
**The potential of improving napier
grass under smallholder dairy farmers'
conditions in Kenya**

Promotor:

Dr. ir. S. Tamminga

Hoogleraar op het vakgebied van de veevoeding in
het bijzonder de voeding van herkauwers

Co-promotors:

Dr. C.K. Gachuri

Lecturer, Department of Animal Production,
University of Nairobi, Kenya.

Dr. G.K. Gitau

Research Associate, International Livestock Research
Institute (ILRI), Nairobi, Kenya.

The potential of improving napier grass under smallholder dairy farmers' conditions in Kenya

John N. Kariuki

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Kariuki, J.N., 1998. The potential of improving napier grass under smallholder dairy farmers' conditions in Kenya. Dairy farming is the main livestock enterprise in the mixed crop/livestock farming system in the high rainfall areas of Kenya. These areas are characterised by a high human population density and very small farms. As a consequence, napier grass (*Pennisetum purpureum*) has been widely adopted because of its relatively high dry matter yield and suitability as a cut fodder. The conventional methods of improving napier grass quality through fertilization or use of concentrates to supplement napier grass diets is limited because most farmers cannot afford these inputs. This has led to poor animal performance mostly attributed to the low protein content in napier grass. The most vulnerable group are heifers which receive far less attention compared to calves and cows. This is reflected by low weight gain (less than 0.25 kg day⁻¹) and poor reproductive and life-time performance. Fortunately, several protein-rich forages (PRF) which have the potential to improve the quality of napier grass-based diets have been identified. These include *Desmodium* spp., *Calliandra calothyrsus*, *Leucaena leucocephala*, *Ipomoea batatas*, *Medicago sativa*, *Musa sapienta*, *Trifolium semipilosum* and *Canna edulis*. The benefits of using PRF include improved rumen function, increased energy and protein intake, improved feed efficiency, increased availability of minerals and vitamins, and generally enhanced animal performance. Appropriate and adequate information on the nutritive value of napier grass at different stages of growth and the PRF would facilitate ration formulation, allow more reliable prediction of subsequent animal performance and assist in the planning of suitable feeding strategies for the resource poor dairy farmers. Therefore, the overall objective of the study was to evaluate the nutritive value of napier grass and determine the potential for improvement in animal performance using PRF. Results from this thesis indicated that intake and utilization can be improved by manipulating the cutting regime of napier grass and varying the levels of PRF supplements. Indeed, PRF had a profound effect on fermentation and subsequently improved the intake of organic matter fermented in the rumen by up to 50%. Protein supplementation strategies for low crude protein tropical grasses should first target at optimising microbial protein production and then consider supplements containing a combination of ruminally degradable and bypass protein for high animal performance. Inadequately fed heifers grow poorly and show poor reproductive performance. The positive growth response obtained from the supplemented heifers were attributed to additional rumen degradable protein and/or bypass protein from PRF that overcame protein deficiency in napier grass. It was concluded that PRF could play an important role in the improvement of the utilization of napier grass and the subsequent animal performance. The data provided in this study, on the nutritive value of these forages will, consequently, facilitate making appropriate choices for diet formulation at the farm level.

PhD thesis, Animal Nutrition Group, Department of Animal Science, Wageningen Agricultural University, Marijkeweg 40, 6709 PG, Wageningen, The Netherlands.

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Statements

1. Supplementation strategies for low protein napier grass should first target at optimising microbial protein production in the rumen and then consider supplements containing a combination of rumen degradable and bypass protein.

This thesis

2. Unsupplemented napier grass diets are likely to be inefficiently utilized because such diets generally lead to sub-optimal rumen ammonia levels.

This thesis

3. Most micro-minerals are present in napier grass at potentially limiting levels to allow optimum animal performance.

This thesis

4. The quality of napier grass is very important because poor quality cannot be fully compensated by increased proportions of supplement in the diet.

This thesis

5. Inter-cropping napier grass with legumes is an under-exploited agronomical practice in tropical countries.

This thesis

6. In Kenya, feed quantity and quality are more often limiting factors for animal production than either marketing or infrastructure.

7. Smallholder farmers opt to adjust the animal production target to the feed available rather than adjusting the feed to fit the animal production target.

8. A scientific researcher must always think of himself as a member of a jury. His only concern should be the adequacy of the evidence and the proofs which support it.

9. Throughout the history of scientific research we find observers leaping too quickly from phenomenon to theory; hence they fall short of the mark and become theoretical.

10. Thinking man has a strange trait. When faced with an unsolved problem he likes to concoct a fantastic mental image, one he can never escape from even when the problem is solved and the truth revealed.

11. He who beholds a phenomenon will often extend his thinking beyond it; he who merely hears about the phenomenon will not be moved to think about it at all.
12. Integrated animal production systems is not a recent invention. "Solomon's daily provisions were ten head of stall-fed cattle, twenty of pasture-fed cattle, a hundred sheep and goats, as well as deer, gazelles, roebucks and choice fowl."

1 Kings 2:22-23

John N. Kariuki - The potential of improving napier grass under smallholder dairy farmers' conditions in Kenya - Wageningen, November 25, 1998.

He causeth the grass to grow for the cattle, and herb for the service of man : that he may bring forth food from the earth.

Psalms 104:14

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Chapter 1

General Introduction

General Introduction

Background

Kenya is situated astride the equator on the eastern part of Africa. It covers an area of approximately 582,600 km² (Jaetzold and Schimdt, 1983). The human population is estimated at about 30 million (UNPF, 1998). Kenya's economy is mainly dependent on agriculture with the main exports in order of importance being tea, coffee and horticultural products. The most important food crops are maize, wheat, potatoes and kales (locally known as sukuma wiki). Livestock have been kept by the different communities for centuries and remain an important sector of Kenyan agriculture.

The country has a wide range of climatic conditions ranging from thick tropical forest to very arid zones. Most of the country (80%) has sparse and erratic rainfall and cannot therefore reliably support rain-fed agricultural crops. Temperature and rainfall differ markedly between areas, largely due to variations in altitude. Thus, areas that are relatively close can have widely divergent climate and hence agricultural potential. There are also considerable variations in soil types with most soils having low fertility (Jaetzold and Schimdt, 1983). The major agro-ecological zones are shown in Table 1.

Table 1: Classification of land on the basis of ecological zones

Ecological zone and Potential	Proportion of total area	Rainfall	Land use
High (I-III)	12%	850-1400 mm	Agricultural land
Medium (IV)	6%	750-850 mm	Marginal agric. land
Low (V & VII)	74%	< 750 mm	Arid and semi arid
Others	8%	-	Lakes & mountains

Source: Sombroek *et al.*, (1982).

Livestock production

Livestock represents a valuable asset in both traditional and modern agriculture in Kenya. They provide meat, milk, skin, eggs, dowry, draught power and manure. For some pastoral communities such as the Maasai, Boran, Somali and Turkana, they are an essential part of the social system, representing a family's wealth and social status and are regarded as the only way of survival. The livestock population per species is estimated at 13 million cattle, 8.7 million sheep, 10.3 million goats, 0.7 million camels, 0.4 million donkeys, 0.2 million pigs and 28 million chicken (MALDM, 1993). Except for dairy cattle, exotic chicken and pigs, the majority of the other livestock species are indigenous reared predominantly in arid and semi-arid regions of the country.

Dairy cattle constitute an estimated 3.5 million head (MALDM, 1993), the majority of which are crosses between zebu (*Bos indicus*) and exotic dairy breeds (*Bos taurus*) and occasionally pure breeds of the latter such as Friesians, Ayrshire, Guernseys and Jerseys. Most of the dairy herd (80%) is kept by smallholders although few specialised large scale farms make a significant contribution to the dairy sector primarily through sale of breeding stock to smallholder farmers.

Smallholder dairy cattle production

Over 80% of the dairy cattle population is found on mixed crop/livestock farms (zone I-III) where on average, 2 to 3 cows are kept (Gitau *et al.*, 1994). Due to high human population density in the region, land is a limiting resource and the mean holding size is less than 2 hectares (Nyangito, 1992). This suggests that if dairy enterprise is to thrive and be economically viable, it has to be intensified. Three dairy production systems can be distinguished namely zero grazing, semi-zero grazing and free grazing (Stotz, 1979). The type of system adopted and the main feed resources used are usually determined by the farm size. The first two systems are the most common and free grazing is restricted to few areas. Feeds vary from purposely grown fodders such as napier grass, crop residues and legumes to road-side grass.

Napier grass (*Pennisetum purpureum*) is the most important feed resource under the smallholder zero and semi-zero grazing systems (Anindo and Potter, 1994). Under these systems, the main constraints to dairy cattle farming have been identified as inadequate feeds especially during the dry season and the generally low nutritive value of available roughages (Abate and Abate, 1991). This has been established to be true for napier grass which has low protein content and low digestibility (Anindo and Potter, 1986; Wouters, 1987) which reduce the efficiency with which it is utilized by dairy cattle. On Kenyan farms, a mean crude protein content of 76 g kg⁻¹ dry matter (DM) was reported (Wouters, 1987).

In 1980, the Ministry of Livestock Development started the National Dairy Development Project (NDDP) whose main objective was to promote smallholder dairy farming in the high potential areas. Consequently, NDDP advised farmers on napier grass management, feeding and other aspects of "zero grazing package" (De Jong, 1996). Through these extension efforts, napier grass became popular among the smallholders. However, the adoption of napier grass was not immediately translated into improved animal production because majority of farmers neither used concentrates to supplement napier grass diets nor applied fertilizers to the grass to improve its quality. This was because most farmers were resource poor and could not afford the inputs (Valk, 1990). The NDDP therefore introduced legumes such as *Desmodium intortum* (Snijders, *et al.*, 1992), *Calliandra calothyrsus* (Kaitho *et al.*, 1993) and leucaena (Mureithi *et al.*, 1995) to be used as supplements to napier grass diets. This added to the list of protein-rich forages (PRF) already documented as useful livestock fodders in Kenya which included sweet potato vines (*Ipomea batatas*) and *Medicago sativa*, banana leaves/stems (*Musa sapienta*), Kenya white clover (*Trifolium semipilosum*) and edible canna (*Canna edulis*) (Karachi, 1982; Boonman, 1993). Crude protein contents in PRF are often above 170 g kg⁻¹ DM (D'Mello and Devendra, 1995) and therefore have the potential to improve animal performance when fed in combination with low quality napier grass.

However, little information is documented on animal performance when these PRF are used in combination with napier grass (Muinga, *et al.*, 1995;

Abdulrazak, *et al.*, 1996). Besides, most the existing chemical composition data of napier grass and the PRF are from Weende proximate analysis (Abate *et al.*, 1984; Wandera, 1997) which alone is an inadequate predictor of nutritive value. Indeed, proximate constituents are neither linked to the digestion process nor to animal performance. The system currently being used in the country is therefore unsatisfactory to assess the nutritional adequacy of napier grass and other forages. Factors such as protein degradation in the rumen and the digestion of bypass protein are of paramount importance. Assessment of Kenyan forages using the newer and more accurate methods of feed evaluation are necessary to conform with the current international practices. This would avoid relying on data from other countries for feed formulation which often overlooks the considerable variations in nutritive value resulting from differences in soils, climate and farming practices.

The benefits of using PRF as protein supplements include improved energy and protein intake, improved feed efficiency, increased availability of minerals and vitamins, improved rumen function and generally enhanced animal performance (Norton and Poppi, 1995). Since PRF can be easily grown on the farm, they are sustainable and would enable the farmer to reduce production costs. However, an appropriate choice of PRF must take into consideration its nutritive value as predicted from both chemical composition and animal responses in feeding trials, and more importantly its suitability to the region and acceptability by the farmer.

The overall objective of the study was therefore to evaluate the nutritive value of napier grass and determine the potential for improvement using PRF and subsequently assess animal performance. The more specific objectives were :-

1. To determine rumen degradation and intestinal digestion of protein in napier grass and other Kenyan forages used by smallholders dairy farmers.
2. To determine the effect of supplementing napier grass with sweet potato vines and desmodium on feed intake and rumen fermentation.

3. To determine the effect of maturity on the mineral composition of two varieties of napier grass during two growing seasons.
4. To determine the effect of feeding napier grass, lucerne and sweet potato vines as sole diets to dairy heifers on nutrient intake, live-weight gain and rumen degradation.
5. To determine the performance of Friesian and Sahiwal heifers fed on napier grass supplemented with graded levels of lucerne.
6. To determine the effect of feeding napier grass/desmodium mixture on intake and weight gains of heifers.
7. To determine the effect of desmodium, sesbania and calliandra supplementation on growth of dairy heifers fed napier grass basal diet.

Thesis outline

This thesis describes the nutritive value of napier grass with or without protein-rich supplements. The general introduction (Chapter 1) gives an overview of smallholder dairy cattle farming in Kenya and the main constraints associated with the use of napier grass as the main feed resource. In Chapter 2, the characteristics of napier grass and the factors limiting its utilization as ruminant feed with respect to Kenya are reviewed. Chapter 3 examines rumen degradation and intestinal digestion of protein in napier grass and other Kenyan that can be used in combination with napier grass. The effects of supplementing napier with sweet potato vines and desmodium on intake and rumen fermentation patterns are described in Chapter 4. In Chapter 5 the mineral profile of macro- and micro-minerals in napier grass as influenced by stage of maturity and season was studied. The effect of feeding napier grass, sweet potato vines and lucerne as sole diets for growing heifers is presented in Chapter 6. Subsequently, in Chapters 7, 8 and 9, the effects of supplementing napier grass with graded levels of different protein-

rich forages on intake, digestibility and live-weight gains using dairy heifers are presented. In Chapter 10 (general discussion), the contributions and conclusions of the results described in previous chapters are discussed with respect to practical implications for the smallholder dairy farmer.

