peterson, M.K., Clanton, D.C. & Britton, R., 1985. Influence of protein degradability in range supplements on abomasal nitrogen flow, nitrogen balance and nutrient digestibility. *J. Anim. Sci.* 60, 1324-1335.

Raliegh, R.J & Wallace, J.D., 1963. Effect of urea at different nitrogen levels on digestibility and on performance of growing steers fed low quality flood meadow roughage. J. Anim. Sci. 22, 330-339.

Redman, R.G., Kellaway, R.C. & Leibholz, J., 1980. Utilization of low quality roughages: Effects of urea and protein supplements of differing solubility on digesta flows, intake and growth rate of cattle eating oat chaff. *Br. J. Nutr.* 44, 343-359.

Scott, R.R. & Hibberd, C.A., 1990. Incremental levels of supplemental ruminal degradable protein for beef cows fed low quality native grass hay. Okla. Agr. Exp. Sta. Misc. Publ. MP-129.

Stokes, S.R., Goetsch, A.L., Jones, A.L. & Landis, K.M., 1988. Feed intake and digestion by beef cows fed prairie hay with different levels of soybean meal and receiving postruminal administration of antibiotics. *J. Anim. Sci.* 66, 1778-1786.

Swingle, R.S., Ariza, A. & Urias, A.R., 1977. Nitrogen utilization by lambs fed wheat straw alone or with supplements containing dried poultry waste, cottonseed meal or urea. *J. Anim. Sci.* 45, 1435-1448.

Tollet, J.T., Swart, R.W., Loset, R.M. & Templeton, J.A., 1969. Biuret as a nitrogen source for wintering steers. J.Anim. Sci. 28, 862(*Abstr.*).

Van der Merwe, F.J. & Smith, W.A., 1991. Animal Feeding. 2nd Rev. Ed. Anim. Sci Pty Ltd, Pinelands.

Van Soest, P.J., 1982. Nutritional ecology of the ruminant. O and B Books, Inc., Corvallis, OR.

Wilson, J. R. & Kennedy, P. M., 1996. Plant and animal constraints to voluntary feed intake associated with fibre characteristics and particle breakdown and passage in ruminants. *Austr. J. Agric. Res.* 47, 199-205.

# Chapter 3

## Evaluation of plant protein sources in degradable protein supplements for beef steers consuming low quality roughage

### Introduction

Generally rumen degradable protein (RDP) is considered to be the dietary component that is first limting to the utilization of low quality forage. It is also generally accepted that true RDP will enhance fibre digestion and microbial growth efficiency in comparison to ammonia ($NH_3$) alone (Rooke & Armstrong, 1989; Merry *et al.*, 1990). Proteolytic and deaminative enzymes produced by rumen microorganisms degrade dietary protein to volatile fatty acids (VFA's), peptides, amino acids and $NH_3$ (Kang-Meznarich & Broderick, 1981). A fraction of the dietary protein can escape the rumen fermentation to provide essential amino acids in the duodenum, while the peptides and amino acids can be directly incorporated into microbial crude protein (MCP), with a subsequent lower energy cost than $NH_3$ (Nolan *et al.*, 1976).

Ammonia is the primary nitrogen source for the growth of rumen microorganisms (Nolan *et al.*, 1975; Aharoni *et al.*, 1991) and is essential for the existence of several species of rumen bacteria (Allison, 1970 & Bryant, 1973). On the other hand it is also frequently suggested that intact proteins supply other microbial growth factors. According to Köster (1996) scientists emphasized the importance of amino acids and peptides as such in stimulating microbial growth and digestion. Bryant & Robinson (1962) stated that 82% of rumen bacteria can grow with ammonia as the sole nitrogen (N) source, 25 % would not grow unless ammonia is present and 56% could utilize either ammonia or amino acids. Russell *et al.*, (1992) reported that starch and sugar degrading bacteria require peptides and amino acids for optimal growth, while cellulolytic bacteria use ammonia as primary N source. Carro & Miller (1999) is of opinion that both structural and non-structural carbohydrate fermenting bacteria could utilize ammonia as well as pre-formed amino acids as a N source. According to Köster (1996) it has been noted that the amino acid requirements of fibrolytic bacteria parallels the provision of branched chain volatile fatty acids (BCVFA) from the deamination of specific amino acids. In fact BCVFA have been suggested to play a role as growth factors in improving cellulose digestion.

A study to determine the amount of RDP needed to maximize digestible organic matter (OM) intake in beef cows consuming low-quality, tallgrass prairie forage was done by Köster (1996). Results from the study are currently used as guideline to formulate protein supplements for beef cattle on low-quality roughage more accurately. According to these results mature non-pregnant beef cows fed low-quality forages required 4g total RDP/kg BW $^{0.75}$ to maximize digestible OM intake. Urea can provide up to 50 to 75% of the supplemental RDP to beef cattle on low-quality roughages without compromising forage intake and digestion. The rest should be provided by an oilcake meal. Cotton oilcake, soybean oilcake and sunflower oilcake are available natural protein sources in South Africa. These oilcake meals could however differ in there degradable protein, as well as ammonia, amino acids and peptides supply in the rumen, which could influence the results (McDonald *et al.*, 2002). Therefore, some questions still remains unanswered regarding the practical use of these results of Köster (1996) under South African conditions and needs to be investigated, primarily because of the cost implication on lick formulation and the soundness of on farm supplementary feeding recommendations.

The aim of this study was to determine the best natural (plant) source of RDP not provided by urea to maximize the digestible organic matter intake of low quality winter pasture hay (roughage) by beef steers.

## Material and Methods

### Crude protein degradability

Six rumen fistulated steers were used to determine the degradability of cotton oilcake, soybean oilcake, sunflower oilcake and natural winter pasture. Dormant winter pasture hay of the Northern Variation of the Cymbopogon – Themeda pasture type was cut, baled and stored in a dry location. According to Acocks (1975) the Northern Variation of the Cymbopogon – Themeda pasture type (no. 48b) comprises mainly the following species: *Themeda triandra, Cymbopogon plurinades, Heteropogon contortus, Setaria sphacelata, Eragrostis racemosa, Eragrostis chloromelas, Elionurus muticus, and Brachiaria serrata*. The steers were fed individually. The natural winter pasture hay was offered at 130% of the previous five-day average consumption (Köster *et al.*, 1996). A mixture consisting of equal parts of three oilcake supplements with a physical and chemical composition as indicated in Table 1 was fed twice daily at 07:00 and 19:00. These supplements were used in an intake and digestibility study as described later. The supplements were formulated to provide in the RDP requirements of steers (4.01g RDP/kgW $^{0.75}$) as recommended by Köster (1996).The cotton-, soybean- and sunflower oilcake provided 50% of the supplemental RDP while the remainder of the RDP was supplied by urea. It was further assumed that winter pasture contains 3.5% crude protein (CP) with a degradability of 51%. It was further assumed (Köster *et al.*, 1996) that the trail animals would maintain a dry matter intake (DMI) of 1.7% of their body weight of the natural winter pasture hay. Supplemental RDP requirements were calculated as the difference between the total RDP requirements and the RDP provided by the natural winter pasture hay.

**Table 1 Physical and chemical composition of degradable protein supplements on an air-dry matter basis.**

| | | Supplements | |
|---|---|---|---|
| Item | Cotton oilcake | Soybean oilcake | Sunflower oilcake |
| **Physical Composition (%)** | | | |
| Urea | 6.40 | 6.90 | 6.36 |
| Salt | 6.66 | 7.19 | 6.63 |
| Bagasse | 6.66 | 7.19 | 6.63 |
| Molasses | 19.99 | 28.76 | 19.88 |
| Sunflower oilcake | | | 60.17 |
| Soybean oilcake | | 49.60 | |
| Cotton oilcake | 59.96 | | |
| Feed grade sulphur | 0.33 | 0.36 | 0.33 |
| **Chemical composition (%)[1]** | | | |
| Crude protein | 42.54 | 40.71 | 46.94 |
| Degradable protein | 36.53 | 36.38 | 42.28 |
| Non protein nitrogen 'equivalent urea | 17.87 | 17.86 | 20.70 |
| Metabolisible energy (MJ/kg) | 8.82 | 8.64 | 9.29 |
| Calcium | 0.43 | 0.47 | 0.48 |
| Phosphorous | 0.66 | 0.66 | 0.46 |

1) Values of ingredients determined before formulation

The supplements were formulated in such a way as to ensure that they were equivalent and/or comparable in feed ingredient and chemical composition.

Feed grade sulphur was added to maintain a ratio of 10N to 1sulphur (S). Macro- and micro trace elements in the from of a premix pack were added to supply in the animals needs as recommended by the NRC (2000).

The degradability trial consists of a 14-day adaptation period and a 4-day collection period. The *in sacco* technique described by (Erasmus *et al.* 1988; Erasmus *et al* 1990) and adapted to NRC (2001) was used. An approximately 5g moisture free sample of a specific oilcake or natural pasture was milled to pass trough a 2 mm screen and weighed into each bag (~ 15 mg DM/ $cm^2$ bag surface area). In order to avoid period effects all samples were incubated simultaneously for each of the following durations:

Day 1: 1, 4, 12, 48 hours.
Day 2: 2, 8 and 24 hours.
Day 3: 72 hours (only roughage)
Dry matter and N disappearance were measured in duplicate in three randomly selected steers out of a group of six steers as recommended by Mehrez & Ørskov (1977), giving a total of six repetitions per sample.

After removing the samples from the rumen, bags were washed in running water for a minute and put into a bucket half filled with clean water. The bucket was shaked for one minute and the water then removed. This procedure was repeated until the water was clear. The bags were dried in a convection oven for 24 hours at 60°C. The bags were left overnight in a decicator to cool of and weighed again. The content of the bags were removed and milled in a Wiley mill to pass through a 1 mm sieve. Milled samples were stored in polyethylene vials for later analyses.

The percentage dry matter (DM) and N disappearance at each incubation period was calculated from the proportion remaining after rumen incubation:

$$\text{Degradability} = \frac{\text{Initial N- N after incubation}}{\text{Initial N}}$$

The degradation rate was adapted to the equation as suggested by Ørskov & McDonald (1979):

$$p = a+b\ (1-e^{-ct})$$

Where p = proportion degraded at time

a, b and c = non-linear parameters estimated by an iterative least square procedure (McaDonald *et al.*, 2002)

The effective protein degradability was calculated as follows (Ørskov & McDonald, 1979):

$$P = a + bc/(c+r)$$

Where a = an intercept representing soluble protein.

b = insoluble but potentially degradable fraction.

c = degradation rate of the b fraction.

r = fractional outflow rate

The fractional outflow rate (r = 0.02) for cattle at low planes of nutrition (McDonald *et al.*, 2002) were used.

Intake and digestibility

Seven steers per treatment with an average weight of 217 kg (SD= ± 9.91 kg) were used in three treatments randomly allocated to determine the best natural RDP source. The experimental period consisted of a 14-day adaptation period, 21-day intake- and 7-day collection period (total 42 days). Hay intake was monitored to enable the calculation of the daily hay allowance as 130% of the previous 5-d-average consumption (Köster, 1996). The degradability values of the three oilcakes and winter pasture hay were used to calculate the intake of the three supplements (Table 1) to supply in the RDP- requirements of steers (Köster, 1996). Hay and supplements were supplied twice daily as described.

Representative feed samples were collected daily at both feeding times. Ort samples were taken in the morning and weighed and composite per steer for each period. Faecal samples were taken every morning and a representative sample of 10% was collected per steer. The samples were dried at 50°C for 96 hours and composite per steer for each period and weighed. The faecal, feed and orts samples were weighed and milled with a Willey mill to pass through a 1 mm sieve and stored for later analysis.

Rumen fluid characteristics

The day after the collection period (day 43), approximately 35 ml of rumen fluid was obtained from each animal three hours after the initiation of morning feeding. A vacuum pump and plastic rumen tube were used to obtain the samples. The samples were strained through four layers of cheesecloth and pH immediately determined using a portable meter. For determination of concentrations and molar proportions of individual volatile fatty acids (VFA), 10 ml of each sample was stored frozen. The remaining 25 ml was acidified with a few drops of concentrated sulphuric acid to give a pH of ± 2 and stored frozen for later analysis of ammonia-nitrogen (AN) concentration.

Steers were fasted for 24 hours and weighed at the beginning and end of each period.

*Laboratory analyses*

The chemical composition of feed, orts and faeces was determined according to the methods prescribed by the AOAC (1995).

Samples were dried at 100°C in a convention oven to a constant mass in order to determine DM content. The organic matter (OM) content was determined by ashing samples in a muffle furnace at 500°C for 8 hours. By subtracting the ash from the DM content the OM content was determined.

Kjeldahl nitrogen (N), Neutral detergent fibre (NDF) was determined according to the methods of Van Soest *et al.*, (1991). Gross energy was determined by means of bomb calorimetry. VFA of rumen fluids were determined using a Hewlett Packard 5890 A gaschromatgraph. AN concentration was determined by means of spectrophotometer.

*Statistical analyses*

The SAS (1995) procedure for variance analyses (PROC ANOVA) was used to test for significant differences between the treatments. A complete randomized design was used. Dependent variables that were found to be significantly different ($P < 0.05$) were further subjected to multiple comparison tests using Tukey's test.

## Results and Discussion

### Crude protein degradability

The *in sacco* procedure has emerged as the most widely used approach for estimating rumen degradable protein (Stern *et al.*, 1997; NRC, 2001). Consequently it is used in the present study. McDonald *et al.*, (2002) have suggested that a major factor affecting protein degradability is the amino acid sequence within the protein molecule. If this is so then the nature of the microbial produced rumen peptidases is of considerable importance and it seems doubtful whether any simple laboratory test for degradability is possible.

The CP content and protein degradability of the three different oilcakes and natural winter pasture hay in the present study, are compared with those in the available literature in Table 4. It seems that soybean oilcake recorded the highest and sunflower oilcake the lowest protein content in the current study. These differences were however not supported by Erasmus *et al.*, (1988) and Van der Merwe & Smith (1991). Erasmus *et al.*, (1988) also observed the highest value for soybean oilcake but the lowest for cotton – and sunflower oilcake.

On the other hand Van der Merwe & Smith (1991) reported the highest value for both soybean- and cotton oilcake. The variation in CP content of oilcakes stress the importance of chemical analysis to accurately compile CP-supplements.

The quality of the *Cymbopogon Themeda* natural pasture hay used in the present study is reflected by the low CP – (3.51%) and high NDF content (74.52%). Köster (1996) used tall grass prairie hay to quantify the amount of degradable intake protein required to optimize intake and digestion. From Table 2 the exceptionally low CP-content of the hay used by Köster (1996) can be observed. Differences in hay quality could possibly influence degradable protein requirements. Therefore further research is needed to test the results of Köster (1996) under practical conditions in different regions in South Africa.

Current systems for the evaluating of food protein for ruminant animals involve determinations of the degradability of protein in the rumen, the synthesis of microbial protein, the digestion in the lower gut of both food and microbial proteins and the efficiency of utilization of absorbed amino acids (biological value). According to McDonald *et al.* (2002) nitrogen fractions within the diet will vary in their susceptibility to breakdown from immediately degraded to undegradable and from 0 to 1 in the extent to which they are degraded. Degradability will depend upon such factors as the surface area available for microbial attack, the physical and chemical nature of the protein and the protective action of other constituents (Polan, 1992; NRC, 2001; McDonald *et al.*, 2002).

**Table 2. Protein degradability of oilcakes and natural winter pasture hay on a dry matter basis.**

| Item | CP<br>%| Effective protein degrad ability<br>% | Effective degradable protein<br>% | a[1]<br>% | b[1]<br>% | c[1]<br>% | $r^2$ |
|---|---|---|---|---|---|---|---|
| **Cotton oilcake** | | | | | | | |
| Current study | 41.09 | 78.24 | 32.15 | 16.43 | 85.68 | 0.05 | 0.02 |
| Erasmus *et al.*, (1988) | 40.20 | 72.00 | 28.94 | | | | |
| Van der Merwe & Smith (1991) | 45.6 | | | | | | |
| **Soybean oilcake** | | | | | | | |
| Current study | 45.24 | 79.50 | 35.97 | 6.59 | 127.44 | 0.03 | 0.02 |
| Erasmus *et al.*, (1988) | 44.10 | 79.50 | 35.05 | | | | |
| Van der Merwe & Smith (1991) | 46.7 | | | | | | |
| **Sunflower oilcake** | | | | | | | |
| Current study | 38.70 | 87.06 | 33.69 | 26.32 | 70.60 | 0.12 | 0.02 |
| Erasmus *et al.*, (1988) | 40.30 | 93.50 | 37.68 | | | | |
| Van der Merwe & Smith(1991) | 43.5 | | | | | | |
| **Natural pasture** | | | | | | | |
| Current study | 3.51 | 67.48 | 2.37 | 9.93 | 266.84 | 0.01 | 0.02 |
| Köster (1996) | 1.90 | 53.00 | 1.01 | | | | |

1) Fitted parameters a, b, c derived from the *in sacco* determination of effective ruminal protein degradability where:

a = Rapidly soluble nitrogen fraction

b = Fraction which will degrade in time more slowly

c = Rate at which fraction b degrades

2) Fractional outflow rate (McDonald *et al.*, 2002)

From Table 2 it appears that the protein degradability of cotton – and soybean oilcake was comparable. The protein degradability of sunflower oilcake was however higher compared to the other two oilcakes. These results are in disagreement with those of Erasmus *et al.* (1988) who also found the highest protein degradability for sunflower oilcake but the lowest for cotton oilcake with soybean oilcake intermediate.

In accordance with protein degradability the highest rapidly soluble nitrogen fraction and rate at which fraction b degrades was recorded for sunflower oilcake. Soybean oilcake recorded the lowest rapidly soluble nitrogen fraction and rate at which fraction b degrades. According to McDonald *et al.* (2002) the part of the food crude protein that is immediately degradable is unlikely to be as an effective source of nitrogen for microorganisms than the fraction that is degraded slower. Therefore soybean oilcake seems to be the most and sunflower oilcake the less effective source of nitrogen for microorganisms. Accordingly soybean oilcake showed the highest fraction which will degrade in time.

In terms of CP- and effective degradable protein content the rapidly soluble nitrogen fraction was low in the natural winter pasture hay used in the current study. This was even more the case (protein and effective degradable protein) for the tall-grass prairie hay used by Köster (1996) in his study.