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Chapter 2

Napier grass: Its potential and limitations as a ruminant feed

Napier grass: Its potential and limitations as a ruminant feed

Origin and characteristics

Napier grass (*Pennisetum purpureum*), also known as elephant grass is a perennial forage native to eastern and central Africa. Its natural habitat is rain forest margins and river-beds, areas characterised by high soil fertility and rainfall (Boonman, 1993; Bogdan, 1977). The grass has been introduced to all tropical regions of the world. The grass is named after Colonel Napier, who early this century urged Rhodesia's (now Zimbabwe) Department of Agriculture to explore the possibilities of using napier grass for commercial livestock production (Boonman, 1997). The name "elephant grass" is probably more associated with the African elephant's (*Loxodonta africana*) special preference for napier grass.

Napier grass is a robust, tall perennial forage with mature plants reaching up to 4 m in height and having up to 20 nodes (Henderson and Preston, 1977). However, dwarf "Mott" napier grass recently bred at the Hannah Research Station in Gainesville, Florida, has a maximum height of about 1.5 m (Hanna and Monson, 1988). Unlike the tall napier grass, this new dwarf variety is leafy and non-flowering. The tall napier grass resembles sugar-cane in habit and adaptation. Napier grass is propagated vegetatively because seeds have low genetic stability and viability (Humphreys, 1994).

Climatic and soil requirements

Napier grass grows optimally at the temperature range of 25 to 40°C but ceases to grow below 10°C (Bogdan, 1977). It requires over 1000 mm of well distributed rainfall per annum for optimum growth, although it can tolerate mild drought due to its deep roots (Skerman and Riveros, 1990). The giant napier grass cannot withstand frost in contrast to the dwarf type which is frost-tolerant (Legel, 1990). Deep, fertile loams soils produce the best forage growth (Skerman and Riveros, 1990).

Uses

The principal use of napier grass is as a forage for ruminants. Studies have been conducted on napier as a feed for cattle (Ruiz *et al.*, 1992; Sollenberger and Jones, 1989; Anindo and Potter, 1986), goats (Richards *et al.*, 1994; Larbi *et al.*, 1991; Van Eys *et al.*, 1986, 1987), sheep (Rao *et al.*, 1993; Njwe and Chifon, 1991; Dixon and Mora, 1983), horses (Ferreira *et al.*, 1995) and fish (Chikafumbwa, 1996). Other reported non-feed uses include its role as a mulch in plantation crops and for soil erosion control in hilly areas (Niang *et al.*, 1998; Kamau, 1976). Its potential as a raw material in paper manufacturing (Thykeson *et al.*, 1998; Ferraris, 1980) and as a reinforcement in cement-based roofing tiles (Ayyar and Mirilagalla, 1979) have also been explored.

Dry matter yield

Available data indicate that the potential dry matter (DM) yield of napier grass surpasses that of other tropical grasses (Humphreys, 1994; Skerman and Riveros, 1990). This is the main reason for its popularity among smallholder dairy farmers in Kenya (Anindo and Potter, 1994). Reported on-farm DM yield from different regions of the country averaged about 16 tons ha⁻¹ per year (Wouters, 1987) with little or no fertilizer. However, reported yields within the country vary between 10 and 40 tons DM ha⁻¹ depending on soil fertility, climate and management (Schreuder *et al.*, 1993). These DM yields contrast with those of Rhodes grass (*Chloris gayana*) and Kikuyu grass (*Pennisetum clandestinum*), popular pasture grasses which yield between 5 and 15 tons DM ha⁻¹ in the country (Boonman, 1993).

Comparable napier grass DM yields have been recorded elsewhere in the tropics (Woodard and Prine, 1991; Ferraris and Sinclair, 1980). Exceptionally high DM yields of up to 85 tons DM ha⁻¹ have been cited when high rates of fertilizer were applied to napier grass (Skerman and Riveros, 1990). However, DM yield alone may be of limited utility if it is not closely related to DM intake of the animals. At the farm level, the combination of DM yield and observed DM intake can form the basis for estimating the number of livestock units that could be supported by nutrient yield from the available forage land.

Nutritive value

Nutritive value has been defined as the amount of feed ingested and the efficiency with which nutrients are extracted from a given feed (Norton and Poppi, 1995). From this perspective, the nutritive value of napier grass has not been fully known as the bulk of the available literature is on its agronomy. Previous studies on napier grass in eastern Africa have concentrated on aspects such as effects of climate, fertilizers and cutting interval on DM yield, and to a lesser extent on leaf:stem ratio, proximate composition and *in vitro* digestibility (Anindo and Potter, 1994; Wouters, 1987; Karanja, 1984; Reid *et al.*, 1973). Similar studies have been reported from other parts of the world (Chaparro and Sollenberger, 1997; Mislevy *et al.*, 1989). Compared to other well known tropical pasture grasses such as *Digitaria decumbens*, *Chloris gayana*, *Pennisetum clandestinum* and *Panicum maximum*, relatively few data exist on the effects of feeding napier grass on animal performance (Minson, 1990; Minson and McLeod, 1970).

Napier grass is not ideal for grazing because it shows poor persistence under grazing conditions. Compared to other grasses, its growth habit is also a hindrance to uniform grazing. The consequence of this is that there has been little reported work on animal performance on grazed napier grass. Recently, the dwarf napier grass was bred for grazing purposes (Sollenberger and Jones, 1989; Ruiz *et al.*, 1992). Despite its impressive performance in south-eastern USA, dwarf napier grass has not been adopted by smallholder dairy farmers due to its relatively low DM yields (Sotomayor *et al.*, 1997) and its high susceptibility to the fungal snow-mould disease, *Cowdria sphaeroides*, under Kenyan conditions (Boonman, 1997). Smallholder farmers therefore prefer the giant napier grass which is well suited for the intensive "cut-and-carry" feeding system.

The nutritive value of forages is mainly determined by voluntary intake, crude protein and structural carbohydrates. Forage intake is influenced by digestible DM and CP content and the extent of degradation (Minson, 1990). The structural polysaccharides composed primarily of cellulose and hemicellulose are primary restrictive determinants of nutrient intake. The digestibility of forages in the rumen is related to the proportion and extent of lignification (Van Soest, 1994). Chemical composition and digestible DM may be poor indicators of nutritive value of napier

grass because the former fails to take into account nutrient availability whilst the latter does not provide the profile of the absorbed nutrients. Therefore, if nutritive value is to be of practical importance, the ultimate measure would be animal performance. It has been well documented that animal performance is closely associated with the capacity of a feed to promote effective microbial fermentation in the rumen and to supply the quantities and balances of nutrients required for different productive states (Beever, 1997; Sniffen *et al.*, 1992; AFRC, 1992). Thus milk yield or weight gain should closely relate to intake, forage composition and digestibility.

In ruminants, the use of CP or digestible CP to determine nitrogen value is regarded as inadequate because they ignore the role of rumen microbes (AFRC, 1992; Tamminga *et al.*, 1994). Yet, even in all-forage diets as is the case under smallholder conditions, protein quality of each dietary component is important in evaluating responses to supplementation. The current protein evaluation systems partition feed nitrogen into the amount degraded in the rumen and that which escapes rumen degradation (Hvelplund, 1985; INRA, 1988; NRC, 1989; AFRC, 1992; Tamminga *et al.*, 1994). The systems are based on the concept that the nitrogen (N) requirement of rumen microbes is distinct from the requirements of the host animal, which is met by the protein escaping the rumen along with the microbial protein. Thus, determining rumen degradation of dietary protein and the amount that passes through the rumen and subsequently becomes available for digestion by the host animal is important. This information is lacking for napier grass and other Kenyan forages.

Norton and Poppi (1995) have suggested that in order to rank the nutritive value of forages, the main attributes to be considered should include:-

- potential for voluntary intake
- potential digestibility to support high rates of fermentative digestion
- high rates of propionic acid production in the rumen (glucogenic) relative to total volatile acid (VFA) production.
- capacity to provide nutrients (protein, starch, lipid) that bypass the rumen and are absorbed from the small intestine.

The existing knowledge on these attributes with respect to napier grass is limited.

Chemical composition and digestibility

Chemical composition is a major determinant of animal production from tropical grasses (Skerman and Riveros, 1990; Minson, 1990). As napier grass matures, the leaf:stem ratio declines (Kariuki, 1989; Karanja, 1984) causing a change in the chemical composition with a concomitant reduction in feeding value (Minson, 1990). In theory, chemical composition of a forage could affect ruminant performance at both plant and animal levels. At the forage level, species could differ in quality and in the extent and rate of ruminal degradation and hence influence the yield of fermentable substrate. At the animal level, quality could affect voluntary feed intake and animal performance in terms of milk yield or body weight gains. The increases in age in grasses is usually negatively associated with CP content (Minson, 1990; Norton, 1981). The results summarised by Skerman and Riveros, (1990), Woodard and Prine (1991) and Williams and Hanna (1995) confirm this for napier grass. Furthermore, it has been recognised that the rate of decline in CP content in napier grass is more rapid in stems than in leaves (Brown and Chavalimu, 1985).

The cell wall, composed primarily of the structural carbohydrates cellulose and hemicellulose, is the most important factor affecting forage utilization (Van Soest, 1994). It comprises the major fraction of forage DM and its extent of degradation by the microflora has important implications on forage digestibility and intake (Paterson *et al.*, 1994). The cell wall content in napier grass has been shown to increase less prominently with age compared with other tropical grasses such as Kikuyu grass and Pangola grass (Minson and McLeod, 1970) and ranges between 650 to 750 g kg⁻¹ DM. Whereas other tropical grasses showed a daily decline of 0.30 to 0.50 units of DM digestibility, napier grass only declined with 0.20 units per day (Reid *et al.*, 1973) which was lower than the mean of 0.26 unit per day for tropical forages (Minson, 1990).

This observation makes napier grass an attractive feed since it can retain a given level of digestibility for a slightly longer period compared with other grasses cultivated in the tropics. Stobbs and Thompson (1975) reported that OM digestibility of most tropical grasses ranged from 50 to 60% which is consistent

with observations by Minson (1990). The data summarised in Table 1 agrees with these previous reports. However, in well fertilized fields, Chaparro and Sollenberger, (1997) recorded a range of 65 to 79% *in vitro* DM digestibility for the dwarf napier grass. It is important to bear in mind that climate, soil fertility, cutting interval and other management practices have very profound influence on chemical composition and digestibility of napier grass.

At the farm level, the CP content does not always satisfy the 60 to 80 g kg⁻¹ DM which is considered as the minimum requirements for optimum rumen microbial activity (Minson and Milford, 1967). A study covering all the main napier grass growing regions in Kenya showed that the mean CP level at the farms was 76 g kg⁻¹ DM (Wouters, 1987). Results from other regions of the world as summarised by Gohl (1981) and from Kenya as reviewed by Schreuder *et al.*, (1993) indicate that the CP values commonly recorded for napier grass lie between 50 and 90 g kg⁻¹ DM. Observations from other recent studies are generally in agreement as shown in Table 1. These results contrast to those of dwarf napier grass whose CP content has been reported to lie between 80 and 150 g kg⁻¹ DM (Chaparro and Sollenberger, 1997; Flores *et al.*, 1993; Sollenberger and Jones, 1989) under good management and high fertilizer application.

Mineral composition

Inadequate availabilities of macro-mineral elements calcium (Ca), phosphorus (P), sulphur (S), potassium (K), sodium (Na), chlorine (Cl), and magnesium (Mg), and a range of micro-mineral elements may lead to deficiency diseases in ruminants and may limit fibre digestion and microbial protein synthesis (Hannah and Gates, 1990; Durand and Kawashima, 1980). Of particular importance here is the availability of P for nucleic acid formation and S for the synthesis of sulphur amino acids. Calcium is closely related to P metabolism and a calcium ratio of 2:1 is recommended for ruminants (ARC, 1980).

Although Minson (1990) has extensively reviewed the mineral content of several tropical forages, data on the mineral composition of napier grass is scanty. The available data are mainly on Ca and P (Gohl, 1981) with little on the other

Table 1. Chemical composition (g kg⁻¹ DM) and digestible organic matter (g kg⁻¹ DM) of napier grass

Reference	CP	NDF	ADF	ADL	DOM
Serra <i>et al.</i> , 1996	106	668	397	18	-
Devasena <i>et al.</i> , 1993	82	714	-	-	550
Abate and Abate, 1991	90	706	436	58	-
Van Eys <i>et al.</i> , 1986	119	733	441	69	505
Muinga <i>et al.</i> , 1993	72	-	-	-	504
Anindo and Potter, 1994	110	705	-	63	560
Muinga <i>et al.</i> , 1995	64	690	-	-	515
Kariuki <i>et al.</i> , 1998	118	587	301	47	571
Abdulrazak <i>et al.</i> , 1996	79	680	-	-	554
Anindo and Potter, 1966	86	-	413	39	-
Grant <i>et al.</i> , 1974	60	658	450	70	543
Ibrahim <i>et al.</i> , 1995	8.6	647	364	32	634

DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre; ADL = acid detergent lignin; DOM = digestible organic matter.

mineral elements. Recently, Serra *et al.*, (1996) reported the mineral composition of napier grass (Table 3). When contrasted with the required dietary concentrations for ruminants, the authors concluded that napier grass is likely to be deficient in most of the minerals considered.

Mineral deficiencies for Ca, P, Co, Mo, Zn and Cu have been reported in some parts of Kenya and this has been attributed to low soil fertility including non-availability of minerals to the forages caused by soil factors (Jumba *et al.*, 1995a,b; Abate, 1994; Mwakatundu, 1977). It has been recommended that dairy cattle should be given a balanced mineral mixture (MLD, 1991). This general guideline, however, fails to define what constitutes a "balanced" mineral mixture and therefore existing mineral formulation for the smallholder dairy farmer may be based

Table 2. Mineral composition of napier grass

Mineral	Ca	P	Mg	K	Cu	Zn	Mo	Co	Mn	Fe
	(g kg ⁻¹ DM)				(mg kg ⁻¹ DM)					
Concentration	3.5	2.0	1.7	8.0	7.1	50.4	14.4	2.0	33	404
Critical level	3.0	2.5	2.0	0.7	10	30	6	0.1	35	30

Source: Serra *et al.*, 1996.

on unsound assumptions since little is known on mineral composition of napier grass under Kenyan conditions. Feed intake and performance from napier grass have been improved through mineral supplementation (Prabowo *et al.*, 1983) which suggests that mineral levels in napier grass are likely to be below microbial requirements. Effect of season on DM yield and quality

The dry and wet season in Kenya are characterised by remarkable differences in rainfall and temperature (Jaetzold and Schimdt, 1983) which considerably influences DM yield and quality of napier grass fed to dairy cattle. Water-deficit depresses forage yield in the dry season and has a negative effect on CP concentration (Buxton and Mertens, 1995). Temperature temperatures are also relatively high during the dry season and this has been reported to reduce digestibility (Minson and McLeod, 1970). Recent results in Kenya by Anindo and Potter (1994) confirm this and indicate that seasonal variation could cause drastic changes in DM yield and quality characteristics (Table 3).

Conservation

Napier grass can be conserved into silage but the quality of silage obtained would depend upon fresh grass quality, ensiling process and use of additives (Yokota and Ohshima, 1997; Ruiz *et al.*, 1992; Cuhna and Silva, 1977). Successful ensiling which maximises nutrient preservation is achieved by harvesting the crop

Table 3. Effect of season on yield and quality of napier grass

Component	wet season	dry season
DM yield (kg DM ha ⁻¹ day ⁻¹)	178	25
CP (g kg ⁻¹ DM)	148	82
NDF (g kg ⁻¹ DM)	742	629
DM digestibility (%)	0.72	0.56
DM intake (kg ⁻¹ 100 kg BW)	2.7	2.5

Source: Anindo and Potter, (1994); DM = dry matter; CP = crude protein; NDF = neutral detergent fibre; BW = body weight.

at the proper age; minimizing the activities of plant enzymes and undesirable epiphytic microorganisms (naturally present on forage crops); and encouraging the dominance of lactic acid bacteria (Bolsen, 1995). Napier grass has low fermentable sugars and therefore energy sources such as bran and molasses have been found to enhance silage quality (Yokota and Ohshima, 1997; Snijders and Wouters, 1990).

In the dry season, beef cattle fed on napier grass silage lost less body weight compared with those on pasture (Cuhna and Silva, 1977). However, napier silage was of lower quality than maize silage because milk yield declined when the former was substituted for the latter in dairy cattle (Ruiz *et al.*, 1992). In some eastern and coastal regions of Kenya, prolonged dry season could last up to 6 months (Jaetzold and Schimdt, 1983), and during that period, dairy cattle could be sustained on ensiled napier grass (Valk, 1990). Occasionally, excess napier grass is available in the wet season (Anindo and Potter, 1994), and ensiling the surplus is a better option since leaving the napier grass to overgrow would compromise the quality. However, the proportion of farmers doing ensiling is small, a fact attributed to lack of technical know-how on small scale silage making (Valk, 1990).

Table 4: Quality of silage from chopped napier grass added 6% molasses

	DM loss (%)	pH	Ac (%)	Bu (%)	NH ₃ -N (%)	DM (%)	CP (%)	DOM (%)
Fresh napier	-	-	-	-	-	25.7	9.2	60.5
Napier silage	2	4.9	0.2	0.2	11	24.1	8.5	56.6

DM = dry matter; Ac = Acetic acid; Bu = Butyric acid; NH₃-N = Ammonia nitrogen; CP = crude protein; DOM = digestible organic matter.

Source: Snijders and Wouters (1990).

Napier grass ensiling has advantages over maize or sorghum because it is a perennial forage and can therefore be harvested over several seasons. Snijders and Wouters (1990) demonstrated that chopped napier grass wilted for one day and to which molasses (6%) was added produced good silage as evidenced by the levels of pH, volatile fatty acids, CP, ammonia nitrogen and organic matter digestibility (Table 4). Attempts have also been made to make hay out of napier grass (Brown and Chavalimu, 1985, Manyuchi *et al.*, 1996) but the thick and succulent napier grass stem limits the rate of drying (Snijders *et al.*, 1992a).

Animal Performance

Whilst considerable information is available on the chemical composition of napier grass, little is known on intake and animal performance. However, based on the available information, supplementary nutrients are necessary to obtain acceptable levels of performance from cattle fed on napier grass. Within the smallholder dairy farming system, the recommended weaning weight for dairy heifers is 70 kg body weight and a target 300 kg, to be attained by 18 months of age for first service (MLD, 1991). This recommendation assumes that heifers would gain at least 0.5 kg day⁻¹ but in practice, less than 0.25 kg is observed on smallholder farms (Gitau *et al.*, 1994), and therefore puberty is not achieved until after 24 months. This is attributed to the low quality of napier grass fed on the

farms and the absence of concentrate nutrients (Wouters, 1987). However, regardless of the feed type, it is important that heifers are fed in such a way that adequate body size is achieved at puberty to maximise on life-time productivity. Though several factors are known to influence age and weight at puberty, nutrition is among the most important (Bagley, 1993).

Previously, the potential of napier grass for weight gain in cattle has been investigated with or without energy or protein supplements. The results obtained appear to differ widely depending on napier grass quality, cattle species and the level and type of supplement used. Friesian heifers gained between -0.13 and 0.80 kg day⁻¹ when fed on napier grass varying in maturity from flowering to early vegetative stage (CP 63 to 96 g kg⁻¹ DM) and achieved a daily DM intake of 2.1 to 3.1 kg per 100 kg body weight (Arias, 1979). Dixon (1984) obtained a weight gain of 0.72 ± 0.21 kg day⁻¹ from Holstein heifers fed 60 to 65 day old napier grass of unspecified CP content supplemented with 0.2, 0.4 and 0.8% molasses on body weight basis. The author noted no significant influence of molasses on both weight gain, FE and DM intake.

Protein-rich forages (PRF) which can be used in combination with napier grass are endowed with the important attributes of high protein content, palatability and digestibility relative to grasses. For example while the mean protein content of tropical grasses has been reported as 75 g kg⁻¹ DM, that for tropical forage legumes averaged 170 g kg⁻¹ DM (D'Mello and Devendra, 1995). Fortunately, several species have been documented as useful supplements to napier grass which include *Desmodium spp.* (Snijders, et al., 1992b), *Calliandra calothyrsus* (Kaitho et al., 1993) and *Leucaena leucocephala* (Mureithi et al., 1995), *Ipomea batatas* (vines), *Medicago sativa*, *Musa sapienta* (leaves/stems), *Trifolium semipilosum* and *Canna edulis* (Boonman, 1993; Karachi, 1982).

However, few studies have been conducted in which napier grass is fed to cattle in combination with PRF such as legumes. Nevertheless, an ideal forage supplement should increase or at least maintain intake of basal roughage rather than substitute for it (McMeniman et al., 1988). The PRF overcome protein deficiency in tropical grasses forage (Minson, 1990), by providing ruminally

degradable and by-pass protein (Norton and Poppi, 1995; Brandt and Klopfenstein, 1986). In a study where gliricidia and leucaena were used to supplement two groups of zebu steers (mean body weight 173 and 208 kg) offered napier grass *ad libitum*, significant differences were observed in weight gain and DM intake across similar levels of supplementation (Abdulrazak *et al.*, 1996) as summarised in Table 5. These differences in the response between gliricidia and leucaena were remarkable suggesting that the variations depend partly upon factors intrinsic to the supplement and partly to the quality of napier grass fed.

Weight gains from cattle grazing tropical pastures without supplementation range between 0.4 and 0.5 kg day⁻¹ (Stobbs and Thompson, 1975) with an upper limit given as 0.7 kg day⁻¹ (Humphreys, 1994). However, such weight gains are difficult to achieve in the dry season because the grass quality is normally too low and more often animals would lose weight (Preston and Leng, 1987). Sometimes, these weight gain limits may be exceeded when factors such as compensatory gain or when a new technology is used as was the case when beef steers grazing on the new dwarf napier grass gained 0.97 kg day⁻¹ without supplementation (Sollenberger and Jones, 1989).

Studies conducted using sheep and goats have indicated similar trends in that intake, digestion and weight gains improved when energy and protein supplements were included in napier grass diets (Richards *et al.*, 1994; Yates and Panggabean, 1988; Van Eys *et al.*, 1986, 1987).

The mean milk yield in smallholder farms in Kenya is less than 2000 kg cow⁻¹ year⁻¹ (Abate and Abate, 1991). Although it has been established that commercial concentrate supplements could boost milk yield by about 50% under Kenyan conditions (Anindo and Potter, 1986), widespread use is limited by their high costs (Valk, 1990). In a recent study, Muinga *et al.*, (1995) demonstrated that supplementing *Bos indicus* x *Bos taurus* cows fed napier grass *ad libitum* (CP 64 g kg⁻¹ DM) with varying levels of leucaena improved milk production by about 28% (Table 6).

Table 5. Influence of gliricidia and leucaena on DMI and weight gain of zebu steers fed on napier grass

	Level of supplementation (g kg ^{0.75})				
	0	7.5	15	22.5	30
Experiment 1					
DMI (kg day ⁻¹)					
Napier (CP = 76)	5.2	4.7	4.5	4.3	4.2
Gliricidia (CP = 210)	0	0.4	0.7	1.1	1.5
Total	5.2	5.1	5.2	5.4	5.7
Gain (kg day ⁻¹)	0.31	0.36	0.43	0.37	0.48
Experiment 2					
DMI (kg day ⁻¹)					
Napier (CP = 79)	5.2	5.3	5.3	5.3	5.1
Leucaena (CP = 220)	0	0.5	0.9	1.3	1.7
Total	5.2	5.8	6.2	6.6	6.8
Gain (kg day ⁻¹)	0.54	0.71	0.72	0.79	0.85

Source: Abdulrazak *et al.*, 1996; DMI = dry matter intake; CP = crude protein (g kg⁻¹ DM)

Table 6. Effect of leucaena supplementation on dry matter intake milk yield

	Leucaena level (kg fresh day ⁻¹)			
	0	4	8	8*
DM intake (kg day ⁻¹)				
Napier grass	6.3	6.6	5.9	5.7
Total	6.3	7.6	7.9	8.7
DMI g kg ^{0.75}	75	82	92	102
Milk yield (kg day ⁻¹)	5.1	5.4	5.5	6.5

Adopted from Muinga *et al.*, (1995); DMI = dry matter intake.

* 1.2 kg maize bran offered (CP 95 g kg⁻¹ DM; DOM = 75%).

In a study using dairy goats, supplementation of napier grass with *Erythrina spp.* foliage enhanced milk production (Benavides, 1986). In this study, total DM intake was enhanced although some substitution effect was detected. Improved weight gain have also been reported in lambs fed on napier grass supplemented with *Erythrina spp.* (Esnaola and Rios, 1986).

Conclusion

The constraints to napier grass utilization in smallholder dairy farms in Kenya and the possibilities for improvement have been discussed in this review. Its chemical composition and other nutritional factors known to influence animal production have also been highlighted. The lack of sufficient data on its nutritive value has often led to inappropriate ration formulation. Dependence on data from outside Kenya has been questioned because of the considerable variation in nutritive value of napier grass associated with differences in soil, climatic and farming practices between countries. It is therefore necessary that the conditions that prevail in smallholder dairy farms in Kenya are taken into account so that the research results are relevant. Results discussed indicated that even though dairy cattle fed on napier grass as a sole diet could produce some milk and elicit some gain weight, the performance is generally less than optimum and supplementation is therefore necessary to improve performance. On-farm and research station data indicated that the protein content of napier grass is often low. It was mentioned in the discussion that conservation of napier grass in smallholder farms such as small scale silage making has received little attention. Conserved napier grass can assist considerably in preserving quality as well as boosting the feed supply to the dairy cattle during the dry season. Most literature on silage making is from large scale and mechanised systems, aspects that are not applicable to the smallholder dairy farmers in Kenya. Little is also known about palatability and animal production from napier grass silage.

Available evidence indicates that incorporation of legumes and other PRF could markedly improve performance from napier grass but this potential has not been fully studied. How well these forages may be substituted for commercial

protein concentrates is important. There is lack of information on this aspect resulting to low adoption and impact on the farms. Other factors could be responsible for the low adoption among them insufficient information on how to grow the PRF. It should, however, be appreciated that none of these factors operate independently and it is difficult to assess their relative importance in determining animal production when considered in isolation. For optimum utilization of napier grass and the possible protein supplements, it is essential that details of nutritive value including potential animal performance are determined. Studies addressing intake, rumen degradation, supplement effect on rumen fermentation, bypass protein and protein digestion are necessary. This should culminate in animal feeding trials where the actual nutritive result can be translated into milk production or weight gains. There is also need to validate research station results on the farms. Social-economic aspects such as adoption rate and the benefits of using protein-rich forages versus napier alone or napier grass with commercial concentrates need to be addressed. This would ensure that only cost-effective and easily adopted options are given priority in research and development efforts.

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Chapter 3

Rumen degradation and intestinal digestion of protein in napier grass and other Kenyan forages

J. N. Kariuki¹, H. Boer², S. Tamminga², G. K. Gitau³, C.K. Gachui⁴ and J. M. Muia¹

¹ National Animal Husbandry Research Centre,
P.O. Box 25, Naivasha, Kenya.

² Institute of Animal Sciences,
Wageningen Agricultural University,
Animal Nutrition Group, Marijkeweg 40,
6700 AH, Wageningen, The Netherlands.

³ Department of Animal Production,
University of Nairobi, P.O. Box 29053, Nairobi, Kenya.

⁴ International Livestock Research Institute,
P.O. Box 30709, Nairobi, Kenya.