Digestibility

The influence of different plant degradable protein sources on the digestibility of the diet is presented in Table 3. Apart from apparent NDF digestibility of the sunflower oilcake treatment, which was significantly (P<

0.05) higher than that of cotton oilcake and soybean oilcake, no significant differences in dry matter intake (DMI) and apparent

**Table 3: Influence of plant degradable protein source on digestibility of the diet.**

| Item | Cotton Oilcake | Soybean Oilcake | Sunflower Oilcake | Significance | |
|---|---|---|---|---|---|
| | | | | P | CV[1] |
| Grass dry matter intake (kg/steer/day) | 5.11 | 5.25 | 5.19 | 0.8757 | 9.87 |
| Lick dry matter Intake (kg/steer/day) | 0.346 | 0.339 | 0.349 | --- | --- |
| Total dry matter intake (kg/steer/day) | 5.12 | 5.24 | 5.18 | 0.8924 | 9.25 |
| Total organic matter Intake (kg/steer/day) | 4.71 | 4.81 | 4.75 | 0.9122 | 9.29 |
| Apparent digestibility: | | | | | |
| Dry matter digestibility (%) | 50.13 | 52.69 | 55.61 | 0.1871 | 10.10 |
| Organic matter digestibility (%) | 48.94 | 51.56 | 54.23 | 0.1256 | 8.89 |
| Crude protein digestibility (%) | 44.95 | 46.06 | 48.30 | 0.5772 | 12.93 |
| Neutral detergent fibre digestibility (%) | $50.30^b$ | $52.42^b$ | $62.94^a$ | 0.008 | 9.82 |
| Gross energy digestibility (%) | 45.58 | 47.85 | 51.34 | 0.1913 | 11.80 |
| Digestible crude protein (%) | 2.54 | 2.63 | 2.67 | 0.8269 | 15.05 |
| Digestible energy (MJ/Kg) | 7.07 | 7.37 | 7.93 | 0.2104 | 11.92 |
| Metabolisible energy (MJ/kg)[2] | 5.66 | 5.89 | 6.35 | 0.2101 | 11.92 |

Row means with different subscripts differ significantly

1) Coefficient of variation
2) Digestibility x 0.8 (McDonald *et al.*, 2002)

digestibility and energy related data occurred. The other digestibility – and energy related data only tend (P>0.05) to be higher where sunflower oilcake was fed to steers compared to cotton oilcake and soybean oilcake. No information regarding the influence of specifically cotton oilcake, soybean oilcake and sunflower oilcake as degradable protein supplementary sources on the digestibility of low quality roughages could be found in the available literature.

From Table 2 it is clear that the respective fractions of RDP (a and b) differed among the various oilcakes. It is however uncertain whether the higher soluble nitrogen fraction and rate at which b fraction degrades of sunflower oilcake could contribute to the higher (P =0.008) NDF digestibility. Russel *et al.*, (1992) stated that cellulolytic bacteria use ammonia as the primary nitrogen source for microbial synthesis. McDonald *et al.*, (2002) is however of opinion that it is unlikely that immediately degradable protein is an effective source for the nitrogen microorganisms.

It is very difficult to explain the significant higher NDF digestibility for the sunflower oilcake treatment and warrants it further investigation. One reason could be that the supply of ammonia or the protein pool in the sunflower group is more favorable for fiber carbohydrate fermentation. The following quote from the Cornell Nett Carbohydrate and Protein System (CNCPS version 5.0.34, 2002) model biology documentation provides a better understanding of the interaction between fibre carbohydrate (NDF fractions) and non-fibre carbohydrate (primarily starch) fermentation in the rumen.

"Rumen microorganisms can be categorized according to the types of carbohydrate they ferment. In the CNCPS, they are categorized into those that ferment fiber carbohydrates (FC) and no fiber carbohydrate (NFC), as described by Russell *et al.*(1992) and the NRC (2000). Generally, FC microorganisms ferment cellulose and hemicelluloses and grow more slowly, and utilize ammonia as their primary nitrogen source for microbial protein synthesis. NFC microorganisms in contrast ferment starch, pectin and sugars, grow more rapidly and can utilize ammonia and amino acids as nitrogen sources. The FC and NFC microorganisms have different maintenance requirements (the CNCPS uses .05 and .15 g of carbohydrate per g of microorganism per hour, respectively) and efficiency of growth of NFC digesting bacteria is optimized at 14% peptides as a percentage of NFC. These values are conservative and are based on the observations of Russell et al. (1992) that *Streptococcus bovis*, a primary starch fermenter, has about 6 times the maintenance cost of *Fibrobacter succinogenes*, a representative fiber digester. Thus the degradable protein requirement is for supporting optimal utilization of NFC and FC to meet the respective microbial growth requirements. The rate of microbial growth of each category is directly proportional to the rate of carbohydrate digestion, so long as a suitable nitrogen source is available. The extent of digestion in the rumen depends on digestion of FC and NFC feed fractions and how rapidly the feed passes out of the rumen. The extent of digestion thus depends on factors such as level of intake, particle size, rate of hydration, lignifications, and characteristics of each carbohydrate and protein fraction.

The metabolizable energy (ME) and Metabolizable protein (MP) derived in each situation will primarily depend on the unique rates of digestion and passage of the individual feed carbohydrate and protein fractions that are being fed. Digestion rates are feed specific, and depend primarily on type of starch and protein, degree of lignifications, and degree of processing. Extent of ruminal digestion is a function of competition between digestion and passage, and varies with feed type (forage vs. grain) and particle size (peNDF). There are four nitrogen fraction requirements that must be met in evaluating a ration with the CNCPS; two microbial categories (ammonia forthe structural carbohydrates (SC) and peptides and ammonia for the non-structural carbohydrates (NSC) microbial pools), and two animal pools (MP and essential amino acids). In evaluating a diet, one must be able to determine how well all four requirements are being met".

It was therefore decided to evaluate the treatments with the CNCPS model in order to try and explain the significant higher NDF degradability for the sunflower oilcake treatment.

Accordingly to the model documentation of CNCPS version 5.0.34 (2002), "feed composition in the CNCPS is described by carbohydrate and protein fractions and their digestion rates, which are used to compute the amount of SC and NSC available for each of the two microbial pools (Sniffen *et al.* 1992). Digestion and passage rates have been developed for common feeds, based on data in the literature. All of the carbohydrate and protein fractions needed to predict the amounts of degradable carbohydrate and protein fractions available to support rumen fermentation can be determined in feed testing laboratories, using the Van Soest *et al.* (1991) system of feed analysis and proximate analysis. Included are NDF, CP, soluble protein, neutral and acid detergent insoluble protein, fat and ash. The CNCPS feed library contains over 150 feeds that are described by these analyses. Included are digestion rates for sugars (CHO A), starch and pectin (CHO B1), available NDF (CHO B2) and fast (B1), intermediate (B2) and slow (B3) protein. Total carbohydrates are computed as 100-(protein + fat + ash), using tabular or analytical values. Then carbohydrates are partitioned into structural (SC) and nonstructural (NSC) by subtracting NDF from total carbohydrates, with the available fiber being NDF minus NDF protein minus (lignin x 2.4). Data from the literature is used to establish the distribution of sugars and starch in the NSC fraction. The growth of two microbial pools (SC and NSC) is then predicted, based on the integration of rates of digestion and passage, which in turn determines the nitrogen requirements of each pool, microbial protein produced and MP available from this source, carbohydrates escaping digestion and digested postruminally and ME derived from the diet. Passage rates are a function of level of intake, percent forage, and physically effective NDF value. Simultaneously, the degraded and undegraded protein pools are predicted, which are used to determine nitrogen balance for each of the microbial pools, feed protein escaping undegraded and digested postruminally, and MP derived from undegraded feed protein. The protein fractions are expressed as a percentage of the CP. The "A" protein fraction is NPN and the "B1" fraction is true protein that is nearly all degraded in the rumen; these pools are measured as soluble protein. The "C" protein fraction is measured as acid detergent insoluble protein (ADIP) and is assumed to be unavailable. The "B3" or slowly degraded protein fraction can be determined by subtracting the value determined for ADIP from the value determined for neutral detergent insoluble protein (NDIP). The "B2" fraction, which is partly degraded in the rumen, depending on digestion and passage rates, can be then estimated as the difference between CP and the sum of soluble + B3 + C. Feed amino acid content is described by their concentration in the undegraded protein, as described by O'Connor *et al.* (1993). Intestinal digestibility of the amino acids is assumed to be 100% in the B1 and B2 and 80% in the B3 protein escaping ruminal degradation.

The CNCPS rumen model accounts for the effects of a ruminal nitrogen deficiency on forage digestion rates Tedeschi *et al.* (2000). Fiber digestion rate and microbial yield are reduced proportional to the ammonia deficiency."

The dairy One Laboratory in Ithaca, New York analyzed the ingredients used in the formulation of the different supplements as well as the composition of the forage. These ingredients that are described by these analyses have been compiled into a feed library for the CNCPS model. The input data used for this evaluation was the actual data as for the study in terms of the description of the animals, management and environmental conditions and of course dry matter intake regarding forage and supplement. The results of this evaluation are reported in appendices A1, A2 and A3. A summary of these results is shown in Table 4.

Although no statistical analysis was possible on the data, it is obvious from Table 4 that according to the CNCPS model, no marked differences occurred in nutrient utilization between the various oilcake supplement treatments. The higher NDF digestibility of the sunflower oilcake treatment observed in the present study can still not be concluded.

**Table 4: Cornell Nett Carbohydrate and Protein System evaluation of treatments.**

| Item | Soybean oilcake supplement | Sunflower oilcake supplement | Cotton oilcake supplement |
|---|---|---|---|
| Crude protein (%) | 7.1 | 6.8 | 6.9 |
| Neutral detergent fibre concentration in ration (%) | 71.2 | 72.2 | 72 |
| Forage passage rate (%/hr) | 3.98 | 3.99 | 3.99 |
| Carbohydrate degradation | | | |
| B1 (g/day) | 53 | 52 | 53 |
| B2 (g/day) | 1356 | 1365 | 1359 |
| Carbohydrate ferment ability | | | |
| B1 (%) | 8.7 | 9 | 9 |
| B2 (%) | 38.9 | 38.5 | 38.2 |
| Improvement in non fibrous carbohydrate digestion (%) | 18.45 | 18.53 | 18.25 |
| Ration bacterial yield (g/day) | 659. | 645 | 644 |
| Total dietary microbial protein ( g/day) | 311 | 301 | 309 |
| Total bacterial nitrogen (g/day) | 66 | 64 | 64 |
| Total indigestible dry matter in ration (g/day) | 2648 | 2701 | 2722 |
| Recycled ammonia (g/day) | 29 | 29 | 30 |

Intake and weight changes

The influence of different plant degradable protein sources (oilcakes) on intake and weight changes of steers is shown in Table 5. No significant differences (P>0.05) in grass DMI and total DMI occurred between steers.

Grass DMI, expressed as a percentage of steer weight, was more or less 2.1%. Köster *et al.*, (1996) found that the grass DMI of prairie hay was 1.7% of the live mass of the pregnant cows he worked with. Differences in the digestibility of grass hay inter alias could contribute to these different calculated intake values. However, the most obvious explanation for these different intake values is probably the physiological stages that the cattle used in the various studies were in, viz. young, growing steers vs. mature pregnant cows. It can be expected that young cattle such as the steers used in the current study will show a higher feed intake in relation to their body weight as the pregnant cows used by Köster *et al.* (1996). Temperature could also play a role.

According to Köster *et al.* (1996) reviewers of research regarding protein supplementation, suggested that improved performance resulting from protein supplementation was probably due to either increased digestible organic matter intake (DOMI) and (or) improved efficiency of ME used.
Although enhanced efficiency of energy use may be important, most research results suggest that the enhanced DOMI can be explained as a response to protein supplementation. Therefore achieving maximal DOMI would be an appropriate response criterion for evaluating the requirement for supplemental DIP in forage-based diets. Using this criteria (DOMI) in the current study (Table 3), the results revealed that the different oilcakes provided with the same efficiency in the RDP requirements of steers

**Table 5: Influence of degradable protein source on the intake and weight changes of steers consuming a low quality roughage diet.**

| Item | Cotton Oilcake | Soybean Oilcake | Sunflower Oilcake | Significance(P) | CV |
|---|---|---|---|---|---|
| Grass dry matter grass intake (kg/steer/day) | 4.71 | 4.62 | 4.63 | 0.8884 | 7.72 |
| Grass dry matter intake as % of body weight (%) | 2.12 | 2.10 | 2.11 | 0.9563 | 6.26 |
| Supplemental dry matter intake(kg/steer/day) | 0.3461 | 0.3386 | 0.3353 | 0 | 0 |
| Total dry matter intake (kg/steer/day) | 5.05 | 4.96 | 4.96 | 0.8640 | 7.19 |
| Total dry matter intake as % of body weight (%) | 2.27 | 2.25 | 2.27 | 0.9515 | 5.88 |
| Digestible organic matter intake(kg/steer/day) | 4.33 | 4.26 | 4.26 | 0.8885 | 7.72 |
| Digestible organic matter intake/ kg $W^{0.75}$ | 42.68 | 44.70 | 47.24 | 0.1415 | 9.13 |
| Daily crude protein intake (g/steer/day) | 294.02 | 288.26 | 286.97 | 0.4792 | 3.92 |
| Daily digestible protein intake (g/steer/day) | 127.90 | 129.24 | 131.72 | 0.8913 | 11.63 |
| Daily gross energy intake (MJ/steer/day) | 28.49 | 29.20 | 31.38 | 0.2799 | 11.48 |
| Initial weight (kg) | 217.43 | 217.71 | 217.43 | 0.9983 | 4.80 |
| Final weight (kg) | 227.71 | 223.14 | 220.43 | 0.6453 | 6.49 |
| Weight change (kg) | 10.29 | 5.42 | 3.00 | 0.2891 | 136.39 |
| Final weight as % of initial weight (%) | 104.64 | 102.49 | 101.41 | 0.2991 | 3.71 |

Row means with different subscripts differ significantly

1) Coefficient of variation

consuming a low quality roughage. These findings were recorded in spite of the higher (P= 0.008) apparent digestibility for NDF that occurred where sunflower oilcake was included in the supplement (Table 5). The results of the intake study therefore suggested that structural carbohydrate fermenting bacteria could also utilize pre-formed amino acids as N source. Accordingly Carro & Miller (1999) stated that both structural and non-structural carbohydrate fermenting bacteria could utilize ammonia as well as pre-formed amino acids as a N source.

The different oilcakes had no significant (P> 0.05) influence on the weight data of the steers. The experimental period was probably however too short to make any reliable observations in this regard.

Rumen characteristics

There were no significant (P>0.05) differences (Table 6) in the volatile fatty acid content and pH of the rumen fluid of steers receiving different oilcake treatments. These results are expected as no significant differences (P>0.05) were recorded in the intake of grass, licks and organic matter of steers consuming the different oilcake supplements (Table 3). Similarly dry matter- organic matter- and gross energy digestibility in the diet did not differ significantly. These results occurred in spite of the fact that sunflower oilcake showed the highest soluble nitrogen fraction and protein degradation rate. Accordingly to these results the rapidly soluble nitrogen fraction (a) and fraction which would degrade in time (b) were used efficiently by the microbes of steers in all the treatments.

**Table 6: Influence of different oilcakes on the rumen fermentation characteristics of steers consuming a low quality roughage diet.**

| Item | Cotton oilcake | Soybean oilcake | Sunflower oilcake | Significance (P) | CV[1] |
|---|---|---|---|---|---|
| Acetate (mg/l) | 221.88 | 199.14 | 201.02 | 0.6695 | 25.15 |
| Propionate (mg/l) | 66.83 | 61.03 | 61.70 | 0.8510 | 32.91 |
| Isobutyrate (mg/l) | 2.11 | 2.11 | 2.77 | 0.2944 | 37.83 |
| Butyrate (mg/l) | 43.40 | 38.21 | 36.98 | 0.4243 | 24.06 |
| Isovalerate (mg/l) | 1.32 | 1.18 | 1.70 | 0.5112 | 61.50 |
| Valerate (mg/l) | 0.93 | 0.96 | 1.11 | 0.8766 | 70.16 |
| $NH_3N$ (mg/l) | $2.54^{a}$ | $1.80^{ab}$ | $1.25^{b}$ | 0.0397 | 46.88 |
| pH | 7.34 | 7.59 | 7.61 | 0.1874 | 3.99 |

$^{ab}$ Row means with different subscripts differ significantly
1) Coefficient of variation

The $NH_3N$ concentration of rumen fluid of steers that consumed the sunflower oilcake supplements was significantly (P=0.0397) lower than that of cotton oilcake. These results occurred regardless of the fact that sunflower oilcake (Table 2) contained the highest rapidly soluble nitrogen fraction and protein degradation rate. According to these results the rumen microorganisms used the RDP in the sunflower oilcake supplements efficiently at the levels of inclusions in the RDP supplements. These results was confirmed by the better (P=0.008) digestion of fibre (Table 3) by the steers that consumed the sunflower oilcake supplement. This better utilization of RDP in sunflower oilcake supplements was however not supported by the intake results represented in Table 5 and CNCPS model evaluation in Table 4. It therefore seems that fibre digestion and microbial growth are not the only factors that influenced DOMI.

Some researchers (Egan, 1965; Garza & Owens, 1991) are of opinion that independent of rumen conditions, the voluntary intake of low quality roughages may be increased further by undegradable protein (UP). Kempton & Leng (1979) is of opinion that an increased amount of dietary protein that escapes rumen fermentation would supply more digestible protein in the small intestine and should the N status of the animal, which would enhance voluntary intake. The degradability results in Table 2 showed accordingly the highest UP-values for cotton- and soybean oilcake. This may contribute to the non-significant differences in DOMI of steers that consumed the different oilcake supplements.

According to Köster (1996) it further seems that amino acids and peptides are important in stimulating microbial growth and digestion. It was also noted that the amino acid requirements of fibrolytic bacteria parallels the provision of branched chain volatile fatty acids (BCVFA) from the deamination of specific amino acids. This BCFVA play a role as growth factors in improving cellulose digestion. As these aspects was not measured in the current study, no accurate observations and final conclusions in this regard is however possible.

**Conclusion**

It seems from the DM intake, DOMI and gross energy digestibility related results as well as CNCPS model that any of the three oilcakes(sunflower, cotton and soybean) could be used as plant protein sources in the degradable protein supplements for beef cattle consuming low-quality roughage. The most appropriated oilcake would be determined by factors like availability and price. These results were obtained in spite of the differences in effective protein degradability and fractions of protein degradability. It seems that these differences will have no influence on DOMI of low-quality roughage when cotton-, soybean- and sunflower oilcake respectively provided 50% of the supplemental RDP. The effect of immediately degradable protein on microbial growth, fiber digestibility and DOMI of low quality roughage by beef cattle warrants further research. Accordingly the effect of undegradable protein on the DOMI of low quality roughage by ruminants should enjoy further investigation.

## References

Acocks, J.P.H., 1975. Veld types of South Africa (2nd Ed.). Mem. Bot. Surv. S. Afr. 40, Govt. Printer, Pretoria.

Aharoni, Y., Tagari, H & Boston, R.C., 1991. A new approach to the quantitative estimation of nitrogen metabolic pathways in the rumen. *Br. J. Nutr.* 66, 407-422.

Allison, M.J., 1970. Nitrogen metabolism of ruminal microorganisms. In: Physiology of Zdigestion and Metabolism in the Ruminant. Ed. Phillipson, A.T., Oriel Press, Newcastle.