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J. N. Kariuki, H. Boer, S. Tamminga, G. K. Gitau, C.K. Gachuri and J. M. Muia

Abstract

Eighteen forages species used by smallholder dairy farmers in Kenya (seven grasses and 11 non-grasses) were evaluated for dry matter (DM) and crude protein (CP) rumen degradation and the total tract protein digestion using the mobile nylon bag (MNB) and *in vitro* pepsin/pancreatin *in vitro* techniques (IV). Forage species considered varied significantly ($P < 0.05$) in DM and CP degradation. The CP soluble fraction (W) differed significantly among forages ($P < 0.05$) although the means for grasses (245 g kg^{-1} CP) and non-grasses (242 g kg^{-1} CP) were comparable. However, the rate of degradation (k_d) and bypass protein (BP) were significantly greater ($P < 0.05$) in non-grasses than in grasses. The highest BP ($P < 0.05$) were estimated for *Desmodium spp.* and *A. xanthophloea* as reflected in their lower RDP ($P < 0.05$). The ratio between rumen degradable protein (RDP) and rumen fermentable organic matter (DOMR) in grasses was too low to allow optimum microbial protein (MP) production. The digestibility coefficients obtained by the IV method were slightly higher than those for the MNB procedure but there was a significant linear relationship between the MNB and IV results, implying that intestinal CP digestion could reliably be estimated by *in vitro* methods. It was concluded that protein supplementation strategies for low CP tropical grasses should firstly target at optimising microbial protein production and then consider supplements containing a combination of ruminally degradable and bypass protein for high animal performance.

Key words: Grasses, non-grasses, protein, degradation, digestibility.

Introduction

In most tropical countries, 90 to 100% of ruminant diets are composed of grasses and crop residues (Aufrère and Guérin, 1996) which are low in protein content and lead to low animal performance (Minson, 1990; Humphreys, 1994). Protein-rich forages (PRF) such as legumes are cultivated to maintain soil fertility and supplement ruminant diets because the majority of the smallholder farmers cannot afford commercial concentrates. These forages are high in protein, palatability and digestibility relative to the grasses (Minson, 1990; Boonman,

1997). For instance, while the mean protein content of tropical grasses is just above 75 g kg⁻¹ DM that of legumes is 170 g kg⁻¹ DM (D'Mello and Devendra, 1995).

Napier grass is the predominant feed resource in smallholder dairy farms in Kenya even though it is low in crude protein (CP) content (Wouters, 1987; Muinga *et al.*, 1995). During periods of feed shortage, other grasses and crop residues which are similarly low in protein are also used (Boonman, 1997). Recently, several PRF have been introduced as suitable supplements (Snijders *et al.*, 1992; De Jong, 1996). However, existing data on most of these forages are mainly on proximate composition (Gohl, 1981; Abate *et al.*, 1984; Wandera, 1997) which bears little relation to nutrient content and availability. In all-forage or forage based diets, protein quality of each dietary component is important in evaluating responses to supplementation. The current protein evaluation systems partition feed protein into the amount degraded (RDP) in the rumen and that which escapes rumen degradation (ARC, 1984; Hvelplund, 1985; INRA, 1988; NRC, 1989; AFRC, 1992; Tamminga *et al.*, 1994). The new protein systems are based on the concept that the nitrogen (N) requirements of the rumen microbes is distinct from that of the host animal, which is met by the protein escaping the rumen (BP) along with the microbial protein (MP). The efficiency of MP production is related to the amount of rumen fermentable organic matter (DOMR) available in the diet (ARC, 1984; Tamminga *et al.*, 1994). It is estimated that MP production is 150 g kg⁻¹ DOMR (Tamminga *et al.*, 1994). The amount of nitrogen apparently digested in the small intestine is a good indication of the protein available to the host animal (Van Straalen, 1995). Protein available for post-ruminal absorption is influenced by the amount of forage protein that is resistant to rumen degradation plus MP (Brown and Pitman, 1991; Kaitho *et al.*, 1998). Therefore, the total amount of protein available is dependent on the flow of microbial and dietary protein to the duodenum and their respective intestinal digestibilities. While the chemical composition of the Kenyan roughages has been previously reviewed (Lamprey *et al.*, 1980; Gohl, 1981; Abate *et al.*, 1984; Wandera, 1997) there appears to be no published data on rate and extent of digestion.

The objective of the study was therefore to assess dry matter (DM) and CP degradation in the rumen and estimate intestinal digestion of forages commonly used by Kenyan smallholder dairy farmers.

Materials and methods

The study was conducted at the National Animal Husbandry Research Centre, Naivasha, Kenya (0° 40' S, 36° 26' E, 1900 m altitude) between October, 1996 and January, 1998. The mean annual rainfall for the study site is 620 mm with a mean annual temperature of 18°C (Jaetzold and Schimdt, 1983).

Six grasses, one grass/legume mixture, eight legumes and three other forages were studied. These were (1) grasses: *Pennisetum purpureum* (Napier grass, fresh or ensiled with 2% molasses), harvested at 6 or 12 weeks; *Pennisetum clandestinum* (Kikuyu grass); *Panicum maximum* (Guinea grass), *Chloris gayana* (Rhodes grass); *Cynodon plectostachyus* (Naivasha star grass) and *Tripsacum daniellii* (Guatemala grass), all harvested at 8 weeks of regrowth from 2-4 year old fields. The fields received 100 kg each of nitrogen (N), phosphorus (P₂O₅), and potassium (K₂O) fertilizers per hectare annually; (2) grass/legume: napier/desmodium (green-leaf) grown as an inter-crop; (3) legumes: *Trifolium semipilosum* (Kenya white clover), *Medicago sativa* (Lucerne) grown in plots measuring about 30 m² and harvested after 8 weeks of regrowth; *Desmodium intortum* (green-leaf), *Desmodium uncinatum* (silver-leaf) grown on similar plots but harvested after 12 weeks; *Sesbania sesban*, *Calliandra calothyrsus*, *Leucaena leucocephala* and *Acacia xanthophloea* harvested (trimmed) after 12 weeks from existing hedge-rows; (4) other forages: *Musa sapienta* (banana leaves and stems) obtained from plants estimated to be about 24 weeks old; *Ipomoea batatas* (sweet potato vines) and *Canna edulis* grown 30 m² harvested after 12 weeks of regrowth.

Rumen degradation

Four Friesian steers (441 kg, SD = 11.7), each surgically fitted with a rumen fistula, were used for rumen degradation studies. The animals were housed individually. Each animal received *ad libitum* young napier grass (6 weeks; CP = 115 SD = 1.3, NDF = 629, SD = 14.1, g kg⁻¹ DM) throughout the study period. Mineral salts and clean water were available all the time. Dry matter (DM) and N degradation of each forage species was determined using the nylon bag technique. The diet samples were ground through a 3 mm sieve and portions of about 5 g DM placed in polyamide bags (Nybold, Switzerland, porosity 26% mesh size 40 µm, size 6 cm x 12 cm). The bags were incubated in the rumen for 3, 6, 12, 16, 24,

48, 96 and 336 hours. A zero hour residue was obtained by soaking the bags in a water-bath at 38°C for 5 minutes. The incubated bags were washed in tap water for 5 minutes and dried in the oven at 70°C for 24 hours. The dried samples were weighed to determine the DM residue.

Mobile nylon bag procedure (MNB)

The rumen incubation residues for 16 and 24 hours were used to estimate protein digestion in the lower gut. These were pooled per species and incubation time and were ground through a 1 mm sieve. These time points were selected to approximate the digestion of the forages that escape the rumen at the rates of 6 and 4%, respectively. The residues were weighed into quantities of 0.5 g DM per mobile bag (6 cm x 7 cm, same material as above) in quadruplicate per forage and per incubation time.

The intestinal incubation was done using four lactating Holstein/Friesian cows (650 kg, SD = 20.4) with a duodenal cannula in a complete randomised block design. Prior to intestinal incubation, the bags were incubated in 0.1 mol l⁻¹ HCl solution containing 1 g pepsin per litre (Merck 107190) for 1 hour at 38°C. Four bags were inserted in the duodenum every 20 minutes from 06.00 to 18.00 hours. Bags were recovered between 6 and 48 hours later from the faeces. Bags were collected at each defaecation by washing the faeces in a sieve with tap water and they were immediately frozen. For analysis, bags were thawed and washed with cold water in a washing machine without spinning. They were then oven-dried at 70°C for 24 hours. The residues were pooled per forage type, incubation time and animal, ground in a mortar and analyzed for DM and N.

The initial protein content of 16 and 24 hour rumen samples were regarded as rumen bypass protein, while protein loss from the mobile nylon bags was regarded as intestinally digested. The protein residue after 336-hour rumen incubation was defined as truly indigestible protein (U).

***In vitro* procedure (IV)**

The whole tract CP digestibility with the MNB technique was compared with that determined by an *in vitro* (IV) method. Rumen samples prepared as described in the MNB method were pooled per sample. The *in vitro* enzyme digestibility was

measured according to the method adapted from Calsamiglia and Stern (1995) for forage samples. Dried 16-hour rumen incubated residues containing 15 mg N (about 94 mg CP) were incubated for 1-hour in 20 ml of a 0.1 mol l⁻¹ HCl solution containing 1 g l⁻¹ pepsin (Sigma P-6887). After incubation, the solution was neutralised with 1.5 ml of 1.0 N NaOH and 13.5 ml of a phosphate buffer (pH 7.8) containing 37.7 mg of pancreatin (Sigma P-7545) added to the solution. The mixture was incubated at 38°C with continuous magnetic stirring. After 24 hour incubation, the mixture was cooled in ice and filtered through nitrogen free, ashless flocc (Whatman No. 1704010) and thoroughly rinsed with demineralised water. The indigestible N content of the sample was determined by the Kjeldahl method. From the indigestible N content the digestibility coefficient was calculated.

Chemical analysis

Dry matter (DM) was determined using the methods of Association of Analytical Chemists (AOAC, 1990). The forage samples prior to and after incubations were oven-dried at 70°C for 24 hours. They were then ground to pass through a 1 mm Wiley mill screen. Kjeldahl nitrogen and ash were determined according to AOAC (1990) standard procedures. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were obtained using the method of Van Soest and Robertson (1985).

Calculations and statistical analysis

The rumen DM and CP degradation at various incubation times were expressed as residues of original amounts incubated and the results fitted to the model described by Robinson *et al.*, (1986):-

$$R_t = U + (1000 - W - U) * e^{-k_d * t}$$

where,

R_t = residue at time t

U = truly indigestible residue (336-hour incubation)

W = water soluble fraction (0-hour incubation)

k_d = rate of degradation (fraction per hour)

The organic matter apparently fermented in the rumen (DOMR) was estimated from DM degradation characteristics according to Van Vuuren *et al.*, (1991):-

$$\text{DOMR (g kg}^{-1} \text{ DM)} = [W + (D * k_d / (k_p + k_d))] * \text{OM}$$

where, D is the slowly but potentially degradable DM proportion (OM of the residue was not determined but was assumed to disappear uniformly with DM). The rate of passage was presumed to be 0.04 hour⁻¹ (Lechner-Doll *et al.*, 1990).

Similarly, using CP degradation results, protein escaping rumen degradation was calculated from the equation (Perera *et al.*, 1992):-

$$\text{BP} = U + D(k_p / (k_p + k_d))$$

where,

k_p = the passage rate of 0.04 hour⁻¹

D = the potentially degradable proportion (1000-W-U).

Rumen degradable protein was (RDP) was calculated as:-

$$\text{RDP} = W + D(k_d / (k_p + k_d))$$

Similarly, intestinal digestible protein (IDP) was estimated as:-

$$\text{IDP} = D(k_p / (k_p + k_d))$$

The analysis of variance for CP, DM degradation characteristics, MNB and IV intestinal protein digestibility results for the forages was done using the general linear model (GLM) in SAS (1988) according to the following model:-

$$Y_{ij} = \mu + S_i + B_j + e_{ij}$$

where,

Y_{ij} = disappearance of DM or CP after intestinal incubation,

μ = mean,

S_i = forage species effect,

B_j = animal effect

e_{ij} = residual error, assumed to be normally and independently distributed

Regression analysis was carried out to establish the relationship between mobile nylon method (MNB) and the *in vitro* enzymatic procedure (IV). This was also done to establish the correlation between whole tract protein digestion for different rumen pre-incubation times (T16 against T24).

Results

The chemical composition of the forages is shown in Table 1. The CP content of grasses ranged from 33 g kg⁻¹ DM (silage, from 6 weeks old *P. purpureum*) to 95 g kg⁻¹ DM (6 weeks *P. purpureum*), while that of non-grasses was lowest for banana leaves/stems (68 g kg⁻¹ DM) and highest for *C. calothyrsus* (224 g kg⁻¹ DM). The CP content was also relatively high for *T. semipilosum*, *L. leucocephala* and *M. sativa* (> 200 g kg⁻¹ DM) while the mean for the grasses was less than 80 g kg⁻¹ DM. The average ADL for non-grasses was generally higher than for the grasses.

The DM degradation characteristics of the forages incubated in the rumen of steers are summarised in Table 2. There were significant differences ($P < 0.05$) between and within grasses and non-grasses. The soluble (W) and potentially degradable (D) components were significantly higher ($P < 0.05$) for *P. purpureum* (6 weeks and silage) than for other grasses. Napier/desmodium mixture showed intermediate degradation compared to most values in either of the two groups. The variation within grasses was lower than within non-grasses. High degradation values were noted for *T. semipilosum*, *M. sativa*, *L. leucocephala*, *S. sesban*, *M. sapienta*, *I. batatas* and *C. edulis*, significantly raising the mean for the non-grasses ($P < 0.05$). *Acacia xanthophloea* was the least degradable forage species.