AOAC., 1995. Official methods of analysis. 16th Ed. Association of Official Analytical Chemists, Arlington Virginia, USA.

AOAC., 1965. Official methods of analysis (10th ed.). Association of Official Analytical Chemists, Washington, DC.

Bryant, M.P., 1973. Nutritional requirements of the predominant rumen cellulolytic bacteria. *Fed. Proc.* 32, 1809 – 1816.

Bryant, M.P. & Robinson, I.P., 1962. Some nutritional characteristics of predominant culturable rumen bacteria. *J. Bacteriol.* 84, 605-614.

Carro, M.D. & Miller, E.L., 1999. Effect of supplementing a fibre basal diet with different nitrogen forms on ruminal fermentation and microbial growth in an *in vitro* semi-continuous culture system (RUSITEC). *Br. J. Nutr.* 82, 149-157

Egan, A.R., 1965. Nutritional status and intake regulation in sheep. Π. The influence of sustained duodenal infusions of casein or urea upon voluntary intake of low quality protein roughages by sheep. *Aust. J. Agric. Res.* 16, 451-463.

Erasmus, L.J., Prinsloo, J., Botha, P.M. & Meissner, H.H., 1988. The establishment of protein degradability database for dairy cattle using the nylon bag technique. I. Protein Sources. *S. Afr. J. Anim. Sci.* 18, 23(*Abstr*).

Erasmus, L.J., Prinsloo, J., Botha, P.M. & Meissner, H.H., 1990. Establishment of a ruminal protein degradation data base for dairy cattle using the in situ polyester bag technigue. 3. Roughages. *S. Afr. J. Anim. Sci.* 20, 124-134.

Garza, F., & Owens, F.N., 1991. Duodenally infused casein or glucose-urea for steers fed a low quality roughage. *Okla. Ag. Exp. Sta. Res. Rep. MP-129.*

Kang-Meznarich, J.H. & Broderick, G.A., 1981. Effects of incremental urea supplementation on ruminal ammonia concentration and bacterial protein formation. *J. Anim. Sci.* 51(2), 422-431.

Kempton, T.J. & Leng, R.A., 1979. Protein nutrition of growing lambs: 1. Responses in growth and rumen function to supplementation of a low-protein-cellulosic diet with either urea, casein or formaldehyde-treated casein. *Br. J. Nutr.* 42, 289-302.

Köster,H.H., Cochran, R.C., Titgemeyer, E.C., Vanzant, E.S., Abdelgadir,I. & St Jean, G., 1996. Effect of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. *J. Anim. Sci.* 74, 2473-2481.

Köster, H.H., 1996. An evaluation of different levels of degradable intake protein and nonprotein nitrogen on intake, digestion and performance by beef cattle fed low-quality forage. Ph. D. (Agric.)-dissertation , Kans. State. Univ. Manhattan, Kansas.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D. & Morgan, C.A., 1995. Animal nutrition, 5th ed., Longman. Singapore.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D. & Morgan, C.A., 2002. Animal nutrition, 6th ed., Longman. Singapore.

Merry, R.J., McAllan, A.B. & Smith, R.H., 1990. *In vitro* continuous culture studies on the effect of nitrogen source on rumen microbial growth and fiber digestion. *Anim. Feed Sci. Technol.* 31, 55(*Abstr*).

Mehrez, A.Z. & Ørskov, E.R., 1977. A study of the artificial fibre bag technique for determining the digestibility of feeds in the rumen. *J. Agric. Sci. (Camb).* 88:645-655.

Nolan, J., 1975. Quantitative models of nitrogen metabolism in sheep. In. Digestion an Metabolism in the ruminant. Eds. Mcdonald, I.W. & Warner, A.C.I., University of New England Publishing Unit, Armidale, Australia.

Nolan, J., Norton, B.W. & Leng, R.A., 1976. Further studies of the dynamics of nitrogen metabolism in sheep. *Br. J. Nutr.* 35, 127-147.

NRC., 2000. Nutrient Requirements of Dairy Cattle. 7th Ed. National Academy Press. Washington, D.C.

NRC., 2001. Nutrient Requirements of Dairy Cattle. Academy Press. Washington, D.C.

O'Connor, J.D., Sniffen, C.J., Fox, D.G. & Chalupa, W., 1993. A net carbohydrate and protein system for evaluating cattle diets. IV. Predicting amino acid adequacy. *J. Anim. Sci.* 71, 1298-1309.

Polan, C.E., 1992. Protein and amino acids for lactating cows. In: Large Dairy Herd Management, Eds. Van Horn, H.H. & Wilcox, C.J. American Dairy Science Association Champaign, IL. P 236 – 246.

Ørskov, E.R. & McDonald, E., 1979. The estimation of protein degradability in the rumen from incubation measurements weighed according to the rate of passage. *J. Agric. Sci. (Camb.)* 92, 499-503.

Rooke , J.A. & Armstrong, D.G., 1989. The importance of the form of nitrogen on microbial protein synthesis in the rumen of cattle receiving grass silage and continuous intrarumen infusions of sucrose. *Br. J. Nutr.* 61, 113-121.

Russell, J.B., O'Connor, J.D., Fox, D.G., Van Soest, P.J. & Sniffen, C.J., 1992. A net carbohydrate and protein system for evaluating cattle diets. I. Ruminal fermentation. *J. Anim. Sci.* 70, 3551-3561.

SAS, 1995. Statistical Analysis System user's guide (6th ed.) SAS Institute Inc. Raleigh, North Carolina, USA.

Sniffen, C.J., O'Connor, J.D., Van Soest, P.J., Fox, D.G. & Russell, J.B., 1992. A net carbohydrate and protein system for evaluating cattle diets. II. Carbohydrate and protein availability. *J. Anim. Sci.* 70, 3562-3569.

Stern, M.D., Bach,a. & Calsamiglia, S., 1997. Alternative techniques for measuring nutrient digestion in ruminants. *J. Anim. Sci.* 75, 2256-2276.

Tedeschi, L.O., Fox, D.G. & Russell, J.B., 2000. Accounting for the effects of a ruminal deficiency within the structure of the Cornell Net Carbohydrate and Protein System. *J. Anim. Sci.* 78, 1648-1655.

Van der Merwe, F.J. & Smith, W.A., 1991. Animal Feeding. 2nd Rev. Ed Anim Sci Pty Ltd. Pinelands.

Van Soest, P.J., Robertson, J.B. & Lewis, B.A., 1991. Methods of dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* 74, 3583-3595.

# Chapter 4

## Effect of substituting cotton oilcake with urea in rumen degradable protein supplements for beef cattle consuming low quality roughage.

### Introduction

True protein is one of the more costly components in winter supplements. Therefore a great interest prevail in the potential of non-protein nitrogen (NPN) as substitute for true protein in supplements. Several researchers report similar forage intake (Swingle *et al.*, 1977: Köster *et al.*, 1996) and similar microbial nitrogen (N) production or efficiency of microbial N synthesis (Kropp *et al.*, 1977; Peterson *et al.*, 1985) when predominantly urea-based supplements were compared with true protein supplements. In contrast, other researchers (Williams *et al.*, 1963; Helmer & Bartley, 1971; Rush & Totusek, 1973; Rush *et al.*, 1976) suggested that livestock performance with NPN-based supplements was generally inferior when compared to the performance of animals receiving true protein supplements.

Given the ability of fibrolytic bacteria to readily use ammonia as their chief N source (Russell *et al.*, 1992), it seems reasonable to expect that at least some level of NPN inclusion in these supplements should be feasible without comprising performance Köster *et al.*(1996) suggested that one could provide 50-75% of the supplemental rumen degradable protein (RDP) from urea without comprising forage intake and digestion. The balance must be provided by a natural protein source as an oilcake meal. In Chapter 3 it was found that the digestibility of dry matter (DM), organic matter (OM) and gross energy (GE) was not influenced significantly (P>0.05) when cottonseed oilcake, soybean oilcake and sunflower oilcake provided the balance of the RDP. Likewise, digestible organic matter intake (DOMI/kg $W^{0.75}$) did not differ significantly (P>0.05) when the different oilcake supplements were fed.

Therefore cottonseed oilcake meal, as the most available and cheapest source of natural RDP was used to investigate the effect of substituting increasing levels of natural RDP with increasing levels of urea RDP on intake, digestion and rumen fermentation characteristics of steers consuming low quality roughage.

**Material and Methods**

Intake and digestibility

From a group of thirty-five steers (average weight 200kg; SD ± 19.26 kg ) seven were randomly allocated to one of five treatments. The experimental period consisted of a 14-day adaptation, 21-day intake- and 7-day collection period (total 42 days).

Dormant winter pasture hay of the Northern Variation of the Cymbopogon-Themeda pasture type as described in Chapter 3 was cut, baled and stored in a shed. The winter pasture hay was fed twice daily at 07:00 and 19:00. The feed was offered at 130% of the previous 5 – day average consumption Köster *et al.*, 1996). The supplements were also given in two portions during morning and afternoon as described for winter pasture hay. The physical and chemical composition of the degradable protein supplements is shown in Table 1.

**Table 1: Physical and chemical composition of degradable protein supplements on a dry matter basis.**

| | Supplemental degradable protein from urea | | | | |
|---|---|---|---|---|---|
| Item | 0 % | 25% | 50% | 75% | 100% |
| **Physical Composition(%)** | | | | | |
| Urea | 0 | 2.18 | 4.36 | 6.53 | 7.93 |
| Salt | 5 | 5 | 5 | 5 | 5 |
| Begasse | 1.00 | 7.00 | 10.55 | 15.46 | 22.83 |
| Molasses | 9.82 | 23.51 | 40.00 | 55.00 | 60.00 |
| Cotton oilcake | 83.50 | 60.59 | 37.39 | 14.34 | |
| Mono calcium phosphate | 0.68 | 1.63 | 2.61 | 3.57 | 4.14 |
| Feed grade sulphur | 0 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Chemical Composition (%)[1]** | | | | | |
| Crude protein (%) | 31.91 | 30.12 | 28.28 | 26.47 | 25.37 |
| Degradable protein (%) | 25.00 | 25.00 | 25.00 | 25.00 | 25.00 |
| Undegradable protein (%) | 6.88 | 5.05 | 3.17 | 1.32 | 0.21 |
| Metabolizible energy (MJ/kg) | 9.77 | 9.32 | 9.04 | 8.68 | 8.16 |
| Calcium (%) | 0.48 | 0.79 | 1.11 | 1.42 | 1.60 |
| Phosphate (%) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Non protein nitrogen equivalent urea | 0 | 6.25 | 12.50 | 18.75 | 22.76 |
| Nitrogen: Sulphur | 11.6:1 | 11.5:1 | 11.3:1 | 11:1 | 11.4:1 |

1) Values of ingredients determined before formulation

The supplemental RDP was from urea (100% degradable) and cotton oilcake (78.24% degradable). The supplements were formulated to supply in the RDP requirements of steers (4.01g RDP/kg W $^{0.75}$) as recommended by Köster (1996). The degradability values of cotton oilcake and winter pasture hay as determined in Chapter 3 was used to formulate the RDP supplements. A winter pasture hay intake of 1.7% of body weight was assumed (Köster et al. 1996). RDP from urea replaced 0%, 25%, 50%, 75% and 100% of the

RDP from cotton oilcake. Feed grade sulphur was added to maintain a ratio of 10 N to 1 sulphur (S). Macro- and micro trace elements were added in the form of a premix pack to provide the animals' requirements as recommended by the NRC (2000).

Representative feed samples were collected daily at both feeding times. Ort samples were taken in the morning and weighed and composite per steer for each period. Faecal samples were taken every morning and a representative sample of 10% was collected per steer. The samples were dried at 50°C for 96 hours and composite per steer for each period and weighed. The feed, orts and faecal samples were weighed and milled with a Willey mill to pass through a 1 mm sieve.

Rumen fluid characteristics

The day after the collection period ended (day 43), rumen fluid samples of approximately 35 ml were obtained from each animal 3 hours after the initiation of morning feeding. A vacuum pump and plastic rumen tube were used to obtain the samples. The samples were strained through 4 layers of cheesecloth and pH determined immediately using a portable meter. For determination of concentrations and molar proportions of individual volatile fatty acids (VFA), 10 ml of each sample was frozen and stored. The remaining 25 ml was acidified to a pH of approximately 2 with a few drops of concentrated sulphuric acid, frozen and stored for later analysis of ammonia-nitrogen ($NH_3N$) concentration.

Steers were fasted for 24 hours and weighed at the beginning and end of each period.

Laboratory analyses

The chemical composition of feed, orts and faeces was determined according to the methods of AOAC (1995).

Samples were dried at 100°C to a constant mass in a convention oven to a constant mass in order to determine dry matter (DM) content. The organic matter (OM) content was determined by incinerating samples in a muffle furnace at 500°C for 8 hours.

Kjeldahl nitrogen (N) and neutral detergent fibre (NDF) were determined according to the methods of Van Soest *et al.*, (1991).Gross energy was determined by means of a bomb calorimeter. Rumen fluid VFA contents were determined using a Hewlett Packard 5890 A gaschromatgraph. Ammonia nitrogen ($NH_3N$) concentration was determined by means of spectrophotometer-meter.

Statistical analyses

The SAS (1995) procedure for variance analyses (PROC ANOVA) was used to test for significant differences between the treatments. A complete randomized design was used. Dependent variables that were found to be significantly different ($P< 0.05$) were further subjected to multiple comparison tests using Tukey's test.

**Results and Discussion**

Digestibility

The influence of replacing cotton oilcake with urea in rumen degradable protein supplements on the digestibility of the diet by the steers is outlined in Table 2.

No significant differences in intake and digestibility results occurred. This verifies the results of Egan & Doyle (1985) that urea supplementation did not result in clear evidence of a change in either digestibility of OM or the rate of digestion of cell wall constituents. Studies by (Kropp *et al.*, 1977) demonstrated a slight decline in digestibility in response to higher urea inclusion. On the other hand Köster (1996) found a significant ($P<0.01$) quadratic and linear decline in organic matter and NDF digestibility respectively as the supplemental degradable N from urea increased from 0 to 100%. Similarly ruminal digestibility of OM and NDF decreased linearly with increasing urea N in the degradable protein supplement. Factors like degradable protein sources, level of degradable protein supplied, roughage quality type and physiological stage of experimental animals could contribute to these different digestibility results.

**Table 2 Influence of substituting cotton oilcake with urea on the digestibility of a low quality roughage diet.**

| | Supplemental degradable protein from urea | | | | | | |
|---|---|---|---|---|---|---|---|
| Item | 0% | 25% | 50% | 75% | 100% | Significance(P) | CV[1] |
| Grass dry matter intake (kg/steer/day) | 4.9303 | 4.88 | 5.03 | 4.92 | 4.95 | 0.9654 | 6.63 |
| Supplement dry matter intake (kg/steer/day) | 0.4317 | 0.4293 | 0.4282 | 0.4245 | 0.4456 | 0 | 0 |
| Total dry matter intake (kg/steer/day) | 5.36 | 5.31 | 5.46 | 5.34 | 5.36 | 0.9272 | 6.10 |
| Total organic matter Intake (kg/steer/day) | 4.92 | 4.89 | 5.02 | 4.90 | 4.92 | 0.9281 | 6.17 |
| Apparent digestibility: | | | | | | | |
| Dry matter (%) | 49.62 | 49.56 | 50.14 | 50.84 | 50.74 | 0.9577 | 7.96 |
| Organic matter (%) | 48.19 | 48.62 | 49.33 | 49.39 | 49.41 | 0.9488 | 7.14 |
| Crude protein (%) | 31.06 | 37.44 | 32.22 | 36.63 | 32.79 | 0.3689 | 20.86 |
| Neutral detergent fibre (%) | 49.74 | 49.17 | 49.86 | 51.59 | 51.23 | 0.8410 | 9.23 |
| Gross energy (%) | 46.91 | 46.67 | 47.05 | 47.77 | 46.97 | 0.9940 | 9.88 |
| Digestible protein (%) | 1.33 | 1.63 | 1.42 | 1.44 | 1.26 | 0.1982 | 20.39 |
| Digestible energy (MJ/kg) | 7.14 | 7.12 | 7.18 | 7.19 | 7.07 | 0.9984 | 9.89 |
| Metabolizible energy (MJ/kg)[2] | 5.71 | 5.69 | 5.74 | 5.75 | 5.66 | 0.9984 | 9.89 |

1) Coefficient of variation

2) Digestible energy x 0.8 (McDonald *et al.*, 2002)

Köster *et al* (1996) used sodium caseinate (100% degradable) as natural degradable protein source. These researchers reported digestibility values of 49.6% and 47.5% for OM and NDF respectively. According to these digestibility values the winter pasture hay fed in the present study was more or less of the same quality ( organic matter and NDF composition) as the tall grass prairie hay used by Köster *et al.*,(1996). Accordingly the results in Table 2 compared remarkable well with those of the previous study (Chapter 3). This is to be expected as the same steers and winter pasture hay was used.

Intake

In Table 3 the influence of substituting the degradable protein in cotton oilcake with that of urea on the intake of grass hay, total dry matter intake and DOMI of steers can be seen. It is evident that no differences for the mentioned intake measurements occurred. Similarly Köster (1996) observed no significant differences for grass OMI and total OM intake by steers when sodium caseinate degradable protein was completely substituted by that of urea. These results also agree with earlier work (Raleigh & Wallace, 1963; Ammerman *et al.*, 1972; Swingle *et al.*, 1977), which demonstrated similar intake responses when urea-based supplements were directly compared with true protein –based supplements. This indicates that substituting urea for true protein at ruminal level would not alter the potential for N-containing supplements to increase the intake of low quality roughage.

**Table 3 Influence of different level of replacement of natural degradable protein sources on intake.**

| Item | 0% NPN | 25% NPN | 50% NPN | 75% NPN | 100% NPN | Significance(P) | C V[1] |
|---|---|---|---|---|---|---|---|
| Grass dry matter intake (kg/steer/day) | 4.92 | 4.90 | 5.00 | 4.96 | 4.93 | 0.9654 | 5.68 |
| Grass dry matter intake as % of body weight (%) | 2.32 | 2.38 | 2.45 | 2.41 | 2.42 | 0.6848 | 7.49 |
| Lick dry matter intake (kg/steer/day) | 0.4317 | 0.4293 | 0.4282 | 0.4245 | 0.4178 | --- | --- |
| Total dry matter intake (kg/steer/day) | 5.50 | 5.33 | 5.43 | 5.38 | 5.35 | 0.9651 | 5.23 |
| Total dry matter intake as % of body weight (%) | 2.53 | 2.57 | 2.66 | 2.62 | 2.63 | 0.7288 | 7.52 |
| Digestible organic matter intake (kg/steer/day) | 4.54 | 4.51 | 4.61 | 4.57 | 4.54 | 0.9654 | 5.68 |
| Digestible organic matter intake/ kg $W^{0.75}$(g/kg $W^{0.75}$) | 46.42 | 47.38 | 49.54 | 49.04 | 49.05 | 0.6403 | 9.09 |
| Daily crude protein intake (g/steer/day) | 289.46 [a] | 292.84 [a] | 301.68 [a] | 272.86 [b] | 270.87 [b] | 0.0001 | 3.19 |
| Daily digestible crude protein intake (g/steer/day) | 70.93 | 86.81 | 76.99 | 77.54 | 67.52 | 0.2237 | 20.90 |
| Daily metabolizible energy intake (MJ/kg) | 30.58 | 30.79 | 31.19 | 30.94 | 30.34 | 0.9898 | 11.79 |
| Initial Weight (kg) | 200.43 | 200.57 | 200.14 | 200 | 198.57 | 0.9998 | 10.25 |
| Final Weight (kg) | 224.57 | 215.43 | 210.57 | 213.43 | 210.57 | 0.6898 | 9.46 |
| Weight Change (kg) | 24.14 [a] | 14.85 [b] | 10.43 [b] | 13.43 [b] | 12.00 [b] | 0.0073 | 45.94 |
| Final Weight as % of Initial Weight (%) | 112.27 [a] | 107.76 [b] | 105.24 [b] | 105.24 [b] | 106.05 [b] | 0.0111 | 3.43 |

[ab] Row means with different subscripts differ significantly (P<0.05)

1) Coefficient of variation

In contrast, because of the negative affects on total tract digestion, Köster (1996) reported a trend for DOMI to exhibit a decrease when the percentage of supplemental N from urea exceeded 50% of supplemental RDP. A significant ($P<0.03$) decrease in DOMI was observed when the proportion of supplemental N from urea exceeded 75%. These results are contradictory to those obtained during the present study and the difference in results requires further investigation. Although the quality of the roughage used by Köster (1996) and that used in the present study seems to be comparable in terms of organic matter (OM) and NDF digestibility, the possibility exists that some other unknown differences and/or factors could influence the results. Therefore further research is needed on the RDP requirements of ruminants consuming different types of low quality roughage.

From Table 1 it is evident that the undegradable protein content varies in the different experimental degradable protein supplements. Russel *et al.*,(1992) is of opinion that independent of rumen conditions, the voluntary intake of low quality roughages may be increased further by undegradable protein (UP). Accordingly Egan (1965) and Garza & Owens (1991) concluded that metabolic effects play an important role in the control of voluntary intake. In contrast, it appears from the study of Jones *et al.*, (1994) that when sufficient DIP was offered via feedstuffs (e.g. soybean meal and sorghum grain) to maximize intake and forage utilization, additional UIP had no further beneficial effect on the intake. From the results in Table 2 no influence could be detected of UP on intake data. Contrary to this observation the results in Chapter 3 suggested that voluntary intake of low quality roughage may be increased by UP.

Grass DMI as percentage of body weight (2.4%) and total DMI as percentage of body weight (2.6%) of steers did not differ significantly among treatments. The grass DMI as percentage of body weight ± 2.4% was however higher than the 1.7% recorded by Köster (1996) and the 2.1% reflected in Chapter 3. Factors such as animal type, grass type and temperature could influence grass hay DMI.

The daily crude protein (CP) intake of the 0%, 25% and 50% treatments was significantly higher ($P<0.05$) than the 75% and 100% treatments. This could be attributed to the higher crude protein content of the first three treatments (Table 1).

Table 3 also reflects that the weight change of the steers on the 0% treatment was significantly ($P=0.0073$) higher than the other treatments. This may be the result of the higher UP content of the supplement (6.88%), which provide more metabolizable protein (amino acids). In fact weight change of steers tend to decline from 0% to 100% treatments. These weight changes were however recorded in a relative short period and should be interpreted with caution.

## Rumen characteristics

The influence of substituting the cotton oilcake degradable protein in the supplements with that of urea on the ecosystem of the rumen are set out in Table 4. Although variance of analysis revealed significant ($P=0.0369$) differences in the acetate concentration among the various treatments, this was not supported by Tukeys multiple tests. Statistical significant differences among the treatments were however recorded for propionate ($P=0.0252$) and isovalerate ($P=0.0083$).

There was however no clear trend recorded in the concentration of these two short chain fatty acids with increasing levels of supplemental degradable protein derived from urea. In accordance with acetate, the highest propionate concentration in rumen fluid was recorded when urea replaced 75% of the degradable protein in the supplement. This is probably an indication of maximum microbe production and rumen fermentation.

**Table 4: Influence of different levels of urea on the rumen environment.**

| Item | 0 | 25 | 50 | 75 | 100 | P | CV[1] |
|---|---|---|---|---|---|---|---|
| Acetate (mg/l) | 170.98 | 221.60 | 212.82 | 243.08 | 178.76 | 0.0369 | 22.6524 |
| Propionate (mg/l) | 67.23[b] | 82.72[ab] | 77.66[ab] | 91.84[a] | 69.37[ab] | 0.0252 | 18.9917 |
| Isobutyrate (mg/l) | 3.34 | 3.41 | 2.97 | 3.27 | 2.08 | 0.1229 | 34.1334 |
| Butyrate (mg/l) | 35.69 | 46.13 | 42.32 | 44.91 | 32.97 | 0.1019 | 26.0066 |
| Isovalerate (mg/l) | 1.81[ab] | 2.05[a] | 1.35[ab] | 0.95[b] | 0.80[b] | 0.0083 | 50.3056 |
| Valerate (mg/l) | 1.03 | 1.53 | 1.18 | 1.26 | 0.55 | 0.1773 | 66.287 |
| $NH_3N$ (mg/l) | 1.55 | 1.47 | 1.77 | 1.58 | 2.45 | 0.3508 | 55.5921 |
| pH | 7.37 | 7.26 | 7.43 | 7.16 | 7.49 | 0.0810 | 3.1683 |

[ab] Rows means with different superscripts differ significantly (P< 0.05)

1) Coefficient of variation

These findings were however not supported by the intake and digestion results of the current study. Köster (1996) using beef cattle and Nolte *et al.*, (2003) using sheep found no significant (P>0.05) influence on rumen fluid propionate concentration when sodium caseinate was replaced by urea in the rumen degradable protein supplement.

In contrast with acetate and propionate levels, the highest (P=0.0083) value for isovalerate concentration in rumen fluid was found when 25% of the supplemental degradable protein was from urea. However, a high coefficient of variance (CV's) was recorded throughout and this complicates the interpretation of the rumen fatty acid results. The results recorded in Table 4 show increasing levels of urea had no effect on either the rumen $NH_3N$-concentrations (P = 0.3508) or pH (P=0.0810). Nolte *et al.*, (2003) reported similar findings with sheep for both ammonia nitrogen ($NH_3N$)-concentration and pH while Köster (1996) reported similar results with beef cattle for $NH_3$-N concentration. Köster (1996) found that the ruminal pH decreased with increasing supplemental RDP. Köster et al., (1996) stated that although treatments were isonitrogenous, urea is fermented at a faster rate than cotton oilcake, with a subsequent quicker release of ammonia ($NH_3$) at higher levels of urea inclusion. According to Satter & Slyter (1974) and Slyter *et al.* (1979) the rumen $NH_3N$ requirements for maximum MCP production is 20 to 50 mg/l. Although a higher non significant $NH_3N$ concentration were observed at the 100% NPN treatment in the current study , the lack of treatment effects on rumen digestibility parameters indicates that $NH_3$ N was probably not limiting microbial fermentation. They concluded that low quality roughage generally require lower $NH_3N$ concentrations for maximum digestion than feeds of higher fermentation ability. In this regard Köster *et al.*, (1996) found that although total N flow to the duodenum tended to decrease somewhat with an increasing supply of urea, a significant decline was not evident in microbial N, ammonia N or non microbial non ammonia N fractions, or in efficiency of microbial protein synthesis.

The lack of an effect on these characteristics agrees with previous work (Köster *et al.*, 1996) that reported little effect on microbial N production or efficiency of microbial protein synthesis when NPN- and true protein-based supplements were compared.

**Conclusion**

From the results of the present study it seems that all the RDP requirements of beef cattle consuming a low quality winter pasture hay could be supplied by urea. This is in contrast to Köster *et al.* (1995b) who suggested that one could provide 50-75% of the supplemental RDP from urea without compromising forage intake and digestion. Factors like the physiological stage of the animals and grass hay type could probably influence the RDP requirements. Therefore the RDP requirements of beef cattle at different physiological stages consuming different types of low quality roughage warrant further investigation.

References

Ammerman, C.B., Gladys, J.V., Moore, J.E., Burns, W.C. & Chicco, C.F., 1972. Biuret, urea and natural proteins as nitrogen supplements for low quality roughage for sheep. *J. Anim. Sci.* 35, 121-131.

AOAC., 1995. Official methods of analysis. 16th Ed. Association of Official Analytical Chemists, Arlington Virginia, USA.

Egan, A.R., 1965. Nutritional status and intake regulation in sheep. Π. The influence of sustained duodenal infusions of casein or urea upon voluntary intake of low quality protein roughages by sheep. *Aust. J. Agric. Res.* 16, 451-463.

Egan, A.R. & Doyle, P.T., 1985. Effects of intraruminal infusion of urea on the response in voluntary food intake by sheep. *Aust. J. Agric. Res.* 36, 483-495.

Garza, F., & Owens, F.N.,1991. Duodenally infused casein or glucose-urea for steers fed a low quality roughage. *Okla. Ag. Exp. Sta. Res. Rep. MP-129.*

Helmer, L.G., & Bartley, E.E., 1971. Progress in the utilization of urea as a protein replacer for ruminants. A Review. *J. Dairy Sci.* 54, 25(*Abstr*).

Jones, T.J., Cochran, R.C., Olson, K.C., Köster, H.H., Vanzant, E.S. & Titgemeyer, E.C., 1994. Influence of post-ruminal protein supply on gain and forage intake of beef cows consuming dormant, tallgrass-prairie forage. *J. Anim. Sci.* 72(Suppl. 1), 353-365.

Köster,H.H., Cochran, R.C., Titgemeyer, E.C., Vanzant, E.S., Abdelgadir,I. & St Jean, G., 1996. Effect of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. *J. Anim. Sci.* 74, 2473-2481.

Köster, H.H., 1996. An evaluation of different levels of degradable intake protein and nonprotein nitrogen on intake, digestion and performance by beef cattle fed low-quality forage. Ph. D. (Agric.)-dissertation , Kans. State. Univ. Manhattan, Kansas.

Kropp, J.R., Johnson, R.R., Males, J.R. & Owens, F.N., 1977. Microbial protein synthesis with low-quality roughage rations: Level and source of nitrogen. *J. Anim. Sci.* 46, 844-854.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D. & Morgan, C.A., 2002. Animal nutrition, 6$^{th}$ ed., Longman. Singapore.

Nolte, J. van E., Ferreira, A.V. & Köster, H.H., 2003.Effect of amount of rumen degradable protein on the utilization of wheat straw by Dohne Merino wethers. *J.Anim.Sci.* 76, 319-326.

NRC., 2000. Nutrient Requirements of Dairy Cattle. 7$^{th}$ Ed. National Academy Press. Washington, D.C.

Peterson, M.K., Clanton, D.C. & Britton, R., 1985. Influence of protein degradability in range supplements on abomasal nitrogen flow, nitrogen balance and nutrient digestibility. *J. Anim. Sci.* 60, 1324-1335.

Raleigh, R.J & Wallace, J.D.,1963. Effect of urea at different nitrogen levels on digestibility and on performance of growing steers fed low quality flood meadow roughage. *J. Anim. Sci.* 22, 330-339.

Russell, J.B., O'Connor, J.D., Fox, D.G., Van Soest, P.J. & Sniffen, C.J., 1992. A net carbohydrate and protein system for evaluating cattle diets. I. Ruminal fermentation. *J. Anim. Sci.* 70, 3551-3561.

Rush, I. & Totusek, R., 1973. Urea and biuret in range cow supplements. *J. Anim. Sci.* 37, 355(*Abstr*).

Rush, I.G., Johnson, R.R. & Totusek, R., 1976. Evaluation of beef cattle range supplements containing urea and biuret. *J. Anim. Sci.* 42, 1297(*Abstr*).

SAS, 1995. Statistical Analysis System user's guide ($6^{th}$ ed.) SAS Institute Inc. Raleigh, North Carolina, USA.

Satter, L.D. & Slyter, L.L., 1974. Effect of ammonia concentration on rumen microbial protein production *in vitro*. *Br. J. Nutr.* 32, 199-208.

Slyter, L.L., Satter, L.D. & Dinius, D.A., 1979. Effect of ammonia concentration on nitrogen utilization by steers. *J. Anim. Sci.* 48, 906-912.

Swingle, R.S., Ariza, A. & Urias, A.R., 1977. Nitrogen utilization by lambs fed wheat straw alone or with supplements containing dried poultry waste, cottonseed meal or urea. *J. Anim. Sci.* 45, 1435-1448.

Williams, D.L., Whiteman, J.V. & Tillman, A.D., 1963. Urea utilization in protein supplements for cattle consuming poor quality roughages on the range. *J. Anim. Sci.* 28, 807-815.

Van Soest, P.J., Robertson, J.B. & Lewis, B.A., 1991. Methods of dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* 74, 3583-3595.

## General conclusions

Low quality roughages and natural pasture are important sources of nutrients and especially energy to maintain beef cattle. The rumen degradable fractions of crude protein are the first limiting dietary component for efficient utilization of low quality roughages. Cotton oilcake, soybean oilcake and sunflower oilcake and urea are the most important and available rumen degradable crude protein sources in South Africa. The results of the present showed the differences in crude protein content, effective rumen degradability and fractions of degradability namely rapidly soluble nitrogen which is considered to be immediately degradable, fraction which will degrade more slowly over time and rate at which the former fraction degrades. Urea on the other hand consists of 100% rapidly soluble nitrogen and is the cheapest nitrogen and/or rumen degradable nitrogen source. In spite of these differences between sources the digestibility results with the exception of neutral detergent fibre (NDF) as well as intake results revealed that urea can be used as the only rumen degradable protein source in supplements to beef cattle on low quality roughage. Therefore it seems that urea can be used as the only degradable protein source to supply as high as 4.01g RDP/kg $W^{0.75}$ to beef cattle consuming low quality roughage. These findings are however in disagreement with guidelines that are currently used to formulate protein supplements namely that urea can only provide 50 to 75% of the supplemental degradable protein. Factors like physiological stage of the animal and roughage type (chemical composition) could probably influence the results. Therefore the rumen degradable protein (RDP) requirements of beef cattle at different physiological stages consuming different types of low quality roughages needs further investigation.

The provision of 50% of supplemental RDP from sunflower- compared to cotton- and soybean oilcake and the rest from urea, resulted in a higher NDF digestibility. This was supported by a lower $NH_3$-N concentration of rumen fluid of steers that consumed the sunflower oilcake supplement. These findings were not supported by the other digestibility as well as intake data. In fact these findings were also not supported by the Cornell Nett Carbohydrate and Protein System (CNCPS) model. Furthermore the lower $NH_3N$ concentration of rumen fluid of steers occurred in spite of a higher rapidly soluble nitrogen fraction and protein degradation rate in sunflower oilcake. These discrepancies need further investigation.

Furthermore the results of the study (Chapter 3) to determine the best natural source of RDP not provided by urea to maximize the digestible organic matter intake of low quality pasture hay suggested that the voluntary intake of low quality roughages may be influenced by undegradable protein. This suggestion was however not supported by the results in Chapter 4. This anomaly warrants also further investigation.

**Abstract**

A study was conducted to determine the best natural source of rumen degradable protein (RDP) not provided by urea to maximize the digestible organic matter intake (DOMI) of a SA natural winter pasture hay (3.51% crude protein (CP) and 74, 23% neutral detergent fibre (NDF). The crude protein degradability of natural winter pasture hay (Cymbopogon-Themeda), cotton oilcake, soybean oilcake and sunflower oilcake was determined by means of the *in- sacco-* technique. These crude protein degradability values were used to formulate three RDP supplements according to current recommendations (4.01g RDP/kg W $^{0.75}$) using the three oilcakes respectively. Urea provided 50% of the supplemental RDP. The other feed ingredients were salt, begasse, molasses, feed grade sulphur and trace minerals. Seven steers (217 SD ± 9.91 kg) per treatment randomly divided were used. The experimental period consist of 14 –day's adaptation, 21- days' intake and 7 days collection period (conventional digestibility study). A significant ($P< 0.0001$) higher apparent digestibility of NDF occurred when the sunflower oilcake supplement was fed to the steers. The apparent digestibility of dry matter (DM), organic matter (OM), CP and gross energy (GE) was however not influenced significantly ($P> 0.05$) when different oilcakes supplements were fed. Likewise DOMI/kg W $^{0.75}$ , rumen volatile fatty acid concentration and rumen pH did not differ significantly ($P> 0.05$). The ammonia nitrogen ($NH_3N$) concentration of the rumen fluid of steers that consumed the sunflower oilcake supplements were significantly ($P< 0.04$) lower than that of cotton oilcake.

In a second study the optimum ratio of supplemented urea to the most available oilcake (cotton seed) was investigated. Urea replaced: 0%, 25%, 50%, 75% and 100% of the natural supplemental RDP. The same procedure

as described in the first study was used. Steers with an average mass of 200 ± 19.96 kg were used. The replacement of natural supplemental RDP with urea did not significantly (P>0.05) influenced the apparent digestibility of DM, CP, NDF and GE. Accordingly DOMI/kg$W^{0.75}$ did not differ significantly (P>0.05).

The highest (P< 0.05) acetate and propionate concentration in rumen fluid of steers was recorded when urea replaced 75% of the natural RDP in the supplement. The highest (P= 0.008) value for isovalerate concentration in rumen fluid was found when 25% of the supplemental degradable protein was from urea. Increasing levels of urea had no affect on either the rumen $NH_3N$ concentrations (P=0.3508) or pH (P= 0.0810). According to the results of both studies it seems that urea can supply all the supplemental RDP to steers on low quality roughage.

From the results it was concluded that further research is needed on the RDP-requirements of ruminants consuming different types of low quality roughages.