The soluble fraction (W) for CP differed significantly among forages ($P < 0.05$) but the mean for grasses (245 g kg⁻¹ CP) and non-grasses (242 g kg⁻¹ CP) were comparable (Table 3). The k_d and D means for non-grass forages were significantly greater than for grasses ($P < 0.05$). Similarly, the mean bypass protein (BP) for non-grasses was significantly higher ($P < 0.05$) than for grasses in accordance with the observed k_d values. Significantly greater ($P < 0.05$) BP proportions were estimated for *Desmodium spp.* and *A. xanthophloea* which were

Table 1. Chemical composition (g kg⁻¹ DM) of forages

Species	DM	OM	CP	NDF	ADF	ADL	Ash
(a) Grasses							
<i>Pennisetum purpureum</i>							
6 weeks	132	823	95	542	289	44	177
12 weeks	174	903	52	638	329	56	97
silage (6 weeks)	420	816	74	431	271	39	184
silage (12 weeks)	468	875	33	546	311	48	125
<i>Pennisetum clandestinum</i>	183	893	82	682	324	32	107
<i>Cynodon plectostachyus</i>	167	946	73	715	310	45	154
<i>Panicum maximum</i>	221	892	78	696	381	38	108
<i>Chloris gayana</i>	194	890	81	725	366	49	110
<i>Tripsacum laxum</i>	176	900	75	698	280	77	100
Mean	237	882	71	630	317	48	129
(b) Grass/legume mixture							
Napier/desmodium	157	852	99	634	314	52	148
(c) Legumes							
<i>Desmodium intortum</i>	223	889	183	714	432	112	111
<i>Desmodium uncinatum</i>	196	904	179	729	389	131	96
<i>Trifolium semipilosum</i>	124	920	219	398	327	21	80
<i>Medicago sativa</i>	189	911	206	428	296	72	89
<i>Leucaena leucocephala</i>	241	895	216	498	369	98	105
<i>Sesbania sesban</i>	236	854	199	321	237	61	146
<i>Acacia plectostachyus</i>	264	939	185	410	289	64	61
<i>Calliandra calothyrsus</i>	219	879	224	530	480	120	121
(d) Others							
<i>Musa sapienta</i>							
(leaves/stems)	97*	886	68*	587	405	68	114
<i>Ipomoea batatas</i> (vines)	103	907	175	497	284	51	93
<i>Canna edulis</i>	88*	898	131	564	351	64	102
Mean (legume + others)	199	907	192	516	351	78	102

DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre; ADL = acid detergent lignin.

* Omitted from mean since outside normal ranges.

Table 2. Dry matter (DM) degradation characteristics (W, D, U (g kg⁻¹), k_d (% hour⁻¹) and DOMR (g kg⁻¹ DM) of the forages

Species	W	D	k _d	U	DOMR
(a) Grasses					
<i>Pennisetum purpureum</i>					
6 weeks	239	513	3.1	248	642
12 weeks	197	451	2.8	352	512
silage (6 wk)	269	476	3.3	255	646
silage (12 wk)	224	424	3.5	352	513
<i>Pennisetum clandestinum</i>	179	501	2.9	320	526
<i>Cynodon plectostachyus</i>	206	449	3.6	345	468
<i>Panicum maximum</i>	205	457	3.1	338	519
<i>Chloris gayana</i>	228	432	3.5	340	515
<i>Tripsacum dactyloides</i>	238	418	3.7	344	506
Mean	221	458	3.3	324	539
(b) Grass/legume mixture					
Napier/desmodium*	252	498	3.9	250	592
(c) Legumes					
<i>Desmodium intortum</i>	175	518	3.6	307	508
<i>Desmodium uncinatum</i>	183	494	3.8	323	483
<i>Trifolium semipilosum</i>	316	624	5.1	60	642
<i>Medicago sativa</i>	263	611	4.2	126	616
<i>Leucaena leucocephala</i>	263	574	3.9	163	619
<i>Sesbania sesban</i>	280	597	4.1	123	673
<i>Acacia xanthophloea</i>	98	312	2.5	590	309
<i>Calliandra calothyrsus</i>	223	485	3.3	292	556
(d) Others					
<i>Musa sapienta</i>					
(leaves/stems)	321	566	5.1	113	643
<i>Ipomoea batatas</i> (vines)	325	601	5.5	74	637
<i>Canna edulis</i>	333	567	4.6	100	665
Mean (legumes + others)	253	541	4.2	206	577
SED	8.4	1.6	0.2	17.2	14.8

W = soluble fraction; D = slowly but potentially degradable fraction; k_d = rate of degradation (% hour⁻¹); U = truly indigestible residue (336 hour incubation); *napier desmodium mixture was grown as an inter-crop; SED = standard error of difference.

reflected in their respectively lower RDP ($P < 0.05$). Although the IDP mean for grasses ($210 \text{ g kg}^{-1} \text{ CP}$) was lower than non-grasses ($256 \text{ g kg}^{-1} \text{ CP}$), *P. pennisetum*, and *C. plectostachyus* had significantly higher IDP than the other grasses. The forage species *M. sativa* and *I. batatas* (non-grasses) showed greater IDP content than all other forages. The RDP/DOMR ratio was significantly higher for non-grasses (0.16) than for grasses (0.06) except in *Desmodium spp.*, *M. sapienta*, *I. batatas* and *C. edulis* which showed unfavourable ratios.

The mean whole tract protein digestion (16-hour) for grasses ($721 \text{ g kg}^{-1} \text{ CP}$) was greater than for non-grasses ($686 \text{ g kg}^{-1} \text{ CP}$) a similar trend being evident for the 24-hour rumen pre-incubation (Table 4). The CP digestibility after 16-hour pre-rumen incubation estimated by MNB (DCP₁₆) was significantly lower ($P < 0.05$) than that estimated by the *in vitro* method (IV₁₆). The regression relationship between the two methods was high and significant as indicated in Figure 1 and in the following regression equation (S.E. in parentheses):-

$$\text{DCP}_{16} = -3.17 (20.3) + 0.98 (0.04) \text{IV}_{16} \quad (R^2 = 0.97, P < 0.001).$$

The rumen pre-incubation time (16 or 24 hour) showed little effect on whole tract digestion. Similarly, the relationship was highly significant ($P > 0.001$) as depicted in Figure 2 and the regression equation (S.E. in parentheses):-

$$\text{T}_{16} = 49.2 (58.6) + 0.92 (0.08) \text{T}_{24} \quad (R^2 = 0.87, P < 0.001).$$

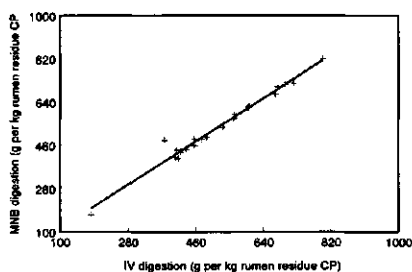


Figure 1. Relationship between MNB and IV digestion.

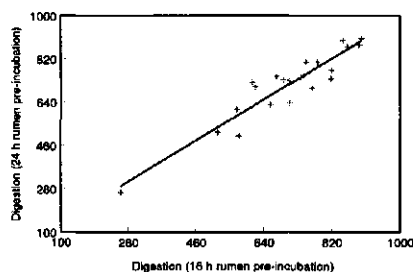


Figure 2. Relationship between 16-hour and 24-hour rumen incubation on whole tract digestion.

Table 3. Crude protein degradation constants, indigestible CP (U), bypass protein (BP), rumen degradable protein (RDP) and intestinal degradable protein (IDP) of forages (g kg⁻¹ of original forage CP)

Forage species	CP	Degradation constants							
		W	k _d	U	D	BP	RDP	IDP	RDP/DOMR
(a) Grasses									
<i>Pennisetum purpureum</i>									
6 weeks	95	246	4.4	280	474	506	494	248	0.07
12 weeks	52	213	3.2	307	480	574	426	213	0.04
silage (6 wk)	74	248	3.1	277	475	545	455	207	0.05
silage (12 wk)	33	228	2.6	282	490	579	421	193	0.03
<i>Pennisetum clandestinum</i>	82	251	3.4	311	438	548	452	201	0.07
<i>Cynodon plectostachyus</i>	73	254	5.1	262	484	475	525	271	0.08
<i>Panicum maximum</i>	78	234	2.4	289	477	587	413	179	0.06
<i>Chloris gayana</i>	81	257	2.9	295	448	555	445	188	0.07
<i>Tripsacum daniellii</i>	75	271	2.0	305	424	541	459	188	0.07
Mean	71	245	3.2	290	465	546	454	210	0.06
(b) Grass/legume mixture									
Napier/desmodium	99	228	3.1	219	553	531	469	361	0.08
(c) Legumes									
<i>Desmodium intortum</i>	183	199	3.3	440	361	638	362	244	0.13
<i>Desmodium uncinatum</i>	179	218	3.1	427	355	627	373	214	0.14
<i>Trifolium semipilosum</i>	219	366	4.5	143	491	374	626	260	0.21
<i>Medicago sativa</i>	206	275	8.1	232	493	395	605	330	0.20
<i>Leucaena leucocephala</i>	216	251	6.9	231	518	421	579	328	0.20
<i>Sesbania sesban</i>	199	301	4.2	113	586	399	601	300	0.18
<i>Acacia xanthophloea</i>	185	148	3.3	544	308	713	287	139	0.23
<i>Calliandra calothyrsus</i>	224	265	3.9	291	444	516	484	219	0.20
(d) Others									
<i>Musa sapienta</i>									
(leaves/stems)	68	206	5.8	224	570	457	543	148	0.06
<i>Ipomoea batatas</i>									
(vines)	175	217	4.3	123	660	441	559	342	0.15
<i>Canna edulis</i>	131	214	5.4	284	502	498	502	288	0.10
Mean (legumes + others)	181	242	4.8	277	481	498	494	256	0.16
SED	-	8.2	0.2	6.9	-	-	-	-	-

W = soluble fraction; D = slowly but potentially degradable fraction; k_d = rate of degradation (% hour⁻¹); U = truly indigestible residue (336 hour incubation); *napier desmodium mixture was grown as an inter-crop; SED = standard error of difference.

Table 4. Mean disappearance of DM and CP in the rumen (g kg⁻¹ of original forage), intestine (g kg⁻¹ of rumen CP residual) and total tract (g kg⁻¹ of original forage CP) measured with nylon bag, MNB and *in vitro* methods

Digestion site	Rumen				Intestine			Total tract	
Forage species	DM_16	DM_24	CP_16	CP_24	DCP_16	DCP_24	IV_16	T16	T24
(a) Grasses									
<i>Pennisetum purpureum</i>									
6 weeks	463	489	504	617	697	732	712	850	897
12 weeks	401	436	441	482	678	560	703	820	772
silage (6 wk)	342	387	372	340	457	436	485	658	628
silage (12 wk)	307	332	340	365	409	560	441	610	721
<i>Pennisetum clandestinum</i>	508	563	543	602	457	510	459	752	805
<i>Cynodon plectostachyus</i>	483	521	505	553	561	569	572	783	807
<i>Panicum maximum</i>	389	350	342	397	420	508	432	618	703
<i>Chloris gayana</i>	358	408	395	442	490	520	493	692	732
<i>Tripsacum dactyloides</i>	304	360	335	399	562	396	590	709	637
Mean	395	427	420	466	527	532	543	721	745
(b) Grass/legume									
Napier/desmodium	476	489	501	438	477	542	486	739	743
(c) Legumes									
<i>Desmodium intortum</i>	216	258	235	288	435	451	442	568	609
<i>Desmodium uncinatum</i>	239	264	275	312	414	270	405	575	498
<i>Trifolium semipilosum</i>	575	606	617	649	720	649	717	893	877
<i>Medicago sativa</i>	532	584	580	553	671	708	673	862	870
<i>Leucaena leucocephala</i>	229	286	270	256	601	634	622	709	728
<i>Sesbania sesban</i>	456	529	500	567	798	779	819	899	904
<i>Acacia xanthophloea</i>	-	65	98	112	182	237	171	261	264
<i>Calliandra calothyrsus</i>	184	202	225	226	378	373	480	518	515
(d) Others									
<i>Musa sapienta</i> (leaves/stems)	485	529	450	571	407	408	411	674	746
<i>Ipomoea batatas</i> (vines)	525	557	545	517	599	455	617	818	737
<i>Canna edulis</i>	447	496	504	528	533	361	535	768	698
Mean (legume + others)	359	398	391	416	522	484	536	686	677

DM_16 = dry matter disappearance after 16-hour incubation; DM_24 = dry matter disappearance after 24-hour incubation; CP_16 = crude protein disappearance after 16-hour incubation; CP_24 = crude protein disappearance after 24-hour incubation; DCP_16 = 16-hour digestible crude protein in residue (MNB method); DCP_24 = 24-hour digestible crude protein in residue (MNB method); IV_16 = 16 hour digestible crude protein in residue (*in vitro* method); T16 = digestible crude protein in whole tract based on 16-hour residue (MNB method); T24 = digestible crude protein in whole tract based on 24-hour residue (MNB method); SED = standard error of difference.

Discussion

The data indicated that there was considerable variation between forage species in the rate and extent of DM and CP degradation in the rumen and the subsequent CP digestion in the lower gut. It has been argued that, provided availability is not restricted, dry matter intake (DMI) of tropical forages largely depends upon their rate of DM disappearance which is in turn influenced by chemical composition (O'Reagain *et al.*, 1995). Overall, grasses had lower DM degradation characteristics in terms of proportions and rates of degradation of the soluble and potentially digestible fractions than non-grasses. Similarly, grasses had lower rates of CP degradation but somewhat higher W and D consistent with previous reports on tropical (Mgheni *et al.*, 1994; Ibrahim *et al.*, 1995) and temperate forages (Minson, 1990).

Assuming that the efficiency of conversion of RDP into MP is 85% (Brun-Bellut *et al.*, 1990), about 167 g RDP (ratio 0.167) would produce 150 g MN kg⁻¹ DOMR considered as the optimum microbial yield (Tamminga *et al.*, 1994). This means that a RDP/DOMR ratio of about 0.17 would be ideal for optimum MP production. The observed RDP/DOMR ratios for all the grasses (< 100 g CP g kg⁻¹ DM) were always below this limit suggesting that RDP would restrict rumen fermentation or MP production because of inadequate amino acids and ammonia to match the available energy. Indeed, the importance of RDP lies in its proportion in DOMR and the subsequent availability in the rumen at the right moment. There was surplus RDP in non-grasses except in *Desmodium spp.* and *I. batatas* in which values were slightly below requirements but *M. sapienta* and *C. edulis* had unfavourable RDP/DOMR ratios.