**Opsomming**

'n Studie is uitgevoer om te bepaal wat die beste natuurlike bron van rumen degradeerbare proteïen (RDP) is wat nie deur ureum verskaf word nie, wat maksimum verteerbare organiese materiaal inname (VOMI) van 'n tipiese Suid Afrikaanse winterveld ( 3.51% ru-proteïen (RP) en 74.23% neutral bestande vesel (NBV)) sal bewerkstellig. Die ruproteien degradeerbaarheid van winterveldhooi ( *Cymbopogon-*, *Themeda*), katoensaadoliekoek, soja oliekoek en sonneblomoliekoek is deur middel van die *in- sacco-* tegniek bepaal. Hierdie proteïen degradeerbaarheid waardes is gebruik om drie RDP aanvullings met die drie oliekoeke onderskeidelik te formuleer wat aan die huidige aanbevelings voldoen (4.01g RDP/kg W $^{0.75}$ ). Ureum het 50% van die aanvullende RDP verskaf. Die ander bestandele was sout, bagasse, molasses, voergraad swawel en spoorminerale. Sewe osse (217 ± 9.91 kg) per behandeling wat ewekansig verdeel is, is gebruik. Die proeftydperk het bestaan uit 'n ; 14 dae aanpassing, 21 dae inname en 7 dae miskolleksie periode (konvensionele verteringstudie). 'n Betekenisvolle ($P<0.0001$) hoër skynbare verteerbaarheid vir NBV is verkry waar sonneblomoliekoek aan osse gevoer is. Die skynbare verteerbaarheid van droë materiaal (DM), organiese materiaal (OM), RP en bruto energie (BE) is nie betekenisvol ($P>0.05$) beïnvloed wanneer verskillende oliekoekaanvullings gevoer is nie. VOMI/kg W $^{0.75}$ , vlugtige vetsure en pH is ook nie betekenisvol ($P>0.05$) beïnvloed nie.

Die ammonium stikstof ($NH_3N$) konsentrasie van die rumenvloeistof van osse wat die sonneblomoliekoek- in vergelyking met die katoenoliekoekaanvulling ontvang het was betekenisvol ($P< 0.05$) laer.

In 'n tweede studie is die optimum verhouding van aanvullende ureum tot die mees komersieël beskikbare oliekoek (katoensaadoliekoek) ondersoek. Ureum het 0%, 25%, 50%, 75% en 100% van die natuurlike RDP vervang. Dieselfde prosedure soos beskryf in die eerste studie is gevolg. Proefosse met 'n gemiddelde massa van 200 ± 19.26 kg is gebruik. Die skynbare verteerbaarheid van DM, RP, NBV en BE is nie betekenisvol (P>0.05) deur die vervanging van natuurlike aanvullende RDP met ureum beïnvloed nie.

Die hoogste (P< 0.05) asynsuur- en propioonsuurkonsentrasies in die rumenvloeistof het voorgekom waar ureum 75% van die RDP in die aanvulling vervang het. Die hoogste (P< 0.008) waarde vir iso-valeraatsuurkonsentrasie in rumenvloeistof is gevind waar 25% van die aanvullende RDP vanaf ureum afkomstig is. Toenemende peile van ureum het geen effek op rumen $NH_3N$ konsentrasie (P= 0.3508) of pH (P= 0.0810) uitgeoefen nie. Volgens die resultate van beide studies blyk dit dat ureum al die aanvullende RDP aan osse op laegraadse ruvoer kan verskaf.

Vanaf die resultate is daar tot die slotsom gekom dat verdere navorsing nodig is rakende die RDP behoeftes van herkouers wat verskillende tipes laegraadse ruvoer benut.

# Appendix A1

## Summary Report (Cotton oilcake Supplement)

**Diet Concentrations**

Ration Dry Matter : 93%
Apparent TDN : 42 (%DM)
ME : 6.3 (MJ/kg DM)
NEm : 2.8 (MJ/kg DM)
NEg : 0.6 (MJ/kg DM)
CP : 6.9 (%DM)
Soluble Protein : 44%
DIP : 64%
NDF : 72.0 (%DM)
peNDF : 71 (%DM)
Physically Effective NDF Bal. : 3.0
Total Forage in Ration : 93 (%DM)
Total NFC : 13%
Ca : 0.49 (%)
P : 0.11 (%)
DCAB1 (Simple) : 40 meq/kg
DCAB2 (Complex) : 95 meq/kg

Dietary Lignin (%DM): 9.48
Dietary Lignin (%NDF): 13.17
Forage NDF Intake (%BW): 1.61

**Rumen Values**

MP From Bact. : 242 (g/day)
MP From Undeg. Feed : 67 (g/day)
MP From Bact. : 78 (% MP Sup.)
MP From Undeg. Feed : 22 (% MP Sup.)
Peptide Balance : -7 (g/day)
% Peptide Balance : 63 (% of Req.)
Ruminal N Balance : -2 (g/day)
% Ruminal N Balance : 98 (% of Req.)
% Reduction in FC Digestion : 2 (%)
Predicted Ruminal pH : 6.46
Excess N Excreted : -2 (g/day)
Predicted PUN : 7 (mg/dl)
Urea Cost : 0.0 (MJ/day)

**Summary of Animal Inputs**

Animal Type : Growing/Finishing
Age : 9 months
Shrunk Body Weight : 217 (kg)
Mature Weight : 500 (kg)
Condition Score (1-9) : 5.0

**Summary of Environmental Inputs**

Previous Temperature : 15.6 deg C
Current Temperature : 15.6 deg C
Humidity : 20%
Wind Speed : 1.60 (kph)
Coat Condition : No Mud
Housing Type : Continuous Grazing

## Ration Carbohydrate and Protein Fractions

### NDF, Physically Effective NDF and Forage Analyses

| Feed Name | Qty. Fed (kg/day) | NDF (kg/day) | peNDF (kg/day) | Forage (kg/day) |
|---|---|---|---|---|
| Potch Highveld Grass | 4.60 | 3.47 | 3.47 | 4.60 |
| P2.1 Bagasse (M) | 0.02 | 0.02 | 0.02 | 0.02 |
| P2.1 Molasses (M) | 0.06 | 0.00 | 0.00 | 0.00 |
| P2.1 Cotton Oilcake Meal (M) | 0.21 | 0.07 | 0.03 | 0.00 |
| P2.1 Urea (M) | 0.02 | 0.00 | 0.00 | 0.00 |
| P2.1 Feedgrade Sulpher (M) | 0.00 | 0.00 | 0.00 | 0.00 |
| P2.1 Salt (M) | 0.03 | 0.00 | 0.00 | 0.00 |
| Totals | 4.95 | 3.56 | 3.51 | 4.62 |

Forage Concentration in Ration : 93.5%
NDF Concentration in Ration : 72.0%
peNDF Concentration in Ration : 71.1%
peNDF to NDF Concentration in Ration : 98.7%

### Carbohydrate and Protein Composition - Percentage Basis

| Feed Name | Carbohydrate Fractions (%DM) | | | | | | Protein Fractions (%DM) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tota | A | B1 | B2 | C | NFC | A | B1 | B2 | B3 | C | Total |
| Potch Highveld Grass | 85.5 | 10.6 | 1.2 | 50.0 | 23.7 | 11.8 | 1.5 | 0.1 | 0.7 | 0.8 | 1.0 | 4.0 |
| P2.1 Bagasse (M) | 85.4 | 0.0 | 0.0 | 69.2 | 17.6 | 0.0 | 0.9 | 0.0 | 0.5 | 0.7 | 0.9 | 3.1 |
| P2.1 Molasses (M) | 83.3 | 82.5 | 0.4 | 0.1 | 0.3 | 82.9 | 4.1 | 0.4 | 0.0 | 0.1 | 0.0 | 4.6 |
| P2.1 Cotton Oilcake Meal (M) | 50.4 | 19.7 | 1.4 | 14.6 | 14.8 | 21.0 | 1.5 | 2.2 | 32.3 | 3.6 | 1.4 | 41.0 |
| P2.1 Urea (M) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 287. | 0.0 | 0.0 | 0.0 | 0.0 | 287.0 |
| P2.1 Feedgrade Sulpher (M) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| P2.1 Salt (M) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

## Ration Degradation and Passage

### Carbohydrate B2 Fraction Degradation Rate Adjustment

Rumen pH : 6.5
Relative Yield Adjustment : 0.99

| Feed Name | CHO-B2 Rate (%/hr) | Yield | Adjusted Yield | Adjusted CHO-B2 Rate (%/hr) |
|---|---|---|---|---|
| Potch Highveld Grass | 4.00 | 0.20 | 0.20 | 4.00 |
| P2.1 Bagasse (M) | 3.00 | 0.13 | 0.13 | 3.00 |
| P2.1 Molasses (M) | 20.00 | 0.36 | 0.36 | 20.00 |
| P2.1 Cotton Oilcake Meal (M) | 6.00 | 0.27 | 0.26 | 6.00 |
| P2.1 Urea (M) | 0.00 | 0.00 | 0.00 | 0.00 |
| P2.1 Feedgrade Sulpher (M) | 0.00 | 0.00 | 0.00 | 0.00 |
| P2.1 Salt (M) | 0.00 | 0.00 | 0.00 | 0.00 |

### Passage Rates

Forage Passage Rate : 3.99 %/hr
Concentrate Passage Rate : 5.37 %/hr

| Feed Name | Adjustment | Passage Rate |
|---|---|---|
| Potch Highveld Grass | 0.69 | 2.75 |
| P2.1 Bagasse (M) | 0.64 | 2.55 |
| P2.1 Molasses (M) | 1.11 | 5.96 |
| P2.1 Cotton Oilcake Meal (M) | 0.98 | 5.24 |
| P2.1 Urea (M) | 1.11 | 5.96 |
| P2.1 Feedgrade Sulpher (M) | 1.11 | 5.96 |
| P2.1 Salt (M) | 1.11 | 5.96 |

## Carbohydrate and Protein Ruminal Degradation

| Feed Name | Carbohydrate Fractions (g/day) | | | Protein Fractions (g/day) | | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B1 | B2 | A | B1 | B2 | B3 | Peptides |
| Potch Highveld Grass | 484 | 50 | 1334 | 67 | 3 | 27 | 1 | 31 |
| P2.1 Bagasse (M) | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Molasses (M) | 53 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| P2.1 Cotton Oilcake Meal (M) | 40 | 2 | 16 | 3 | 4 | 40 | 0 | 45 |
| P2.1 Urea (M) | 0 | 0 | 0 | 69 | 0 | 0 | 0 | 0 |
| P2.1 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 577 | 53 | 1359 | 142 | 7 | 67 | 1 | 76 |

## Carbohydrate and Protein Ruminal Escape

| Feed Name | Carbohydrate Fractions (g/day) | | | | Protein Fractions (g/day) | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B1 | B2 | C | B1 | B2 | B3 | C |
| Potch Highveld Grass | 5 | 5 | 963 | 1090 | 0 | 7 | 34 | 45 |
| P2.1 Bagasse (M) | 0 | 0 | 8 | 4 | 0 | 0 | 0 | 0 |
| P2.1 Molasses (M) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Cotton Oilcake Meal (M) | 1 | 0 | 14 | 31 | 0 | 27 | 7 | 3 |
| P2.1 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 7 | 5 | 985 | 1125 | 0 | 34 | 41 | 48 |

## Microbial Yields

Maintenance Rate of FC Bacteria (KM-FC) : 0.05 g FC/g Bacteria / h
Maintenance Rate of NFC Bacteria (KM-NFC) : 0.15 g NFC/g Bacteria / h

Theoretical Maximum Yield of FC Bacteria (YG-FC) : 0.40
Theoretical Maximum Yield of NFC Bacteria (YG-FC) : 0.40

Peptides / (Peptides+NFC) : 0.1
% Improvement in NFC Digestion : 18.25 (due to peptides)

| Feed Name | CHO-A Yield | CHO-B1 Yield | CHO-B2 Yield |
|---|---|---|---|
| Potch Highveld Grass | 0.46 | 0.39 | 0.27 |
| P2.1 Bagasse (M) | 0.46 | 0.39 | 0.24 |
| P2.1 Molasses (M) | 0.47 | 0.39 | 0.36 |
| P2.1 Cotton Oilcake Meal (M) | 0.46 | 0.38 | 0.30 |
| P2.1 Urea (M) | 0.00 | 0.00 | 0.00 |
| P2.1 Feedgrade Sulpher (M) | 0.00 | 0.00 | 0.00 |
| P2.1 Salt (M) | 0.00 | 0.00 | 0.00 |

| Feed Name | Bacterial Yield Fractions (g Microbial DM) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | NFC | NFC-N | FC | FC-N | Total | Total-N | PEP | PEP-N |
| Potch Highveld Grass | 238 | 24 | 356 | 36 | 594 | 59 | 31 | 5 |
| P2.1 Bagasse (M) | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 |
| P2.1 Molasses (M) | 24 | 2 | 0 | 0 | 24 | 2 | 0 | 0 |
| P2.1 Cotton Oilcake Meal (M) | 19 | 2 | 5 | 0 | 24 | 2 | 45 | 7 |
| P2.1 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 282 | 29 | 363 | 36 | 644 | 64 | 76 | 12 |

Ration Bacterial Yield : 644 (g/day)

**Ruminal Escape of Bacterial Fractions**

Fraction of Microbial Composition Composed of Fraction X :

| CHO-A | CHO-B1 | CHO-B2 | CHO-C | PRT-A | PRT-B1 | PRT-B2 | PRT-B3 | PRT-C |
|---|---|---|---|---|---|---|---|---|
| 0.1688 | 0.0422 | 0 | 0 | 0.0938 | 0.3750 | 0 | 0 | 0.1563 |

| Feed Name | Ruminal Escape Fractions (g/day) | | | | | |
|---|---|---|---|---|---|---|
| | True Protein | Cell Wall | Nucleic Acids | CHO | Fat | Ash |
| Potch Highveld Grass | 223 | 93 | 56 | 125 | 71 | 26 |
| P2.1 Bagasse (M) | 1 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Molasses (M) | 9 | 4 | 2 | 5 | 3 | 1 |
| P2.1 Cotton Oilcake Meal (M) | 9 | 4 | 2 | 5 | 3 | 1 |
| P2.1 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 242 | 101 | 60 | 136 | 77 | 28 |

**Intestinally Digested Protein**

| Feed Name | Feed (g/day) | | | | Microbial | | Total |
|---|---|---|---|---|---|---|---|
| | B1 | B2 | B3 | Feed | TP | NA | |
| Potch Highveld Grass | 0 | 7 | 27 | 34 | 223 | 56 | 313 |
| P2.1 Bagasse (M) | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| P2.1 Molasses (M) | 0 | 0 | 0 | 0 | 9 | 2 | 11 |
| P2.1 Cotton Oilcake Meal (M) | 0 | 27 | 6 | 33 | 9 | 2 | 44 |
| P2.1 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Intestinally Digested Carbohydrate and Fat**

| Feed Name | Carbohydrate Fractions (g/day) | | | Fat Fractions (g/day) | | |
|---|---|---|---|---|---|---|
| | Feed | BACT | Total | Feed | BACT | Total |
| Potch Highveld Grass | 201 | 119 | 321 | 66 | 68 | 133 |
| P2.1 Bagasse (M) | 2 | 0 | 2 | 0 | 0 | 1 |
| P2.1 Molasses (M) | 1 | 5 | 6 | 0 | 3 | 3 |
| P2.1 Cotton Oilcake Meal (M) | 4 | 5 | 9 | 3 | 3 | 5 |
| P2.1 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 |

**Feed Contributions to Fecal Output**

| Feed Name | Protein Fractions (g/day) | | | Carbohydrate Fractions (g/day) | | | | Other Fractions (g/day) | |
|---|---|---|---|---|---|---|---|---|---|
| | B3 | C | Feed | B1 | B2 | C | Feed | Ash | Fat |
| Potch Highveld Grass | 7 | 45 | 52 | 1 | 771 | 1090 | 1862 | 207 | 3 |
| P2.1 Bagasse (M) | 0 | 0 | 0 | 0 | 6 | 4 | 10 | 1 | 0 |
| P2.1 Molasses (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| P2.1 Cotton Oilcake Meal (M) | 1 | 3 | 4 | 0 | 12 | 31 | 42 | 8 | 0 |
| P2.1 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| P2.1 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 |

**Microbial Contributions to Fecal Output**

| Feed Name | Bacterial Fractions (g/day) | | | | | |
|---|---|---|---|---|---|---|
| | CW | CP | CHO | Fat | Ash | Total |
| Potch Highveld Grass | 93 | 93 | 6 | 4 | 13 | 116 |
| P2.1 Bagasse (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Molasses (M) | 4 | 4 | 0 | 0 | 1 | 5 |
| P2.1 Cotton Oilcake Meal (M) | 4 | 4 | 0 | 0 | 1 | 5 |
| P2.1 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 |

Total Fecal Bacterial Cell Wall Protein : 101 (g/day)

**Indigestible Dry Matter Determination**

| Feed Name | Fecal-CHO | Indig. DM (g/day) |
|---|---|---|
| Potch Highveld Grass | 1869 | 2609 |
| P2.1 Bagasse (M) | 10 | 14 |
| P2.1 Molasses (M) | 0 | 12 |
| P2.1 Cotton Oilcake Meal (M) | 42 | 71 |
| P2.1 Urea (M) | 0 | 1 |
| P2.1 Feedgrade Sulpher (M) | 0 | 1 |
| P2.1 Salt (M) | 0 | 15 |

Total Indigestible Dry Matter in Ration : 2722 (g/day)

**Endogenous Fecal Components**

| Feed Name | Endogenous Fecal Component (g/day) | | |
|---|---|---|---|
| | Protein | Fat | Ash |
| Potch Highveld Grass | 235 | 55 | 78 |
| P2.1 Bagasse (M) | 1 | 0 | 0 |
| P2.1 Molasses (M) | 1 | 1 | 1 |
| P2.1 Cotton Oilcake Meal (M) | 6 | 2 | 4 |
| P2.1 Urea (M) | 0 | 0 | 0 |
| P2.1 Feedgrade Sulpher (M) | 0 | 0 | 0 |
| P2.1 Salt (M) | 1 | 0 | 0 |

**Fecal Output**

| Feed Name | Fecal Component (g/day) | | | | |
|---|---|---|---|---|---|
| | Protein | Carbohydrat | Fat | Ash | Output |
| Potch Highveld Grass | 380 | 1869 | 62 | 299 | 2609 |
| P2.1 Bagasse (M) | 2 | 10 | 0 | 2 | 14 |
| P2.1 Molasses (M) | 5 | 0 | 1 | 6 | 12 |
| P2.1 Cotton Oilcake Meal (M) | 15 | 42 | 3 | 12 | 71 |
| P2.1 Urea (M) | 0 | 0 | 0 | 0 | 1 |
| P2.1 Feedgrade Sulpher (M) | 0 | 0 | 0 | 1 | 1 |
| P2.1 Salt (M) | 1 | 0 | 0 | 13 | 15 |

Total Fecal Output : 2722 (g/day)

**Metabolizable Protein**

| Feed Name | Metabolizable Protein (g/day) |
|---|---|
| Potch Highveld Grass | 257 |
| P2.1 Bagasse (M) | 1 |
| P2.1 Molasses (M) | 9 |
| P2.1 Cotton Oilcake Meal (M) | 42 |
| P2.1 Urea (M) | 0 |
| P2.1 Feedgrade Sulpher (M) | 0 |
| P2.1 Salt (M) | 0 |

Total Dietary Metabolizable Protein : 309 (g/day)

# Bacterial Nitrogen

## Rumen Flow

Liquid Passage Rate : 8.8 (%/hr)
Liquid Growth Rate : 1.1 (1/hr)

Liquid Survival Rate : 0.9 (1/hr)

Uptake Coefficient : 7.0 (1/hr)
Peptide Degradation Rate : 3 (g/hr)
Peptide Uptake Rate : 76 (g/day)