These results indicated that the first limiting factor for ruminants fed tropical grasses is likely to be RDP. Although protein sources with low RDP improve total N flow to the small intestine (Cecava and Parker, 1993; Ludden and Cecava, 1995), high RDP may be beneficial in low CP tropical forages because it would considerably increase DOMR (Kariuki *et al.*, 1998a) and hence MP production. The higher RDP proportion, coupled with the generally greater absolute quantities of CP in non-grasses led to greater overall RDP yield from legumes than from grasses. For

a number of non-grasses, the surplus of RDP was restricted to the W fraction. This would suggest that such supplements should be fed more frequently in small quantities. Van Eys *et al.*, (1986) attributed improved weight gains in goats fed on *P. purpureum* supplemented with *Gliricidia*, *Leucaena* or *Sesbania* to the amount and characteristics of RDP in the legumes and its effect on microbial protein production.

Desmodium spp. and *A. xanthophloea* had high bypass protein but subsequent low IDP. Although tannin levels were not measured in this study, there is evidence to suggest that the two species could have had elevated tannin contents (Kiura, 1992; Kaitho *et al.*, 1998). Tannin levels above 4% in DM could negatively influence digestibility but contents that are below this limit may play a beneficial role by reducing protein degradation in the rumen (Mangan, 1988; Fassler and Lascano, 1995).

Judging from whole tract CP digestion, *A. xanthophloea* had low protein value, *Desmodium spp.* were intermediate while the rest of the non-grasses showed high protein values indicating their suitability as supplements. Although *Musa sapienta* had high quality protein, it could not be considered as a favourite protein source because its total CP was too low (68 g kg⁻¹ DM). Certain forage proteins such as *T. semipilosum*, *S. sesban* and *M. sativa* and showed extensive rumen degradation which was reflected in their low BP. Sweet potato vines, showed similar degradation characteristics consistent with the findings of Kariuki *et al.*, (1998b). In general, the forages studied in this trial provided BP levels ranging from 374 to 713 g kg⁻¹ with apparent digestibility of about 18 to 80% (DCP₁₆). The overall mean apparent digestibility was however much lower than that reported for temperate forages (Van Bruchem *et al.*, 1989; Valk *et al.*, 1996; Van Straalen *et al.*, 1995) but comparable to Kaitho *et al.*, (1998) for tropical forages.

Although there were notable differences in whole tract protein digestion between species, the means for grasses and non-grasses were comparable confirming previous observations that CP digestibility of tropical grasses could be high (Brown and Pitman, 1991; Chiou *et al.*, 1995). To a considerable extent this

observation is in agreement with the fact that only a small proportion of grass CP is bound to cell wall (Aufrère and Guérin, 1996). Protein bound to certain cell wall components like lignin is not degraded in the rumen and is considered indigestible in the intestine (Chalupa and Sniffen, 1996).

The BP proportion of *P. purpureum* silage was greater than that of the corresponding unconserved grass but the IDP was lower. This is compatible with the finding that ensiling forages increases their fraction C proteins (heat damaged and lignin protein) and so intestinal digestibility is reduced (Van Straalen, 1995). This observation could imply that *P. purpureum* silage and probably silage from other tropical grasses are poor sources of IDP.

The results of intestinal digestion showed that digestibility coefficients obtained by IV method were higher than those for the MNB procedure. Similar observations have been made previously by Van Straalen (1995) and Kaitho *et al.*, (1998). This has been attributed to rapid enzyme saturation upon substrate leading to faster rates of protein degradation than observed in *in vivo* trials (Chalupa and Sniffen, 1996). The extent of total intestinal digestibility appeared to be influenced by rumen pre-incubation time which is consistent with previous work by Varviko and Vanhatalo, (1991) and Kaitho *et al.*, (1998) for tropical browses. The rumen incubation time of 16-hours gave lower whole tract digestion for grasses than 24-hour incubation but in non-grasses, the 24-hour result was slightly lower and not significant. However, the results somewhat contrasted to those on temperate forages where rumen incubation times of 12 and 16 hours appeared to have little effect on total intestinal digestion (Valk *et al.*, 1996). Results with concentrates have been variable with certain feeds showing depressed intestinal digestibility of undegraded N and total tract digestibility with increasing rumen incubation times, while others are not significantly affected (Beckers *et al.*, 1996).

The regression relationship between the MNB and IV methods was significant and accounted for 97% of the variation suggesting that the latter method could be a good predictor of intestinal protein digestibility. However, the MNB procedure is known to somewhat overestimate protein digestibility (Hvelplund, 1985) which according to the results from this study would also be

true for the IV method. Fortunately, the procedure has good reproducibility (De Boer *et al.*, 1987) and linear relationship to *in vivo* data (Hvelplund, 1985), which makes it suitable for routine estimation of intestinal digestibility and ranking of feeds according to that coefficient.

Conclusion

Low CP in tropical grasses limit MP production and therefore protein supplementation strategies to such grasses should firstly target at satisfying the rumen microbial requirements. Protein supplements containing a combination of ruminally degradable and bypass protein could then be considered for high animal performance. Using protein-rich forages which showed favourable RDP/DOMR ratios as supplements on grass diets would improve the animals metabolic capacity which would subsequently enhance voluntary intake and animal performance. Further research is necessary to determine how animal performance is influenced when the protein-rich forages are included in grass diets.

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Chapter 4

Intake, DM degradation and rumen fermentation as affected by varying levels of desmodium and sweet potato vines in napier grass fed to cattle

J. N. Kariuki¹, S. Tamminga², C.K. Gachui³, G. K. Gitau⁴, and J. M. K. Muia¹

¹ National Animal Husbandry Research Centre,
P.O. Box 25, Naivasha, Kenya.

² Institute of Animal Sciences, Wageningen Agricultural University,
P.O. Box 338, 6700 AH, Wageningen, The Netherlands.

³ Department of Animal Production, University of Nairobi,
P.O. Box 29053, Nairobi, Kenya.

⁴ International Livestock Research Institute,
P.O. Box 30709, Nairobi, Kenya.

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Intake, DM degradation and rumen fermentation as affected by varying levels of desmodium and sweet potato vines in napier grass fed to cattle

J. N. Kariuki, S. Tamminga, C.K. Gachuri, G.K. Gitau and J. M. K. Muia

Abstract

Two experiments were conducted to assess the effect of the level of desmodium and sweet potato vines (SPV) on dry matter (DM) intake, degradation and rumen fermentation of napier grass. Four fistulated steers were offered diets constituted to contain napier grass with 0, 10, 20 and 30% of desmodium (Experiment A) or SPV (Experiment B) in 4 x 4 latin square. The organic matter (OM) intake increased significantly ($P < 0.05$) with increased level of desmodium (74 to 90 g kg^{-0.75}) and SPV (78 to 94 g kg^{-0.75}). Crude protein intake also increased progressively ($P < 0.05$) with the increase in the levels of desmodium (7.6 to 13.0 g kg^{-0.75}) and SPV (7.9 to 12.9 g kg^{-0.75}). Supplementation also significantly ($P < 0.05$) improved DM degradation. Rumen fermentable organic matter (DOMR) increased by up to 52% and 43% for desmodium and SPV respectively at the highest levels of supplementation. Ammonia nitrogen levels increased significantly ($P < 0.05$) with the level of desmodium (130 to 214 mg l⁻¹) and SPV (139 to 235 mg l⁻¹). Inclusion of desmodium and SPV in the diets led to significant ($P < 0.05$) increases in total and individual volatile fatty acids. This study showed that desmodium and SPV increased intake, degradation and rumen fermentation. It was concluded that the two forage supplements could play an important role in improving animal performance when napier grass is the basal diet.

Key words: Napier, desmodium, sweet potato vines, intake, degradation, fermentation.

Introduction

The low protein content of tropical grasses and crop residues have been cited as a major constraint to animal production (Egan, 1997; Minson, 1990). Napier grass (*Pennisetum purpureum*), the main fodder used by smallholder dairy farmers in Kenya, has a mean crude protein (CP) content of less than 8 g kg⁻¹ dry matter (DM) (Wouters, 1987). For moderate production of dairy cattle, the CP content in the diet should be above 12 g kg⁻¹ DM (ARC, 1984). The low protein

content reported in napier grass not only limits feed intake but also results in inadequate supply of amino acids to be absorbed from the small intestine which subsequently lead to reduced performance. However, napier grass can be presumed to meet most of the energy requirements for cattle reared by smallholder dairy farmers (Muinga *et al.*, 1993).

Since majority of the farmers, do not use the expensive commercial protein sources on cattle or fertilizers to improve napier grass quality, (Valk, 1990), efforts have been made to identify appropriate protein-rich forages grown on the farm which can be optimally combined with napier grass. As a consequence, desmodium (*Desmodium intortum*) has been promoted by the National Dairy Development Project (NDDP, 1990) and has now been widely adopted by small-holder dairy farmers (Snijders *et al.*, 1992; De Jong, 1996). Another alternative has been sweet potatoes (*Ipomoea batatas*) grown as a human food (roots) but the vines are important fodder (Karachi, 1982). The quantities of these forages fed with napier grass as supplements to cattle depends on season, with higher inclusion rates in the wet season than in the dry season (Valk, 1990). However, it has not been established how the inclusion influences the utilization of napier grass and subsequent animal performance.

The objective of this study was, therefore, to determine the effect of supplementing steers fed on a napier grass basal diet with different levels of desmodium and sweet potato vines (SPV) on intake, DM degradation and rumen fermentation.

Materials and methods

Study site

The study was conducted at the National Animal Husbandry Research Centre, Naivasha, in the Kenyan rift valley (0° 40' S, 36° 26' E, 1900 m above sea level) between December, 1996 and June, 1997. The mean annual rainfall for the study site is 620 mm with a mean annual temperature of 18°C (Jaetzold and Schimdt, 1983).

Management of forages

Napier grass (*Pennisetum purpureum*, variety Bana), green-leaf desmodium (*Desmodium intortum*) and SPV (*Ipomoea batatas*, variety Musinya) were grown using the recommended cultural practices (MLD, 1991). Since rain water was not adequate, the forages were irrigated to allow continuous forage growth. Napier grass was harvested for feeding at 8 weeks (about 1.0 m height) while desmodium and SPV were harvested at 12 weeks. The harvesting schedule was such that the forages fed each day were of the same age during the entire experimental period.

Experimental design

Four Friesian steers, (body weight = 411 ± 18 kg; age 22 ± 2 months), fitted with rumen fistulas (10 cm diameter) were used in two 4×4 latin squares. The two feeding experiments were designated A (desmodium supplement) and B (SPV supplement). The steers were drenched with an anti-helminthic at the start of the experiment and thereafter sprayed with an acaricide weekly to control ticks.

In experiment A, the four steers were randomly allocated to the following diets:- napier alone (D1); napier + 10% desmodium (D2); napier + 20% desmodium (D3); napier + 30% desmodium (D4). Each feeding period lasted for 21 days. The initial 10 days were allowed for adaptation to the diets while intake was measured during the next 8 days. Days 19, 20 and 21 were used to sample rumen fluid. In experiment B, sweet potato vines were substituted for desmodium and the new diets were similarly designated as S1, S2, S3 and S4. The procedure in experiment A was then repeated.

The forages were harvested fresh each morning, chopped separately into 2.5 cm pieces and the diets constituted by thorough mixing. The steers were then offered the respective diets *ad libitum* (110% of the previous day's intake) in two equal portions, twice daily. The steers were housed and fed individually. Clean water and mineral supplement were made available to all steers.

Feed sampling and intake measurements

Diet samples were collected daily before morning feeding and composited weekly for analysis. Feed refusals were removed from the troughs and weighed before the morning ration was given. Dry matter intake was estimated by difference between feed on offer and refusals. Samples of these were routinely oven-dried at 105°C for 24 hours to determine DM content.

Rumen fermentation and DM degradation

Rumen fluid was collected from the rumen every three hours on days 19, 20 and 21 throughout the 24 hour period each day. A plastic pipe (about 50 cm in length, inner diameter 15 mm) closed at one end with a cork and perforated with approximately 120 holes of 2.5 mm in diameter was inserted through the fistula and positioned such that the perforated end reached the liquor phase in the ventral sac of the rumen. The rumen liquor was drawn using a sucking equipment improvised by creating a vacuum in a corked plastic container connected to the plastic pipe. Samples of approximately 200 ml were taken at each time. A portion of the rumen sample was acidified (1 ml 20% H₂SO₄ per 5 ml rumen fluid) and kept frozen in tightly capped containers until analysed for ammonia nitrogen (AOAC, 1975). A second portion was acidified with 5% metaphosphoric acid (1 ml acid per 5 ml rumen fluid). This was then centrifuged and kept refrigerated (4°C) in tightly capped containers until assayed for VFA using gas liquid chromatography. A third portion (50 ml) was taken to the laboratory for pH determination.