NSC Bacterial Peptide Uptake : 21 (g/hr)
Liquid Disappearance Rate : 0.2 (hr)
Peptide Passage Rate : 1 (g/day)

## Bacterial Nitrogen Balances

<u>NSC Bacterial Nitrogen Balance</u>

| | Peptides | Bacterial NH3 (g N/day) | Diet NH3 | Recycled NH3 | Ruminal NH3 |
|---|---|---|---|---|---|
| Available | 12 | 0 | 23 | 30 | 52 |
| Required | 19 | | | | 10 |
| Balance | -7 | | | | 43 |

<u>SC Bacterial Nitrogen Balance</u>

| | Ruminal NH3 | | | Total Bacterial N Balance |
|---|---|---|---|---|
| Available | 43 | | Available | 64 |
| Required | 37 | | Required | 66 |
| Balance | 5 | | Balance | -2 |

## Bacterial Nitrogen Excretion

Total Bacterial Nitrogen : 64 (g/day)
Total Absorbed Bacterial Nitrogen : 48 (g/day)
Bacterial Nitrogen Utilized (Post-Absorption) : 39 (g/day)
Bacterial Nucleic Acids (Urinary) : 10 (g/day)
Bacterial Excess Nitrogen (Urinary) : 0 (g/day)
Fecal Bacterial Nitrogen : 16 (g/day)

### Endogenous Fecal Components

| Feed Name | Endogenous Fecal Component (g/day) | | |
|---|---|---|---|
| | Protein | Fat | Ash |
| Potch Highveld Grass | 235 | 55 | 78 |
| P2.1 Bagasse (M) | 1 | 0 | 0 |
| P2.1 Molasses (M) | 1 | 1 | 1 |
| P2.1 Cotton Oilcake Meal (M) | 6 | 2 | 4 |
| P2.1 Urea (M) | 0 | 0 | 0 |
| P2.1 Feedgrade Sulpher (M) | 0 | 0 | 0 |
| P2.1 Salt (M) | 1 | 0 | 0 |

### Fecal Output

| Feed Name | Fecal Component (g/day) | | | | |
|---|---|---|---|---|---|
| | Protein | Carbohydrate | Fat | Ash | Output |
| Potch Highveld Grass | 380 | 1869 | 62 | 299 | 2609 |
| P2.1 Bagasse (M) | 2 | 10 | 0 | 2 | 14 |
| P2.1 Molasses (M) | 5 | 0 | 1 | 6 | 12 |
| P2.1 Cotton Oilcake Meal (M) | 15 | 42 | 3 | 12 | 71 |
| P2.1 Urea (M) | 0 | 0 | 0 | 0 | 1 |
| P2.1 Feedgrade Sulpher (M) | 0 | 0 | 0 | 1 | 1 |
| P2.1 Salt (M) | 1 | 0 | 0 | 13 | 15 |

Total Fecal Output : 2722 (g/day)

### Metabolizable Protein

| Feed Name | Metabolizable Protein (g/day) |
|---|---|
| Potch Highveld Grass | 257 |
| P2.1 Bagasse (M) | 1 |
| P2.1 Molasses (M) | 9 |
| P2.1 Cotton Oilcake Meal (M) | 42 |
| P2.1 Urea (M) | 0 |
| P2.1 Feedgrade Sulpher (M) | 0 |
| P2.1 Salt (M) | 0 |

Total Dietary Metabolizable Protein : 309 (g/day)

## Ration Energy

### TDN Fractions

| Feed Name | TDN Fractions | | | |
|---|---|---|---|---|
| | App (g/day) | App (%DM) | True (g/day) | True (%DM) |
| Potch Highveld Grass | 1884 | 41% | 2349 | 51% |
| P2.1 Bagasse (M) | 9 | 37% | 11 | 47% |
| P2.1 Molasses (M) | 50 | 77% | 57 | 88% |
| P2.1 Cotton Oilcake Meal (M) | 132 | 64% | 148 | 72% |
| P2.1 Urea (M) | 0 | 0% | 0 | 0% |
| P2.1 Feedgrade Sulpher (M) | 0 | 0% | 0 | 0% |
| P2.1 Salt (M) | 0 | 0% | 0 | 0% |
| Totals | 2073 | 42% | 2566 | 52% |

### Metabolizable Energy

| Feed Name | ME (MJ/day) | ME Concentration (MJ/kg) |
|---|---|---|
| Potch Highveld Grass | 28.5 | 6.2 |
| P2.1 Bagasse (M) | 0.1 | 5.6 |
| P2.1 Molasses (M) | 0.8 | 11.6 |
| P2.1 Cotton Oilcake Meal (M) | 2.0 | 9.7 |
| P2.1 Urea (M) | 0.00 | 0.00 |
| P2.1 Feedgrade Sulpher (M) | 0.00 | 0.00 |
| P2.1 Salt (M) | 0.00 | 0.00 |
| Totals | 7.49 | 6.3 |

# Nitrogen Excretion

## Feed Nitrogen Influx

| Feed Name | Feed-N | Fecal-N | N-Utilized | Purchased Feed-N | Purchased Fecal-N | Purchased N-Utilized |
|---|---|---|---|---|---|---|
| | (g/day) | | | | | |
| Potch Highveld Grass | 29 | 8 | 21 | 29 | 8 | 21 |
| P2.1 Bagasse (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Molasses (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Cotton Oilcake Meal (M) | 14 | 1 | 13 | 14 | 1 | 13 |
| P2.1 Urea (M) | 11 | 0 | 11 | 11 | 0 | 11 |
| P2.1 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.1 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | |
| Totals | 55 | 9 | 46 | 55 | 9 | 46 |

## Animal Nitrogen Requirements

| | | Metabolizable | Net | Urinary |
|---|---|---|---|---|
| | | | | |
| **Maintenance** | *Scurf* | 1 | 1 | |
| | *Tissue* | 10 | 10 | |
| | *Metabolic Fecal* | 39 | 39 | |
| | *Total* | 50 | 50 | 0 |
| | | | | |
| **Pregnancy** | | 0 | 0 | 0 |
| | | | | |
| **Lactation** | *True Protein (NPN not included)* | 0 | 0 | 0 |
| | | | | |
| **Growth** | | 0 | 0 | 0 |
| | | | | |
| **Total** | | 50 | 50 | 0 |

## Bacterial Nitrogen Flow

Total Bacterial Nitrogen : 64 (g/day)
Total Absorbed Bacterial Nitrogen : 48 (g/day)
Bacterial Nitrogen Utilized (Post-Absorption) : 39 (g/day)

Bacterial Nucleic Acids (Urinary) : 10 (g/day)
Bacterial Excess Nitrogen (Urinary) : 0 (g/day)
Fecal Bacterial Nitrogen : 16 (g/day)

## Nitrogen Excretion

| | Fecal (g/day) | | | Urinary (g/day) |
|---|---|---|---|---|
| *Feed* | 9 | | *Bacterial Excess Nitrogen* | 0 |
| *Bacterial* | 16 | | *Bacterial Nucleic Acids* | 10 |
| *Metabolic Fecal Nitrogen* | 39 | | *Met. to Net Supply* | 0 |
| | | | *Tissue Turnover (Maintenance)* | 10 |
| | | | | |
| *Total* | 64 | | *Total* | 19 |

## Total Nitrogen Excretion

Fecal 64 (g/day)
Urinary 19 (g/day)

Total 84 (g/day)

## Nitrogen Distribution (% of Total Nitrogen Intake)

Fecal : 117.9%
Urine : 35.4%
Manure : 153.3%
Milk : 0.0%
Growth : 0.0%
Pregnancy : 0.0%
Maintenance : 91.7%

## Digestibility of Nitrogen

Total Ration Nitrogen : 83.4%
Purchased Nitrogen : 83.4%
Home Grown Nitrogen : 0.0%

## Carbohydrate Fermentability

| Feed Name | A (%D | NDF (%DM) | B2 CHO % of NDF | B2 CHO g/d av | B1 (%DM | B1 (%NS | B1 CHO % of B1 | B1 CHO g/d av | Total CHO |
|---|---|---|---|---|---|---|---|---|---|
| Potch Highveld | 10.6% | 75.4% | 38.5% | 133 | 1.2% | 10.1% | 91.6 | 50 | 40.6% |
| P2.1 Bagasse (M) | 0.0% | 88.5% | 41.4% | 9 | 0.0% | 100.0 | 0.0% | 0 | 36.7% |
| P2.1 Molasses (M) | 82.5% | 0.5% | 13.0% | 0 | 0.4% | 0.5% | 83.4 | 0 | 81.9% |
| P2.1 Cotton | 19.7% | 34.4% | 22.2% | 16 | 1.4% | 6.6% | 82.7 | 2 | 28.1% |
| P2.1 Urea (M) | 0.0% | 0.0% | 0.0% | 0 | 0.0% | 0.0% | 0.0% | 0 | 0.0% |
| P2.1 Feedgrade | 0.0% | 0.0% | 0.0% | 0 | 0.0% | 0.0% | 0.0% | 0 | 0.0% |
| P2.1 Salt (M) | 0.0% | 0.0% | 0.0% | 0 | 0.0% | 0.0% | 0.0% | 0 | 0.0% |
| | | | | | | | | | |
| Totals | 11.8% | 72.0% | 38.2% | 135 | 1.2% | 9.0% | 91.1 | 53 | 40.2% |

# Appendix A2

## Summary Report (Sunflower oilcake supplement)

**Diet Concentrations**

Ration Dry Matter : 93%
Apparent TDN : 42 (%DM)
ME : 6.4 (MJ/kg DM)
NEm : 2.9 (MJ/kg DM)
NEg : 0.6 (MJ/kg DM)
CP : 6.8 (%DM)
Soluble Protein : 47%
DIP : 66%
NDF : 72.2 (%DM)
peNDF : 71 (%DM)
Physically Effective NDF Bal. : 3.0
Total Forage in Ration : 94 (%DM)
Total NFC : 13%
Ca : 0.50 (%)
P : 0.11 (%)
DCAB1 (Simple) : 35 meq/kg
DCAB2 (Complex) : 94 meq/kg

Dietary Lignin (%DM): 9.56
Dietary Lignin (%NDF): 13.25
Forage NDF Intake (%BW): 1.60

**Rumen Values**

MP From Bact. : 242 (g/day)
MP From Undeg. Feed : 60 (g/day)
MP From Bact. : 80 (% MP Sup.)
MP From Undeg. Feed : 20 (% MP Sup.)
Peptide Balance : -6 (g/day)
% Peptide Balance : 66 (% of Req.)
Ruminal N Balance : -1 (g/day)
% Ruminal N Balance : 99 (% of Req.)
% Reduction in FC Digestion : 1 (%)
Predicted Ruminal pH : 6.46
Excess N Excreted : -1 (g/day)
Predicted PUN : 7 (mg/dl)
Urea Cost : 0.0 (MJ/day)

**Summary of Animal Inputs**

Animal Type : Growing/Finishing
Age : 9 months
Shrunk Body Weight : 217 (kg)
Mature Weight : 500 (kg)
Condition Score (1-9) : 5.0

**Summary of Environmental Inputs**

Previous Temperature : 15.6 deg C
Current Temperature : 15.6 deg C
Humidity : 20%
Wind Speed : 1.60 (kph)
Coat Condition : No Mud
Housing Type : Continuous Grazing

## Ration Carbohydrate and Protein Fractions

### NDF, Physically Effective NDF and Forage Analyses

| Feed Name | Qty. Fed (kg/day) | NDF (kg/day) | peNDF (kg/day) | Forage (kg/day) |
|---|---|---|---|---|
| Potch Highveld Grass | 4.58 | 3.45 | 3.45 | 4.58 |
| P2.2 Bagasse (M) | 0.02 | 0.02 | 0.02 | 0.02 |
| P2.2 Molasses (M) | 0.06 | 0.00 | 0.00 | 0.00 |
| P2.2 Sunflower Oilcake Meal (M) | 0.20 | 0.07 | 0.01 | 0.00 |
| P2.2 Urea (M) | 0.02 | 0.00 | 0.00 | 0.00 |
| P2.2 Feedgrade Sulpher (M) | 0.00 | 0.00 | 0.00 | 0.00 |
| P2.2 Salt (M) | 0.02 | 0.00 | 0.00 | 0.00 |
| Totals | 4.91 | 3.55 | 3.48 | 4.60 |

Forage Concentration in Ration : 93.6%
NDF Concentration in Ration : 72.2%
peNDF Concentration in Ration : 70.8%
peNDF to NDF Concentration in Ration : 98.1%

### Carbohydrate and Protein Composition - Percentage Basis

| Feed Name | Carbohydrate Fractions (%DM) | | | | | | Protein Fractions (%DM) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tota | A | B1 | B2 | C | NF | A | B1 | B2 | B3 | C | Total |
| Potch Highveld Grass | 85.5 | 10.6 | 1.2 | 50.0 | 23.7 | 11.8 | 1.5 | 0.1 | 0.7 | 0.8 | 1.0 | 4.0 |
| P2.2 Bagasse (M) | 85.4 | 0.0 | 0.0 | 69.2 | 17.6 | 0.0 | 0.9 | 0.0 | 0.5 | 0.7 | 0.9 | 3.1 |
| P2.2 Molasses (M) | 83.3 | 82.5 | 0.4 | 0.1 | 0.3 | 82.9 | 4.1 | 0.4 | 0.0 | 0.1 | 0.0 | 4.6 |
| P2.2 Sunflower Oilcake Meal (M) | 51.0 | 17.3 | 1.0 | 14.0 | 18.6 | 18.3 | 3.1 | 5.3 | 28.5 | 2.3 | 0.9 | 40.2 |
| P2.2 Urea (M) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 287. | 0.0 | 0.0 | 0.0 | 0.0 | 287.0 |
| P2.2 Feedgrade Sulpher (M) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| P2.2 Salt (M) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

# Ration Degradation and Passage

## Carbohydrate B2 Fraction Degradation Rate Adjustment

Rumen pH : 6.5
Relative Yield Adjustment : 0.99

| Feed Name | CHO-B2 Rate (%/hr) | Yiel d | Adjusted Yield | Adjusted CHO-B2 Rate (%/hr) |
|---|---|---|---|---|
| Potch Highveld Grass | 4.00 | 0.20 | 0.20 | 4.00 |
| P2.2 Bagasse (M) | 3.00 | 0.13 | 0.13 | 3.00 |
| P2.2 Molasses (M) | 20.00 | 0.36 | 0.36 | 20.00 |
| P2.2 Sunflower Oilcake Meal (M) | 4.00 | 0.20 | 0.20 | 4.00 |
| P2.2 Urea (M) | 0.00 | 0.00 | 0.00 | 0.00 |
| P2.2 Feedgrade Sulpher (M) | 0.00 | 0.00 | 0.00 | 0.00 |
| P2.2 Salt (M) | 0.00 | 0.00 | 0.00 | 0.00 |

## Passage Rates

Forage Passage Rate : 3.99 %/hr
Concentrate Passage Rate : 5.36 %/hr

| Feed Name | Adjustment | Passage Rate |
|---|---|---|
| Potch Highveld Grass | 0.69 | 2.74 |
| P2.2 Bagasse (M) | 0.64 | 2.54 |
| P2.2 Molasses (M) | 1.11 | 5.95 |
| P2.2 Sunflower Oilcake Meal (M) | 1.07 | 5.75 |
| P2.2 Urea (M) | 1.11 | 5.95 |
| P2.2 Feedgrade Sulpher (M) | 1.11 | 5.95 |
| P2.2 Salt (M) | 1.11 | 5.95 |

## Carbohydrate and Protein Ruminal Degradation

| Feed Name | Carbohydrate Fractions (g/day) | | | Protein Fractions (g/day) | | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B1 | B2 | A | B1 | B2 | B3 | Peptide |
| Potch Highveld Grass | 482 | 50 | 1345 | 67 | 3 | 27 | 1 | 31 |
| P2.2 Bagasse (M) | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Molasses (M) | 51 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| P2.2 Sunflower Oilcake Meal (M) | 34 | 2 | 12 | 6 | 10 | 36 | 0 | 47 |
| P2.2 Urea (M) | 0 | 0 | 0 | 66 | 0 | 0 | 0 | 0 |
| P2.2 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 567 | 52 | 1365 | 141 | 13 | 63 | 1 | 78 |

## Carbohydrate and Protein Ruminal Escape

| Feed Name | Carbohydrate Fractions (g/day) | | | | Protein Fractions (g/day) | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B1 | B2 | C | B1 | B2 | B3 | C |
| Potch Highveld Grass | 5 | 5 | 942 | 1085 | 0 | 7 | 34 | 45 |
| P2.2 Bagasse (M) | 0 | 0 | 7 | 4 | 0 | 0 | 0 | 0 |
| P2.2 Molasses (M) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Sunflower Oilcake Meal (M) | 1 | 0 | 17 | 38 | 0 | 21 | 5 | 2 |
| P2.2 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 7 | 5 | 966 | 1127 | 1 | 28 | 39 | 47 |

## Microbial Yields

Maintenance Rate of FC Bacteria (KM-FC) : 0.05 g FC/g Bacteria / h
Maintenance Rate of NFC Bacteria (KM-NFC) : 0.15 g NFC/g Bacteria / h

Theoretical Maximum Yield of FC Bacteria (YG-FC) : 0.40
Theoretical Maximum Yield of NFC Bacteria (YG-FC) : 0.40

Peptides / (Peptides+NFC) : 0.1
% Improvement in NFC Digestion : 18.53 (due to peptides)

| Feed Name | CHO-A Yield | CHO-B1 Yield | CHO-B2 Yield |
|---|---|---|---|
| Potch Highveld Grass | 0.46 | 0.40 | 0.27 |
| P2.2 Bagasse (M) | 0.46 | 0.40 | 0.24 |
| P2.2 Molasses (M) | 0.47 | 0.40 | 0.36 |
| P2.2 Sunflower Oilcake Meal (M) | 0.46 | 0.40 | 0.27 |
| P2.2 Urea (M) | 0.00 | 0.00 | 0.00 |
| P2.2 Feedgrade Sulpher (M) | 0.00 | 0.00 | 0.00 |
| P2.2 Salt (M) | 0.00 | 0.00 | 0.00 |

| Feed Name | Bacterial Yield Fractions (g Microbial DM) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | NFC | NFC-N | FC | FC-N | Total | Total-N | PEP | PEP-N |
| Potch Highveld Grass | 241 | 24 | 359 | 36 | 599 | 60 | 31 | 5 |
| P2.2 Bagasse (M) | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 |
| P2.2 Molasses (M) | 24 | 2 | 0 | 0 | 24 | 2 | 0 | 0 |
| P2.2 Sunflower Oilcake Meal (M) | 17 | 2 | 3 | 0 | 20 | 2 | 47 | 8 |
| P2.2 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 281 | 28 | 364 | 36 | 645 | 64 | 78 | 13 |

Ration Bacterial Yield : 645 (g/day)