Rumen degradation of the diets was estimated by incubation of a single composite sample obtained from dried samples fed daily in experiments A and B. The diet samples were ground to pass through a 3 mm sieve, and 5 g placed in nylon bags (Nybold Switzerland; polyamide, porosity 26%, mesh size 40 µm). The bags were incubated for 0, 3, 6, 12 (in duplicate), 24, 48, and 96 hours (in triplicate) in each steer. All the steers received *ad libitum* a basal feed composed of napier grass, desmodium and SPV in the ratio 8:1:1, respectively. After incubation, the nylon bags were washed in tap water for 5 minutes then oven-dried at 70°C for 48 hours. A zero-hour residue was obtained by soaking the bags in a

water-bath at 38°C for 5 minutes then oven-drying in a similar way as incubated samples. The dried samples were then weighed and DM disappearance at the various times of incubation were expressed as proportions in original amounts incubated and the results fitted to the Ørskov and McDonald (1979) exponential model:

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

where P is the DM disappearance at time t, 'a' the zero time intercept, 'b' the slowly degradable fraction and 'c' the rate of degradation. Potential degradability (PD) was estimated as (a+b) while effective degradation was calculated using Ørskov and McDonald (1979) equation:

$$ED = a + bc/(k + c)$$

where, an outflow rate (k) of 0.04 hour⁻¹ (Lechner-Doll *et al.*, 1990) was used. The organic matter fermented in the rumen (DOMR) was subsequently determined as:

$$DOMR = ED * OM \text{ intake.}$$

Chemical analysis

Diet samples for chemical analysis (offered and refusals) were ground to pass through a 1 mm screen using a Wiley mill. The diets were then analysed for DM (105° C for 24 hours), organic matter (OM, ashing at 500° C) and Kjeldahl nitrogen (AOAC, 1990). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analysed using the method of Van Soest and Robertson (1985).

Statistical analysis

The ANOVA procedure was used to compute analyses of variance (SAS, 1988) for DM and nutrient intake and least significant difference (LSD) test applied

to compare diet means. To assess diet effect on pH, rumen ammonia and volatile fatty acids, repeated measure analysis with time as a repeated term was applied. The effects in the statistical models included diet, period and animal effects.

Results

The chemical composition of the diets are shown in Table 1 and 2. The DM content increased progressively with increase in the proportion of desmodium but decreased with increased SPV containing levels. The inclusion of desmodium and SPV in the diets tended to increase OM levels while depressing NDF and ash levels. The ADL in the diet was higher, the higher the proportion of desmodium. The CP content in napier only diets (91 and 89 g kg⁻¹ DM respectively for experiment A and B) was lower than in the supplemented diets. The CP content increased with increased proportion of the supplement in the diet.

Table 1: Chemical composition napier + desmodium^a diets fed to steers (experiment A): DM (g kg⁻¹), OM, CP, NDF, ADL and ash (g kg⁻¹ DM).

Composition	Diet							
	D1	s.d	D2	s.d	D3	s.d	D4	s.d
DM	150	4.1	154	3.9	162	4.7	175	5.6
OM	842	13.2	855	14.4	860	12.3	872	
		16.1						
CP	91	3.5	97	3.7	108	2.5	117	5.8
NDF	603	11.6	591	10.4	583	9.8	575	8.7
ADF	311	7.2	315	6.6	319	5.2	323	6.2
ADL	28	2.2	40	1.2	46	3.1	52	2.9
Ash	158	8.1	153	7.5	147	8.5	143	7.7

^aMean CP for pure desmodium was 175 g kg⁻¹ DM; s.d. = standard deviation; D1 = napier + 0% desmodium; D2 = napier + 10% desmodium; D3 = napier + 20% desmodium; D4 = napier + 30% desmodium; DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre; ADL = acid detergent lignin.

Table 2: Chemical composition napier + sweet potato vines (SPV^a) diets fed to steers (experiment B: DM (g kg⁻¹), OM, CP, NDF, ADL and ash (g kg⁻¹ DM).

	Diet							
	S1	s.d.	S2	s.d.	S3	s.d.	S4	s.d.
DM	146	8.1	141	7.9	136	9.4	128	8.6
OM	829	11.9	841	13.2	853	10.5	867	
12.7								
CP	89	2.9	99	3.2	109	2.5	120	3.2
NDF	614	13.4	581	14.6	573	15.1	565	
13.7								
ADF	318	5.1	319	6.7	320	5.8	321	5.2
ADL	29	1.9	30	2.4	30	1.8	31	1.7
Ash	161	7.7	157	8.3	153	6.9	149	7.5

^a Mean CP for SPV was 189 g kg⁻¹ DM; s.d.=standard deviation; S1=napier+0% SPV; S2=napier + 10% SPV; S3=napier+20% SPV; S4=napier+30%SPV; DM=dry matter; OM=organic matter; CP=crude protein; NDF=neutral detergent fibre; ADF=acid detergent fibre; ADL=acid detergent lignin;

The mean DM, OM, CP and NDF intake are presented in Table 3 and 4. There were significant differences in intake ($P<0.05$) across the diets in experiment A and B. Except for NDF, intake increased with the increase in the levels of desmodium and SPV in the diets. The DM and OM intake for the unsupplemented diets and the 10% supplementation did not significantly differ ($P>0.05$) in both experiments.

The soluble fraction (a) and the rate of degradation (c) were not significantly associated ($P>0.05$) with the levels of desmodium and SPV in the diets in both experiments (Table 3 and 4). The slowly degradable fraction showed a similar trend except in experiment A where D4 was marginally significantly different ($P<0.05$) from the other means. The supplements significantly increased ($P<0.05$) the values of ED and PD. However, the PD between the unsupplemented diets and the 10% supplementation level were not significantly different ($P>0.05$) in both

experiments. The DOMR intake improved significantly ($P < 0.05$) with increase in the level of supplementation from 34.6 to 52.6 g kg^{-0.75} (desmodium) and from 36.3 to 52.0 g kg^{-0.75} (SPV).

The mean values of rumen pH, rumen ammonia nitrogen (NH₃-N), total volatile fatty acids (VFA), molar percentages of each VFA and the acetate:propionate ratio are shown in Table 5 and 6. Although rumen pH was significantly influenced by changes in supplementation level ($P < 0.05$), the fluctuations were small. However, concentration of NH₃-N increased with increasing levels of desmodium and SPV in the diets ($P < 0.05$). Time of sampling significantly affected ($P < 0.05$) NH₃-N concentrations but there were no significant interactions between diet and time of sampling. Maximum NH₃-N concentrations were recorded at 11.00 hours and 20.00 hours, approximately 3 hours after the trough was filled again with new feed. The minimum NH₃-N concentrations were recorded about 12 hours post feeding. The variations in total and individual VFA were significantly associated ($P < 0.05$) with the level of desmodium or SPV in the diets.

Table 3 : The intake (DM, OM, CP and NDF), in sacco rumen degradation and organic matter fermented in the rumen (DOMR intake kg^{-0.75}) of napier grass and desmodium diets fed to steers (Experiment A).

Diet	D1	D2	D3	D4	SED
Intake (kg DM day ⁻¹)					
DM	7.8 ^a	8.1 ^{ab}	8.7 ^{bc}	9.4 ^c	0.37
OM	6.8 ^a	7.2 ^{ab}	7.6 ^b	8.4 ^c	0.27
Intake (g kg ^{-0.75})					
OM	74 ^a	76 ^a	83 ^b	90 ^c	2.13
CP	7.6 ^a	8.5 ^b	11.3 ^c	13.0 ^d	0.15
NDF	53 ^a	52 ^a	51 ^a	51 ^a	1.72
Degradation characteristics (g kg ⁻¹ DM)					
a	197 ^a	189 ^a	186 ^a	190 ^a	4.1
b	492 ^a	481 ^a	488 ^a	453 ^b	8.1
c	0.044 ^a	0.043 ^a	0.046 ^a	0.045 ^a	0.006
PD	667 ^a	688 ^a	727 ^b	715 ^b	9.2
ED	468 ^a	533 ^b	543 ^b	584 ^b	20.7
DOMR intake	34.6	40.5	45.1	52.6	-
% rise in DOMR intake (%)	0	17.1	30.3	52.0	-

D1 = napier + 0 % desmodium; D2 = napier + 10% desmodium; D3 = napier + 20% desmodium; D4 = napier + 30% desmodium.

Table 4 : The intake (DM, OM, CP and NDF), in sacco rumen degradation of napier grass and in sacco rumen degradation and organic matter fermented in the rumen (DOMR intake $\text{kg}^{0.75}$) of sweet potato vines diets fed to steers (Experiment B).

Diet	S1	S2	S3	S4	SED
Intake (kg DM day^{-1})					
DM	8.2 ^a	8.6 ^{ab}	8.7 ^b	9.7 ^c	.17
OM	7.1 ^a	7.5 ^a	7.7 ^b	8.2 ^a	0.19
Intake ($\text{g kg}^{0.75}$)					
OM	78 ^a	80 ^{ab}	86 ^b	94 ^c	2.82
CP	7.9 ^a	8.7 ^b	12.3 ^c	12.9 ^d	0.21
NDF	55 ^a	51 ^{ab}	47 ^{bc}	46 ^c	2.15
Degradation characteristics ($\text{g kg}^{-1} \text{ DM}$)					
a	202 ^a	201 ^a	211 ^a	198 ^a	5.3
b	462 ^a	463 ^a	480 ^a	477 ^a	10.3
c	0.044 ^a	0.044 ^a	0.048 ^a	0.046 ^a	0.006
PD	663 ^a	682 ^a	715 ^b	747 ^c	8.8
ED	465 ^a	515 ^b	541 ^c	553 ^c	5.1
DOMR intake	36.3	41.2	46.5	52.0	-
% rise in DOMR intake	0	13.5	28.1	43.3	-

S1 = napier + 0% SPV; S2 = napier + 10% SPV; S3 = napier + 20% SPV; S4 = napier + 30% SPV; S.E.D = standard error of difference; DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fibre; a = soluble fraction; b = slowly degradable fraction; c = degradation rate; PD = potential degradation; ED = effective degradation; (DOMR intake = OM intake * ED; Within a row figures bearing different superscripts (a, b and c) indicate significance ($P < 0.05$).

Table 5 : Rumen pH, concentration of $\text{NH}_3\text{-N}$ (mg l^{-1}), total VFA, molar VFA proportions and acetate:propionate ratio in steers fed napier diets with varying levels of desmodium (Experiment A)

Parameter	Diet				SED
	D1	D2	D3	D4	
Fermentation characteristics					
Rumen pH	6.6 ^a	6.8 ^b	6.6 ^a	6.7 ^{ab}	0.2
Rumen $\text{NH}_3\text{-N}$	130 ^a	162 ^b	200 ^c	214 ^d	9.8
Volatile fatty acids					
Total VFA (mmol l^{-1})	87.3 ^a	88.3 ^{ab}	89.2 ^{bc}	90.6 ^c	4.6
Molar percentage					
Acetate	68.8 ^a	70.3 ^b	70.2 ^b	68.6 ^a	1.5
Propionate	16.3 ^a	16.4 ^a	16.5 ^a	17.4 ^b	0.5
Butyrate	10.4 ^a	10.5 ^a	11.2 ^a	11.0 ^a	1.6
Others	2.9 ^a	2.8 ^b	2.1 ^c	3.0 ^c	0.2
Acetate:Propionate	4.4 ^a	4.3 ^a	4.3 ^a	4.0 ^b	0.3

D1 = napier + 0% desmodium; D2 = napier + 10% desmodium; D3 = napier + 20% desmodium; D4 = napier + 30% desmodium.

Table 6 : Rumen pH, concentration of $\text{NH}_3\text{-N}$ (mg l^{-1}), total VFA, molar VFA proportions and acetate:propionate ratio in steers fed napier diets with varying levels of sweet potato vines (Experiment B)

Parameter	Diet				SED
	S1	S2	S3	S4	
Fermentation characteristics					
Rumen pH	6.9 ^{ab}	6.9 ^{ab}	6.8 ^a	7.0 ^b	0.2
Rumen NH ₃ -N	139 ^a	162 ^b	214 ^c	235 ^d	9.2
Volatile fatty acids					
Total VFA (mmol l ⁻¹)	88.5 ^a	90.2 ^{ab}	88.3 ^b	90.2 ^c	1.9
Molar percentage					
Acetate	68.4 ^a	70.5 ^b	71.0 ^c	69.1 ^d	4.3
Propionate	16.2 ^a	15.8 ^b	15.8 ^b	15.0 ^c	1.7
Butyrate	10.3 ^a	10.7 ^b	9.9 ^c	11.3 ^d	2.1
Others	5.1 ^a	3.1 ^b	3.3 ^b	4.6 ^b	1.6
Acetate:Propionate	4.2 ^a	4.5 ^b	4.6 ^a	4.6 ^b	0.2

S1 = napier + 0% SPV; S2 = napier + 10% SPV; S3 = napier + 20% SPV; S4 = napier + 30% SPV; S.E.D = standard error of difference; Others = sum of iso-butyrate, valerate and iso-valerate; Within a row figures bearing different superscripts (a, b and c) indicate significance ($P < 0.05$)

Discussion

This study showed that increasing the amount of desmodium and sweet potato vines in napier-based diets resulted in improved diet CP, feed intake, rumen $\text{NH}_3\text{-N}$, and VFA. The chemical analysis of refusals showed no evidence of selection, an indication of the effect of chopping prior to feeding. The mean CP content of napier grass in this study are within the range reported earlier by Wouters (1987) and Anindo and Potter (1994) for the central Kenya region (68 to 112 g kg^{-1} DM) but were higher than the CP levels reported in the coast region of between 56 and 79 g kg^{-1} DM (Wouters, 1987; Muinga *et al.*, 1995; Abdulrazak *et al.*, 1996). The variation could be attributed to the differences across regions in soil fertility, climate and farming practices (Jaetzold and Schimdt, 1983; Mureithi, 1992).

The observed increase in DM, OM and CP intake was attributed to the inclusion of desmodium and SPV in the diet. However, it was observed that the improvement in intake was less than the proportion of supplement in the diet

suggesting that some substitution occurred. The results agreed with past studies where legume supplements offered to dairy cattle fed on napier grass increased feed intake (Muinga *et al.*, 1995; Kariuki *et al.*, 1997). Abdulrazak *et al.*, (1996) supplemented napier grass fed to zebu steers with 7.5 to 22.5 g kg^{0.75} gliricidia but did not observe any improvement in intake probably due to palatability problems with gliricidia. An important requirement for a good forage supplement is that it should improve the CP status and intake of grass based diets (Van Eys *et al.*, 1986; Yates and Panggabean, 1988; Richards *et al.*, 1994; Muinga *et al.*, 1995; Kariuki *et al.*, 1997). It is therefore probable that desmodium and SPV stimulated intake by increasing the available nitrogen to the rumen microbes and therefore enhancing the rate of digestion (Norton and Poppi, 1995).