**Ruminal Escape of Bacterial Fractions**

Fraction of Microbial Composition Composed of Fraction X :

| CHO-A | CHO-B1 | CHO-B2 | CHO-C | PRT-A | PRT-B1 | PRT-B2 | PRT-B3 | PRT-C |
|---|---|---|---|---|---|---|---|---|
| 0.1688 | 0.0422 | 0 | 0 | 0.0938 | 0.3750 | 0 | 0 | 0.1563 |

| Feed Name | Ruminal Escape Fractions (g/day) | | | | | |
|---|---|---|---|---|---|---|
| | True Protein | Cell Wall | Nucleic Acids | CHO | Fat | Ash |
| Potch Highveld Grass | 225 | 94 | 56 | 126 | 72 | 26 |
| P2.2 Bagasse (M) | 1 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Molasses (M) | 9 | 4 | 2 | 5 | 3 | 1 |
| P2.2 Sunflower Oilcake Meal (M) | 7 | 3 | 2 | 4 | 2 | 1 |
| P2.2 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 242 | 101 | 60 | 136 | 77 | 28 |

**Intestinally Digested Protein**

| Feed Name | Feed (g/day) | | | | Microbial | | Total |
|---|---|---|---|---|---|---|---|
| | B1 | B2 | B3 | Feed | TP | NA | |
| Potch Highveld Grass | 0 | 7 | 27 | 34 | 225 | 56 | 315 |
| P2.2 Bagasse (M) | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| P2.2 Molasses (M) | 0 | 0 | 0 | 0 | 9 | 2 | 11 |
| P2.2 Sunflower Oilcake Meal (M) | 0 | 21 | 4 | 25 | 7 | 2 | 35 |
| P2.2 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Intestinally Digested Carbohydrate and Fat**

| Feed Name | Carbohydrate Fractions | | | Fat Fractions (g/day) | | |
|---|---|---|---|---|---|---|
| | Feed | BACT | Total | Feed | BACT | Total |
| Potch Highveld Grass | 197 | 120 | 317 | 65 | 68 | 134 |
| P2.2 Bagasse (M) | 1 | 0 | 2 | 0 | 0 | 1 |
| P2.2 Molasses (M) | 1 | 5 | 5 | 0 | 3 | 3 |
| P2.2 Sunflower Oilcake Meal (M) | 4 | 4 | 8 | 4 | 2 | 6 |
| P2.2 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 |

**Feed Contributions to Fecal Output**

| Feed Name | Protein Fractions (g/day) | | | Carbohydrate Fractions (g/day) | | | | Other Fractions (g/day) | |
|---|---|---|---|---|---|---|---|---|---|
| | B3 | C | Feed | B1 | B2 | C | Feed | Ash | Fat |
| Potch Highveld Grass | 7 | 45 | 52 | 1 | 754 | 1085 | 1840 | 207 | 3 |
| P2.2 Bagasse (M) | 0 | 0 | 0 | 0 | 6 | 4 | 10 | 1 | 0 |
| P2.2 Molasses (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| P2.2 Sunflower Oilcake Meal (M) | 1 | 2 | 3 | 0 | 13 | 38 | 51 | 7 | 0 |
| P2.2 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| P2.2 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 |

**Microbial Contributions to Fecal Output**

| Feed Name | Bacterial Fractions (g/day) | | | | | |
|---|---|---|---|---|---|---|
| | CW | CP | CHO | Fat | Ash | Total |
| Potch Highveld Grass | 94 | 94 | 6 | 4 | 13 | 117 |
| P2.2 Bagasse (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Molasses (M) | 4 | 4 | 0 | 0 | 1 | 5 |
| P2.2 Sunflower Oilcake Meal (M) | 3 | 3 | 0 | 0 | 0 | 4 |
| P2.2 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 |

Total Fecal Bacterial Cell Wall Protein : 101 (g/day)

**Indigestible Dry Matter Determination**

| Feed Name | Fecal-CHO | Indig. DM (g/day) |
|---|---|---|
| Potch Highveld Grass | 1847 | 2584 |
| P2.2 Bagasse (M) | 10 | 13 |
| P2.2 Molasses (M) | 0 | 11 |
| P2.2 Sunflower Oilcake Meal (M) | 51 | 78 |
| P2.2 Urea (M) | 0 | 1 |
| P2.2 Feedgrade Sulpher (M) | 0 | 1 |
| P2.2 Salt (M) | 0 | 14 |

Total Indigestible Dry Matter in Ration : 2701 (g/day)

**Endogenous Fecal Components**

| Feed Name | Endogenous Fecal Component (g/day) | | |
|---|---|---|---|
| | Protein | Fat | Ash |
| Potch Highveld Grass | 233 | 54 | 78 |
| P2.2 Bagasse (M) | 1 | 0 | 0 |
| P2.2 Molasses (M) | 1 | 1 | 1 |
| P2.2 Sunflower Oilcake Meal (M) | 7 | 2 | 3 |
| P2.2 Urea (M) | 0 | 0 | 0 |
| P2.2 Feedgrade Sulpher (M) | 0 | 0 | 0 |
| P2.2 Salt (M) | 1 | 0 | 0 |

**Fecal Output**

| Feed Name | Fecal Component (g/day) | | | | |
|---|---|---|---|---|---|
| | Protein | Carbohydrat | Fat | Ash | Output |
| Potch Highveld Grass | 378 | 1847 | 62 | 298 | 2584 |
| P2.2 Bagasse (M) | 2 | 10 | 0 | 2 | 13 |
| P2.2 Molasses (M) | 5 | 0 | 1 | 5 | 11 |
| P2.2 Sunflower Oilcake Meal (M) | 13 | 51 | 3 | 11 | 78 |
| P2.2 Urea (M) | 0 | 0 | 0 | 0 | 1 |
| P2.2 Feedgrade Sulpher (M) | 0 | 0 | 0 | 1 | 1 |
| P2.2 Salt (M) | 1 | 0 | 0 | 12 | 14 |

Total Fecal Output : 2701 (g/day)

**Metabolizable Protein**

| Feed Name | Metabolizable Protein (g/day) |
|---|---|
| Potch Highveld Grass | 259 |
| P2.2 Bagasse (M) | 1 |
| P2.2 Molasses (M) | 9 |
| P2.2 Sunflower Oilcake Meal (M) | 33 |
| P2.2 Urea (M) | 0 |
| P2.2 Feedgrade Sulpher (M) | 0 |
| P2.2 Salt (M) | 0 |

Total Dietary Metabolizable Protein : 301 (g/day)

# Bacterial Nitrogen

## Rumen Flow

Liquid Passage Rate : 8.7 (%/hr)
Liquid Growth Rate : 1.1 (1/hr)

Liquid Survival Rate : 0.9 (1/hr)

Uptake Coefficient : 7.0 (1/hr)
Peptide Degradation Rate : 3 (g/hr)
Peptide Uptake Rate : 78 (g/day)

NSC Bacterial Peptide Uptake : 21 (g/hr)
Liquid Disappearance Rate : 0.2 (hr)
Peptide Passage Rate : 1 (g/day)

## Bacterial Nitrogen Balances

NSC Bacterial Nitrogen Balance

| | Peptides | Bacterial NH3 (g N/day) | Diet NH3 | Recycled NH3 | Ruminal NH3 |
|---|---|---|---|---|---|
| Available | 12 | 0 | 23 | 29 | 52 |
| Required | 19 | | | | 10 |
| Balance | -6 | | | | 42 |

SC Bacterial Nitrogen Balance

| | Ruminal NH3 | | | Total Bacterial N Balance |
|---|---|---|---|---|
| Available | 42 | | Available | 64 |
| Required | 37 | | Required | 65 |
| Balance | 6 | | Balance | -1 |

## Bacterial Nitrogen Excretion

Total Bacterial Nitrogen : 64 (g/day)
Total Absorbed Bacterial Nitrogen : 48 (g/day)
Bacterial Nitrogen Utilized (Post-Absorption) : 39 (g/day)
Bacterial Nucleic Acids (Urinary) : 10 (g/day)
Bacterial Excess Nitrogen (Urinary) : 0 (g/day)
Fecal Bacterial Nitrogen : 16 (g/day)

# Ration Energy

### TDN Fractions

| Feed Name | TDN Fractions | | | |
|---|---|---|---|---|
| | App (g/day) | App (%DM) | True (g/day) | True (%DM) |
| Potch Highveld Grass | 1889 | 41% | 2352 | 51% |
| P2.2 Bagasse (M) | 9 | 38% | 11 | 47% |
| P2.2 Molasses (M) | 48 | 77% | 54 | 88% |
| P2.2 Sunflower Oilcake Meal (M) | 124 | 61% | 140 | 69% |
| P2.2 Urea (M) | 0 | 0% | 0 | 0% |
| P2.2 Feedgrade Sulpher (M) | 0 | 0% | 0 | 0% |
| P2.2 Salt (M) | 0 | 0% | 0 | 0% |
| Totals | 2067 | 42% | 2557 | 52% |

### Metabolizable Energy

| Feed Name | ME (MJ/day) | ME Concentration (MJ/kg) |
|---|---|---|
| Potch Highveld Grass | 28.6 | 6.2 |
| P2.2 Bagasse (M) | 0.1 | 5.7 |
| P2.2 Molasses (M) | 0.7 | 11.6 |
| P2.2 Sunflower Oilcake Meal (M) | 1.9 | 9.3 |
| P2.2 Urea (M) | 0.00 | 0.00 |
| P2.2 Feedgrade Sulpher (M) | 0.00 | 0.00 |
| P2.2 Salt (M) | 0.00 | 0.00 |
| Totals | 7.47 | 6.4 |

# Nitrogen Excretion

## Feed Nitrogen Influx

| Feed Name | Feed-N | Fecal-N | N-Utilized | Purchased Feed-N | Purchased Fecal-N | Purchased N-Utilized |
|---|---|---|---|---|---|---|
| | (g/day) | | | | | |
| Potch Highveld Grass | 29 | 8 | 21 | 29 | 8 | 21 |
| P2.2 Bagasse (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Molasses (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Sunflower Oilcake Meal | 13 | 0 | 13 | 13 | 0 | 13 |
| P2.2 Urea (M) | 10 | 0 | 10 | 10 | 0 | 10 |
| P2.2 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.2 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | |
| Totals | 53 | 9 | 45 | 53 | 9 | 45 |

## Animal Nitrogen Requirements

| | | Metabolizable | Net | Urinary |
|---|---|---|---|---|
| | | | | |
| **Maintenance** | *Scurf* | 1 | 1 | |
| | *Tissue* | 10 | 10 | |
| | *Metabolic Fecal* | 39 | 39 | |
| | *Total* | 50 | 50 | 0 |
| | | | | |
| **Pregnancy** | | 0 | 0 | 0 |
| | | | | |
| **Lactation** | *True Protein (NPN not included)* | 0 | 0 | 0 |
| | | | | |
| **Growth** | | 0 | 0 | 0 |
| | | | | |
| **Total** | | 50 | 50 | 0 |

## Bacterial Nitrogen Flow

Total Bacterial Nitrogen : 64 (g/day)
Total Absorbed Bacterial Nitrogen : 48 (g/day)
Bacterial Nitrogen Utilized (Post-Absorption) : 39 (g/day)

Bacterial Nucleic Acids (Urinary) : 10 (g/day)
Bacterial Excess Nitrogen (Urinary) : 0 (g/day)
Fecal Bacterial Nitrogen : 16 (g/day)

## Nitrogen Excretion

| | Fecal (g/day) | | | Urinary (g/day) |
|---|---|---|---|---|
| *Feed* | 9 | | *Bacterial Excess Nitrogen* | 0 |
| *Bacterial* | 16 | | *Bacterial Nucleic Acids* | 10 |
| *Metabolic Fecal Nitrogen* | 39 | | *Met. to Net Supply* | 0 |
| | | | *Tissue Turnover (Maintenance)* | 10 |
| | | | | |
| *Total* | 64 | | *Total* | 19 |

## Total Nitrogen Excretion

| | |
|---|---|
| Fecal | 64 (g/day) |
| Urinary | 19 (g/day) |
| Total | 83 (g/day) |

## Nitrogen Distribution (% of Total Nitrogen Intake)

Fecal : 119.5%
Urine : 36.2%
Manure : 155.7%
Milk : 0.0%
Growth : 0.0%
Pregnancy : 0.0%
Maintenance : 93.3%

## Digestibility of Nitrogen

Total Ration Nitrogen : 83.6%
Purchased Nitrogen : 83.6%
Home Grown Nitrogen : 0.0%

## Carbohydrate Fermentability

| | | | B2 CHO | | | | B1 CHO | | |
|---|---|---|---|---|---|---|---|---|---|
| Feed Name | A (%D | NDF (%DM) | % of NDF | g/d ay | B1 (%DM | B1 (%NS | % of B1 | g/d ay | Total CHO |
| | | | | | | | | | |
| Potch Highveld | 10.6% | 75.4% | 39.0% | 134 | 1.2% | 10.1% | 91.6 | 50 | 41.0% |
| P2.2 Bagasse (M) | 0.0% | 88.5% | 41.9% | 8 | 0.0% | 100.0 | 0.0% | 0 | 37.1% |
| P2.2 Molasses (M) | 82.5% | 0.5% | 13.2% | 0 | 0.4% | 0.5% | 83.4 | 0 | 81.9% |
| P2.2 Sunflower | 17.3% | 35.9% | 15.9% | 12 | 1.0% | 5.5% | 85.9 | 2 | 23.6% |
| P2.2 Urea (M) | 0.0% | 0.0% | 0.0% | 0 | 0.0% | 0.0% | 0.0% | 0 | 0.0% |
| P2.2 Feedgrade | 0.0% | 0.0% | 0.0% | 0 | 0.0% | 0.0% | 0.0% | 0 | 0.0% |
| P2.2 Salt (M) | 0.0% | 0.0% | 0.0% | 0 | 0.0% | 0.0% | 0.0% | 0 | 0.0% |
| | | | | | | | | | |
| Totals | 11.7% | 72.2% | 38.5% | 136 | 1.2% | 9.0% | 91.4 | 52 | 40.4% |

# Appendix A3

## Summary Report (Soyabean oilcake supplement)

**Diet Concentrations**

Ration Dry Matter : 93%
Apparent TDN : 43 (%DM)
ME : 6.5 (MJ/kg DM)
NEm : 3.0 (MJ/kg DM)
NEg : 0.7 (MJ/kg DM)
CP : 7.1 (%DM)
Soluble Protein : 45%
DIP : 66%
NDF : 71.2 (%DM)
peNDF : 71 (%DM)
Physically Effective NDF Bal. : 3.0
Total Forage in Ration : 94 (%DM)
Total NFC : 14%
Ca : 0.50 (%)
P : 0.09 (%)
DCAB1 (Simple) : 43 meq/kg
DCAB2 (Complex) : 112 meq/kg

Dietary Lignin (%DM): 9.27
Dietary Lignin (%NDF): 13.03
Forage NDF Intake (%BW): 1.59

**Rumen Values**

MP From Bact. : 247 (g/day)
MP From Undeg. Feed : 64 (g/day)
MP From Bact. : 79 (% MP Sup.)
MP From Undeg. Feed : 21 (% MP Sup.)
Peptide Balance : -7 (g/day)
% Peptide Balance : 65 (% of Req.)
Ruminal N Balance : -1 (g/day)
% Ruminal N Balance : 99 (% of Req.)
% Reduction in FC Digestion : 1 (%)
Predicted Ruminal pH : 6.46
Excess N Excreted : 0 (g/day)
Predicted PUN : 7 (mg/dl)
Urea Cost : 0.0 (MJ/day)

**Summary of Animal Inputs**

Animal Type : Growing/Finishing
Age : 9 months
Shrunk Body Weight : 217 (kg)
Mature Weight : 500 (kg)
Condition Score (1-9) : 5.0

**Summary of Environmental Inputs**

Previous Temperature : 15.6 deg C
Current Temperature : 15.6 deg C
Humidity : 20%
Wind Speed : 1.60 (kph)
Coat Condition : No Mud
Housing Type : Continuous Grazing

## Ration Carbohydrate and Protein Fractions

### NDF, Physically Effective NDF and Forage Analyses

| Feed Name | Qty. Fed (kg/day) | NDF (kg/day) | peNDF (kg/day) | Forage (kg/day) |
|---|---|---|---|---|
| Potch Highveld Grass | 4.56 | 3.44 | 3.44 | 4.56 |
| P2.3 Bagasse (M) | 0.03 | 0.02 | 0.02 | 0.03 |
| P2.3 Molasses (M) | 0.09 | 0.00 | 0.00 | 0.00 |
| P2.3 Soyabean Oilcake Meal (M) | 0.17 | 0.02 | 0.01 | 0.00 |
| P2.3 Urea (M) | 0.03 | 0.00 | 0.00 | 0.00 |
| P2.3 Feedgrade Sulpher (M) | 0.00 | 0.00 | 0.00 | 0.00 |
| P2.3 Salt (M) | 0.03 | 0.00 | 0.00 | 0.00 |
| Totals | 4.90 | 3.48 | 3.46 | 4.58 |

Forage Concentration in Ration : 93.6%
NDF Concentration in Ration : 71.2%
peNDF Concentration in Ration : 70.7%
peNDF to NDF Concentration in Ration : 99.4%

### Carbohydrate and Protein Composition - Percentage Basis

| Feed Name | Carbohydrate Fractions (%DM) | | | | | | Protein Fractions (%DM) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | A | B1 | B2 | C | NFC | A | B1 | B2 | B3 | C | Total |
| Potch Highveld Grass | 85.5 | 10.6 | 1.2 | 50.0 | 23.7 | 11.8 | 1.5 | 0.1 | 0.7 | 0.8 | 1.0 | 4.0 |
| P2.3 Bagasse (M) | 85.4 | 0.0 | 0.0 | 69.2 | 17.6 | 0.0 | 0.9 | 0.0 | 0.5 | 0.7 | 0.9 | 3.1 |
| P2.3 Molasses (M) | 83.3 | 82.5 | 0.4 | 0.1 | 0.3 | 82.9 | 4.1 | 0.4 | 0.0 | 0.1 | 0.0 | 4.6 |
| P2.3 Soyabean Oilcake Meal (M) | 39.0 | 28.3 | 1.8 | 6.2 | 2.6 | 30.1 | 2.3 | 3.9 | 39.6 | 5.4 | 0.5 | 51.7 |
| P2.3 Urea (M) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 287.0 | 0.0 | 0.0 | 0.0 | 0.0 | 287.0 |
| P2.3 Feedgrade Sulpher (M) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| P2.3 Salt (M) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

## Ration Degradation and Passage

### Carbohydrate B2 Fraction Degradation Rate Adjustment

Rumen pH : 6.5
Relative Yield Adjustment : 0.99

| Feed Name | CHO-B2 Rate (%/hr) | Yiel d | Adjusted Yield | Adjusted CHO-B2 Rate (%/hr) |
|---|---|---|---|---|
| Potch Highveld Grass | 4.00 | 0.20 | 0.20 | 4.00 |
| P2.3 Bagasse (M) | 3.00 | 0.13 | 0.13 | 3.00 |
| P2.3 Molasses (M) | 20.00 | 0.36 | 0.36 | 20.00 |
| P2.3 Soyabean Oilcake Meal (M) | 6.00 | 0.27 | 0.26 | 6.00 |
| P2.3 Urea (M) | 0.00 | 0.00 | 0.00 | 0.00 |
| P2.3 Feedgrade Sulpher (M) | 0.00 | 0.00 | 0.00 | 0.00 |
| P2.3 Salt (M) | 0.00 | 0.00 | 0.00 | 0.00 |

### Passage Rates

Forage Passage Rate : 3.98 %/hr
Concentrate Passage Rate : 5.35 %/hr

| Feed Name | Adjustment | Passage Rate |
|---|---|---|
| Potch Highveld Grass | 0.69 | 2.74 |
| P2.3 Bagasse (M) | 0.64 | 2.54 |
| P2.3 Molasses (M) | 1.11 | 5.94 |
| P2.3 Soyabean Oilcake Meal (M) | 1.07 | 5.72 |
| P2.3 Urea (M) | 1.11 | 5.94 |
| P2.3 Feedgrade Sulpher (M) | 1.11 | 5.94 |
| P2.3 Salt (M) | 1.11 | 5.94 |

**Carbohydrate and Protein Ruminal Degradation**

| Feed Name | Carbohydrate Fractions (g/day) | | | Protein Fractions (g/day) | | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B1 | B2 | A | B1 | B2 | B3 | Peptides |
| Potch Highveld Grass | 479 | 50 | 1341 | 66 | 3 | 27 | 1 | 31 |
| P2.3 Bagasse (M) | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Molasses (M) | 75 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| P2.3 Soyabean Oilcake Meal (M) | 47 | 2 | 5 | 4 | 6 | 44 | 0 | 51 |
| P2.3 Urea (M) | 0 | 0 | 0 | 73 | 0 | 0 | 0 | 0 |
| P2.3 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 601 | 53 | 1356 | 147 | 9 | 70 | 1 | 82 |

**Carbohydrate and Protein Ruminal Escape**

| Feed Name | Carbohydrate Fractions (g/day) | | | | Protein Fractions (g/day) | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B1 | B2 | C | B1 | B2 | B3 | C |
| Potch Highveld Grass | 5 | 5 | 935 | 1080 | 0 | 7 | 34 | 45 |
| P2.3 Bagasse (M) | 0 | 0 | 8 | 4 | 0 | 0 | 0 | 0 |
| P2.3 Molasses (M) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Soyabean Oilcake Meal (M) | 1 | 1 | 5 | 4 | 0 | 23 | 9 | 1 |
| P2.3 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 7 | 5 | 948 | 1089 | 0 | 30 | 43 | 46 |

**Microbial Yields**

Maintenance Rate of FC Bacteria (KM-FC) : 0.05 g FC/g Bacteria / h
Maintenance Rate of NFC Bacteria (KM-NFC) : 0.15 g NFC/g Bacteria / h

Theoretical Maximum Yield of FC Bacteria (YG-FC) : 0.40
Theoretical Maximum Yield of NFC Bacteria (YG-FC) : 0.40

Peptides / (Peptides+NFC) : 0.1
% Improvement in NFC Digestion : 18.45 (due to peptides)

| Feed Name | CHO-A Yield | CHO-B1 Yield | CHO-B2 Yield |
|---|---|---|---|
| Potch Highveld Grass | 0.46 | 0.39 | 0.27 |
| P2.3 Bagasse (M) | 0.46 | 0.39 | 0.24 |
| P2.3 Molasses (M) | 0.47 | 0.39 | 0.36 |
| P2.3 Soyabean Oilcake Meal (M) | 0.46 | 0.38 | 0.30 |
| P2.3 Urea (M) | 0.00 | 0.00 | 0.00 |
| P2.3 Feedgrade Sulpher (M) | 0.00 | 0.00 | 0.00 |
| P2.3 Salt (M) | 0.00 | 0.00 | 0.00 |

| Feed Name | Bacterial Yield Fractions (g Microbial DM) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | NFC | NFC-N | FC | FC-N | Total | Total-N | PEP | PEP-N |
| Potch Highveld Grass | 240 | 24 | 358 | 36 | 597 | 60 | 31 | 5 |
| P2.3 Bagasse (M) | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 |
| P2.3 Molasses (M) | 35 | 4 | 0 | 0 | 35 | 3 | 0 | 0 |
| P2.3 Soyabean Oilcake Meal (M) | 23 | 2 | 2 | 0 | 24 | 2 | 51 | 8 |
| P2.3 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 297 | 30 | 362 | 36 | 659 | 66 | 82 | 13 |

Ration Bacterial Yield : 659 (g/day)

**Ruminal Escape of Bacterial Fractions**

Fraction of Microbial Composition Composed of Fraction X :

| CHO-A | CHO-B1 | CHO-B2 | CHO-C | PRT-A | PRT-B1 | PRT-B2 | PRT-B3 | PRT-C |
|---|---|---|---|---|---|---|---|---|
| 0.1688 | 0.0422 | 0 | 0 | 0.0938 | 0.3750 | 0 | 0 | 0.1563 |

| Feed Name | Ruminal Escape Fractions (g/day) | | | | | |
|---|---|---|---|---|---|---|
| | True Protein | Cell Wall | Nucleic Acids | CHO | Fat | Ash |
| Potch Highveld Grass | 224 | 93 | 56 | 126 | 72 | 26 |
| P2.3 Bagasse (M) | 1 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Molasses (M) | 13 | 5 | 3 | 7 | 4 | 2 |
| P2.3 Soyabean Oilcake Meal (M) | 9 | 4 | 2 | 5 | 3 | 1 |
| P2.3 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 247 | 103 | 62 | 139 | 79 | 29 |

**Intestinally Digested Protein**

| Feed Name | Feed (g/day) | | | | Microbial | | Total |
|---|---|---|---|---|---|---|---|
| | B1 | B2 | B3 | Feed | TP | NA | |
| Potch Highveld Grass | 0 | 7 | 27 | 34 | 224 | 56 | 314 |
| P2.3 Bagasse (M) | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| P2.3 Molasses (M) | 0 | 0 | 0 | 0 | 13 | 3 | 16 |
| P2.3 Soyabean Oilcake Meal (M) | 0 | 23 | 7 | 30 | 9 | 2 | 42 |
| P2.3 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Intestinally Digested Carbohydrate and Fat**

| Feed Name | Carbohydrate Fractions | | | Fat Fractions (g/day) | | |
|---|---|---|---|---|---|---|
| | Feed | BACT | Total | Feed | BACT | Total |
| Potch Highveld Grass | 196 | 120 | 315 | 65 | 68 | 133 |
| P2.3 Bagasse (M) | 2 | 0 | 2 | 0 | 0 | 1 |
| P2.3 Molasses (M) | 1 | 7 | 8 | 0 | 4 | 4 |
| P2.3 Soyabean Oilcake Meal (M) | 2 | 5 | 7 | 2 | 3 | 5 |
| P2.3 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 |

**Feed Contributions to Fecal Output**

| Feed Name | Protein Fractions (g/day) | | | Carbohydrate Fractions (g/day) | | | | Other Fractions (g/day) | |
|---|---|---|---|---|---|---|---|---|---|
| | B3 | C | Feed | B1 | B2 | C | Feed | Ash | Fat |
| Potch Highveld Grass | 7 | 45 | 52 | 1 | 748 | 1080 | 1829 | 206 | 3 |
| P2.3 Bagasse (M) | 0 | 0 | 0 | 0 | 6 | 4 | 11 | 1 | 0 |
| P2.3 Molasses (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 |
| P2.3 Soyabean Oilcake Meal (M) | 2 | 1 | 3 | 0 | 4 | 4 | 9 | 7 | 0 |
| P2.3 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| P2.3 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 |

**Microbial Contributions to Fecal Output**

| Feed Name | Bacterial Fractions (g/day) | | | | | |
|---|---|---|---|---|---|---|
| | CW | CP | CHO | Fat | Ash | Total |
| Potch Highveld Grass | 93 | 93 | 6 | 4 | 13 | 116 |
| P2.3 Bagasse (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Molasses (M) | 5 | 5 | 0 | 0 | 1 | 7 |
| P2.3 Soyabean Oilcake Meal (M) | 4 | 4 | 0 | 0 | 1 | 5 |
| P2.3 Urea (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 |

Total Fecal Bacterial Cell Wall Protein : 103 (g/day)

**Indigestible Dry Matter Determination**

| Feed Name | Fecal-CHO | Indig. DM (g/day) |
|---|---|---|
| Potch Highveld Grass | 1836 | 2569 |
| P2.3 Bagasse (M) | 11 | 15 |
| P2.3 Molasses (M) | 1 | 17 |
| P2.3 Soyabean Oilcake Meal (M) | 9 | 30 |
| P2.3 Urea (M) | 0 | 1 |
| P2.3 Feedgrade Sulpher (M) | 0 | 1 |
| P2.3 Salt (M) | 0 | 16 |

Total Indigestible Dry Matter in Ration : 2648 (g/day)

**Endogenous Fecal Components**

| Feed Name | Endogenous Fecal Component (g/day) | | |
|---|---|---|---|
| | Protein | Fat | Ash |
| Potch Highveld Grass | 231 | 54 | 77 |
| P2.3 Bagasse (M) | 1 | 0 | 0 |
| P2.3 Molasses (M) | 2 | 1 | 2 |
| P2.3 Soyabean Oilcake Meal (M) | 3 | 2 | 3 |
| P2.3 Urea (M) | 0 | 0 | 0 |
| P2.3 Feedgrade Sulpher (M) | 0 | 0 | 0 |
| P2.3 Salt (M) | 1 | 0 | 0 |

**Fecal Output**

| Feed Name | Fecal Component (g/day) | | | | |
|---|---|---|---|---|---|
| | Protein | Carbohydrate | Fat | Ash | Output |
| Potch Highveld Grass | 376 | 1836 | 61 | 296 | 2569 |
| P2.3 Bagasse (M) | 2 | 11 | 0 | 2 | 15 |
| P2.3 Molasses (M) | 7 | 1 | 1 | 8 | 17 |
| P2.3 Soyabean Oilcake Meal (M) | 9 | 9 | 2 | 10 | 30 |
| P2.3 Urea (M) | 0 | 0 | 0 | 0 | 1 |
| P2.3 Feedgrade Sulpher (M) | 0 | 0 | 0 | 1 | 1 |
| P2.3 Salt (M) | 1 | 0 | 0 | 14 | 16 |

Total Fecal Output : 2648 (g/day)

**Metabolizable Protein**

| Feed Name | Metabolizable Protein (g/day) |
|---|---|
| Potch Highveld Grass | 258 |
| P2.3 Bagasse (M) | 1 |
| P2.3 Molasses (M) | 13 |
| P2.3 Soyabean Oilcake Meal (M) | 40 |
| P2.3 Urea (M) | 0 |
| P2.3 Feedgrade Sulpher (M) | 0 |
| P2.3 Salt (M) | 0 |

Total Dietary Metabolizable Protein : 311 (g/day)

# Bacterial Nitrogen

## Rumen Flow

Liquid Passage Rate : 8.7 (%/hr)
Liquid Growth Rate : 1.1 (1/hr)

Liquid Survival Rate : 0.9 (1/hr)

Uptake Coefficient : 7.0 (1/hr)
Peptide Degradation Rate : 3 (g/hr)
Peptide Uptake Rate : 81 (g/day)

NSC Bacterial Peptide Uptake : 22 (g/hr)
Liquid Disappearance Rate : 0.2 (hr)
Peptide Passage Rate : 1 (g/day)

## Bacterial Nitrogen Balances

<u>NSC Bacterial Nitrogen Balance</u>

| | Peptides | Bacterial NH3 (g N/day) | Diet NH3 | Recycled NH3 | Ruminal NH3 |
|---|---|---|---|---|---|
| Available | 13 | 0 | 24 | 29 | 53 |
| Required | 20 | | | | 10 |
| Balance | -7 | | | | 43 |

<u>SC Bacterial Nitrogen Balance</u>

| | Ruminal NH3 | | | Total Bacterial N Balance |
|---|---|---|---|---|
| Available | 43 | | Available | 66 |
| Required | 36 | | Required | 67 |
| Balance | 6 | | Balance | -1 |

## Bacterial Nitrogen Excretion

Total Bacterial Nitrogen : 66 (g/day)
Total Absorbed Bacterial Nitrogen : 49 (g/day)
Bacterial Nitrogen Utilized (Post-Absorption) : 40 (g/day)
Bacterial Nucleic Acids (Urinary) : 10 (g/day)
Bacterial Excess Nitrogen (Urinary) : 0 (g/day)
Fecal Bacterial Nitrogen : 16 (g/day)

## Ration Energy

### TDN Fractions

| Feed Name | TDN Fractions | | | |
|---|---|---|---|---|
| | App (g/day) | App (%DM) | True (g/day) | True (%DM) |
| Potch Highveld Grass | 1882 | 41% | 2343 | 51% |
| P2.3 Bagasse (M) | 9 | 38% | 12 | 47% |
| P2.3 Molasses (M) | 70 | 77% | 81 | 88% |
| P2.3 Soyabean Oilcake Meal (M) | 135 | 80% | 147 | 87% |
| P2.3 Urea (M) | 0 | 0% | 0 | 0% |
| P2.3 Feedgrade Sulpher (M) | 0 | 0% | 0 | 0% |
| P2.3 Salt (M) | 0 | 0% | 0 | 0% |
| Totals | 2095 | 43% | 2582 | 53% |

### Metabolizable Energy

| Feed Name | ME (MJ/day) | ME Concentration (MJ/kg) |
|---|---|---|
| Potch Highveld Grass | 28.5 | 6.3 |
| P2.3 Bagasse (M) | 0.1 | 5.7 |
| P2.3 Molasses (M) | 1.1 | 11.6 |
| P2.3 Soyabean Oilcake Meal (M) | 2.1 | 12.1 |
| P2.3 Urea (M) | 0.00 | 0.00 |
| P2.3 Feedgrade Sulpher (M) | 0.00 | 0.00 |
| P2.3 Salt (M) | 0.00 | 0.00 |
| Totals | 7.57 | 6.5 |

# Nitrogen Excretion

## Feed Nitrogen Influx

| Feed Name | Feed-N | Fecal-N | N-Utilized | Purchased Feed-N | Purchased Fecal-N | Purchased N-Utilized |
|---|---|---|---|---|---|---|
| | (g/day) | | | | | |
| Potch Highveld Grass | 29 | 8 | 21 | 29 | 8 | 21 |
| P2.3 Bagasse (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Molasses (M) | 1 | 0 | 1 | 1 | 0 | 1 |
| P2.3 Soyabean Oilcake Meal (M) | 14 | 0 | 14 | 14 | 0 | 14 |
| P2.3 Urea (M) | 12 | 0 | 12 | 12 | 0 | 12 |
| P2.3 Feedgrade Sulpher (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| P2.3 Salt (M) | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | |
| Totals | 56 | 9 | 47 | 56 | 9 | 47 |

## Animal Nitrogen Requirements

| | | Metabolizable | Net | Urinary |
|---|---|---|---|---|
| | | | | |
| **Maintenance** | *Scurf* | 1 | 1 | |
| | *Tissue* | 10 | 10 | |
| | *Metabolic Fecal* | 38 | 38 | |
| | *Total* | 49 | 49 | 0 |
| | | | | |
| **Pregnancy** | | 0 | 0 | 0 |
| | | | | |
| **Lactation** | *True Protein (NPN not included)* | 0 | 0 | 0 |
| | | | | |
| **Growth** | | 0 | 0 | 0 |
| | | | | |
| **Total** | | 49 | 49 | 0 |

## Bacterial Nitrogen Flow

Total Bacterial Nitrogen : 66 (g/day)
Total Absorbed Bacterial Nitrogen : 49 (g/day)
Bacterial Nitrogen Utilized (Post-Absorption) : 40 (g/day)

Bacterial Nucleic Acids (Urinary) : 10 (g/day)
Bacterial Excess Nitrogen (Urinary) : 0 (g/day)
Fecal Bacterial Nitrogen : 16 (g/day)

**Nitrogen Excretion**

| | Fecal (g/day) | | | Urinary (g/day) |
|---|---|---|---|---|
| *Feed* | 9 | | *Bacterial Excess Nitrogen* | 0 |
| *Bacterial* | 16 | | *Bacterial Nucleic Acids* | 10 |
| *Metabolic Fecal Nitrogen* | 38 | | *Met. to Net Supply* | 0 |
| | | | *Tissue Turnover (Maintenance)* | 10 |
| | | | | |
| *Total* | 63 | | *Total* | 20 |

**Total Nitrogen Excretion**

| | |
|---|---|
| Fecal | 63 (g/day) |
| Urinary | 20 (g/day) |
| Total | 83 (g/day) |

**Nitrogen Distribution (% of Total Nitrogen Intake)**

Fecal : 113.9%
Urine : 35.2%
Manure : 149.1%
Milk : 0.0%
Growth : 0.0%
Pregnancy : 0.0%
Maintenance : 88.2%

**Digestibility of Nitrogen**

Total Ration Nitrogen : 84.3%
Purchased Nitrogen : 84.3%
Home Grown Nitrogen : 0.0%

## Carbohydrate Fermentability

| | | | B2 CHO | | | | B1 CHO | | |
|---|---|---|---|---|---|---|---|---|---|
| Feed Name | A (%D | NDF (%DM) | % of NDF | g/d ay | B1 (%DM | B1 (%NS | % of B1 | g/d ay | Total CHO |
| | | | | | | | | | |
| Potch Highveld | 10.6 | 75.4% | 39.0% | 134 | 1.2% | 10.1% | 91.6 | 50 | 41.0% |
| P2.3 Bagasse (M) | 0.0% | 88.5% | 42.0% | 9 | 0.0% | 100.0 | 0.0% | 0 | 37.2% |
| P2.3 Molasses (M) | 82.5 | 0.5% | 13.2% | 0 | 0.4% | 0.5% | 83.5 | 0 | 81.9% |
| P2.3 Soyabean | 28.3 | 14.8% | 21.4% | 5 | 1.8% | 6.0% | 81.4 | 2 | 32.4% |
| P2.3 Urea (M) | 0.0% | 0.0% | 0.0% | 0 | 0.0% | 0.0% | 0.0% | 0 | 0.0% |
| P2.3 Feedgrade | 0.0% | 0.0% | 0.0% | 0 | 0.0% | 0.0% | 0.0% | 0 | 0.0% |
| P2.3 Salt (M) | 0.0% | 0.0% | 0.0% | 0 | 0.0% | 0.0% | 0.0% | 0 | 0.0% |
| | | | | | | | | | |
| Totals | 12.4 | 71.2% | 38.9% | 135 | 1.2% | 8.7% | 91.0 | 53 | 41.0% |