Supplementing napier grass with desmodium and SPV improved diet degradation consistent with reports that legumes and other protein-rich forages have a great potential to improve the utilization of poor quality tropical grasses and crop residues (Preston and Leng, 1987; Woolfe, 1990; Norton and Poppi, 1995). The degradation characteristics of desmodium and SPV were similar probably a reflection of their good quality. However, previous studies have shown that desmodium could contain tannins which depress digestion (Skerman *et al.*, 1988; Kiura, 1992). There are reports which have argued that low content of tannins (3-4%) in desmodium could be desirable because they may increase the proportion of bypass protein (Ali and Stobbs, 1980; Topps, 1992). Presence or absence of anti-nutritional factors in SPV has however not been studied (Woolfe, 1990).

The results indicated that both supplements had very profound effects on fermentation and greatly improved DOMR by up to 52% for desmodium and 43% for SPV implying that the supplements are capable of influencing digestibility positively and subsequently increasing energy availability. Indeed, DOMR influences microbial protein (MP) production and it is known that about 150 g of MP are formed per kg DOMR (Brun-Bellut *et al.*, 1990; Tamminga *et al.*, 1994). Indeed, Norton and Poppi (1995) have recently reported that legumes have the greatest potential to improve the protein:energy ratios in tropical grass diets because of their inherently higher crude protein and digestibility.

The study indicated that irrespective of supplement type, or its proportion in the diet, the pH values were in the range of 6.0 to 7.0 considered optimum for the activity cellulolytic microbes (Erdman, 1988) and VFA absorption (Dijkstra *et al.*, 1993). Supplementation increased rumen $\text{NH}_3\text{-N}$ to above 150 mg l^{-1} , the minimum recommended that allows optimum microbial activity for tropical roughages (Preston and Leng, 1987). The results contrast with the preliminary findings of Dixon and Parra (1984) who recorded rather low $\text{NH}_3\text{-N}$ levels of 77 mg l^{-1} when napier alone was fed to zebus but are similar to those of Muinga *et al.*, (1995) and Abdulrazak *et al.*, (1996) when graded levels of leucaena and gliricidia were fed to cattle. However, napier grass only diets had $\text{NH}_3\text{-N}$ levels below requirements implying that such diets are likely to be inefficiently utilized. However, the optimum rumen $\text{NH}_3\text{-N}$ concentration for maximum microbial protein production has remained a subject of debate with Satter and Slyter (1974) giving 50 mg l^{-1} , Hoover (1986), 80 mg l^{-1} and Dixon (1987) indicating that as high as 200 mg l^{-1} may be necessary for low quality roughages. The changes in the levels of rumen $\text{NH}_3\text{-N}$ reflect the supply of nitrogen to rumen microbes and this implies that the unsupplemented diets were deficient in protein. In general, reduced protein supply decreases rumen fermentation, since less $\text{NH}_3\text{-N}$ is available for the microbial synthesis in the rumen.

Changes in the rumen levels of principal volatile fatty acids acetate, propionate and butyrate indicated the effects of these supplements on carbohydrate fermentation. Inclusion of desmodium and SPV resulted to improved rumen VFA concentrations although the effect did not seem to be very profound at a glance. The overall effect was somewhat masked by the fact that VFA production, concentration and absorption is a dynamic process. As VFA production increases, so does absorption (Dijkstra *et al.*, 1993; Van Houtert, 1993). However, the acetate propionate ratio was within the range expected for forage only diets and remained fairly consistent. The high proportion of acetate and low proportions of propionate in the diets are typical of conventional roughage diets and are in accord with earlier studies in which napier grass was supplemented with *Canavalia ensiformis* (Dixon *et al.*, 1983) and more recently with *Leucaena leucocephala*

(Muinga *et al.*, 1995). The influence on rumen pH however appeared slight. This may partly be explained the ability of $\text{NH}_3\text{-N}$ to enhance pH making the changes occurring confounding. The pH of the rumen fluid is negatively related to the concentration of VFA (Van Soest, 1994; Hoover, 1986; Tamminga and Van Vuuren, 1988). Supplementation with desmodium and SPV not only provided more $\text{NH}_3\text{-N}$, but because OM intake was enhanced, the supplements contributed to the total cellulose and hemicellulose pool (energy).

Conclusion

The results showed that desmodium and sweet potato vines in the napier grass diets promoted microbial degradation and rumen fermentation and this would lead to improved metabolic capacity of the animal, consequently leading to improved intake and animal performance. The two protein-rich forages could therefore play an important role in improving animal production from napier grass.

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Chapter 5

Effect of maturity on the mineral content of napier grass

J.N. Kariuki¹, G.K. Gitau², C.K. Gachui³, S. Tamminga⁴, K.R.G. Irungu⁵ and
J.M. Muia¹

¹National Animal Husbandry Research Centre,
P.O. Box 25, Naivasha, Kenya.

²International Livestock Research Institute, P.O. Box 30709, Nairobi, Kenya.

³University of Nairobi, Department of Animal Production, P.O. Box 29053,
Nairobi, Kenya.

⁴Wageningen Agricultural University, Institute of Animal Sciences,
P.O. Box 338, 6700 AH, Wageningen, The Netherlands.

⁵Beef Research Centre, P.O. Box 1275, Nakuru, Kenya.

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J.N. Kariuki, G.K. Gitau, C.K. Gachuri, S. Tamminga, K.R.G. Irungu and J.M. Muia

Abstract

The effect of maturity on the mineral content of Bana and French varieties of napier grass was assessed during the wet and dry seasons. The mineral content declined significantly with maturity except for cobalt (Co). The effect of variety was significant for calcium (Ca), phosphorus (P), potassium (K), iron (Fe) and manganese (Mn). Season significantly influenced the levels of magnesium (Mg), copper (Cu), manganese (Mn) and zinc (Zn). The effect of variety was significant ($P < 0.05$) for Ca, P, K, Fe and Mn. Season significantly influenced ($P < 0.05$) the levels of Mg, Cu, Mn and Zn. The mean levels for Ca, P, Mg, K and Na over all maturity stages were; 3.7, 2.9, 1.5, 4.7 and 0.7 g kg⁻¹ dry matter (DM). The mean levels for micro-minerals were 2.4 ($\times 10^2$), 8.4, 6.6, 2.1 ($\times 10^2$) and 8.0 mg kg⁻¹ DM respectively for Fe, Cu, Mn, Co and Zn. The mineral content of the two varieties were similar and the levels were associated negatively with maturity. The levels of micro-minerals were below those desired for animal production.

Key words: Napier grass, minerals, maturity, season.

Introduction

Napier grass (*Pennisetum purpureum*) is the main dairy cattle feed in zero and semi-zero grazing dairy production systems in Kenya (Anindo and Potter, 1986). The grass has low protein and metabolisable energy so its supplementation with legumes (Abdulrazak *et al.*, 1996; Kariuki *et al.*, 1997) and energy sources (Muinga *et al.*, 1995) has been recommended. Past studies have indicated that deficiencies of some minerals could occur in napier grass (Jumba *et al.*, 1995a,b; Abate, 1994). The concentration of minerals in forages are affected by stage of maturity, climatic and seasonal changes (Minson, 1990) and therefore regular analysis has been recommended to facilitate planning of appropriate mineral supplementation schedules (Spears, 1994). A number of minerals are required by rumen microorganisms for their normal growth and metabolism and deficiencies could negatively affect the ability of microorganisms to digest fibre and synthesize protein

(Durand and Kawashima, 1980; Spears, 1994). The majority of the smallholder farmers in Kenya feed napier grass without mineral supplements (Abate, 1994). At the farm level, the grass is harvested more often in the dry season than in the wet, due to feed shortages. Data on variation in mineral content with maturity and season is essential for ration formulation for the smallholder farmers.

Materials and methods

The study was conducted at Naivasha (1900 m altitude) between September 1992 and April, 1993. The mean annual rainfall and temperature are 620 mm and 18°C. The soils are volcanic in origin, saline and of moderate fertility. The two most common cultivars of napier grass, Bana and French Cameroon, were planted in July 1992 in a well prepared field at a spacing of 0.9 x 0.6 m. The total experimental field was sub-divided into 48 plots of about 2.7 x 4.2 m, each. Three months after establishment, the grass was harvested, leaving a stubble height of about 5 cm. The plots were weeded manually and fertilizer applied at the recommended rates of 100, 100 and 150 kg⁻¹ ha of N, P₂O₅ and K₂O respectively. The experimental plots were harvested in October-December (wet season) and January-March (dry season). After the wet season, all the plots were given a clearing cut and fertilizer was applied at same rates as before. The rainfall in the two growing seasons was 261 mm in October-December, and 140 mm in January-March.

The split-plot experimental design was used with napier grass maturity stage (sub-plot) nested within variety (main-plot). Variety was considered as the fixed effect factor while the maturity stage was considered the random effect factor. The treatments were randomly allocated to the plots with four replications per treatment. The two varieties were harvested at 4, 6, 8, 10, 12 and 14 weeks once during the wet season and once in the dry season. Thus the total number of plots were 48, 2 varieties x 6 treatments x 4 replications. Napier grass was harvested using hand sickles, the perimeter (guard row) being discarded. The herbage from the rest of the plot was chopped into 2.5 cm pieces and mixed thoroughly. A sample of about 15 kg was taken from different portions of the mixture from each

plot and these were spread on a line ridge. Sub-sampling was done by taking two segments from each ridge. For each treatment, two 1 kg samples were taken for dry matter determination and mineral analysis. Ca, Mg, Fe, Cu, Mn, Co and Zn levels were determined by atomic absorption, phosphorus by spectro-photometry and K and Na by flame photometry using (AOAC, 1990) methods. The data were subjected to analysis of variance and mean separation using the general linear model procedures of SAS (1988). All the significant differences given in results were with $P < 0.05$.

Results

The levels of all the macro-minerals decreased significantly with maturity (Table 1). The effect of variety was significant for the macro-minerals Ca, P and K and not significant for the K and Na. Ca was significantly higher in French Cameroon while P and K were higher in Bana. Season significantly influenced the content of only Mg. The levels of the micro-minerals other than Co decreased with advancing maturity (Table 2). The effect of variety was significant for Fe and Mn and not for the other micro-minerals. Season significantly influenced Cu, Mn and Zn but not Fe and Co. The mineral levels observed were compared with the ARC (1980) tabulated requirements.

Discussion

The levels of both macro- and micro-minerals in napier grass declined with advancing maturity, as recognised in grass species (Minson, 1990; Underwood, 1981). The effect of season appeared to be more important on the micro- than the macro-minerals. Seasonal changes are usually caused by periods of rapid growth associated with either an increase in temperature, fertilizer application or the arrival of rains. The mean level of Ca of $3.7 \text{ g kg}^{-1} \text{ DM}$ is comparable to the value of $3.9 \text{ g kg}^{-1} \text{ DM}$ reported for tropical pasture grasses grown in Kenya, Rhodes grass (*C. gayana*), Kikuyu grass (*P. clandestinum*) and star grass (*C. dactylon*) (Mwakatundu, 1977). The slightly lower Ca concentration in this study may be due to the timing of sampling as in most previous studies pastures were sampled at near 'optimum

Table 1. Content of macro-minerals (g kg⁻¹ DM) in Bana (B) and French Cameroon (F) varieties of napier grass

Mineral	Maturity (weeks)														OVERALL MEAN			Required g kg ⁻¹ DM	
	Wet Season							Dry Season							CV	SED	Heifer ^a	Cow ^b	
	4	6	8	10	12	14	Mean	4	6	8	10	12	14	Mean					
Ca																			
B	3.9	3.1	3.4	3.4	3.4	3.2		4.0	3.2	3.4	3.5	3.4	3.4						
F	3.8	3.7	3.9	3.8	3.7	3.4		3.9	3.6	4.0	4.0	3.9	3.3						
Mean	3.9	3.4	3.7	3.6	3.5	3.4	3.6	4.0	3.4	3.7	3.8	3.7	3.4	3.6	3.7	5.9	0.15	3.5	3.2
P																			
B	3.4	3.3	3.1	2.6	2.5	2.5		3.4	3.1	2.9	2.6	3.4	2.2						
F	3.4	3.4	3.3	3.0	2.9	2.9		3.2	3.0	3.0	3.0	2.9	2.7						
Mean	3.4	3.4	3.3	2.8	2.7	2.7	3.1	3.3	3.1	3.0	2.8	2.6	2.5	2.8	2.9	9.0	0.19	2.4	3.0
Mg																			
B	2.0	1.9	1.6	1.6	1.4	1.4		1.8	1.8	1.7	1.4	1.3	1.2						
F	1.9	1.9	1.7	1.5	1.5	1.4		1.7	1.6	1.6	1.3	1.3	1.3						
Mean	2.0	1.9	1.7	1.5	1.5	1.4	1.5	1.8	1.7	1.7	1.4	1.3	1.3	1.5	1.5	9.4	0.10	1.5	1.8
K																			
B	5.1	4.5	4.4	4.4	4.3	4.3		5.0	4.6	4.5	4.5	4.4	4.2						
F	5.1	4.9	4.9	4.6	4.5	4.0		5.1	4.8	4.7	4.5	4.6	4.0						
Mean	5.1	4.7	4.7	4.5	4.4	4.2	4.7	5.1	4.7	4.6	4.5	4.5	4.1	4.6	4.7	4.2	0.13	4.4	4.4
Na																			
B	1.0	1.0	0.8	0.7	0.5	0.4		0.9	0.7	0.7	0.6	0.5	0.4						
F	0.9	0.8	0.7	0.6	0.5	0.5		0.9	0.6	0.7	0.6	0.6	0.5						
Mean	1.0	0.9	0.7	0.7	0.5	0.5	0.7	0.9	0.7	0.7	0.7	0.6	0.5	0.7	0.7	16.4	0.08	0.7	0.7

^a Required levels in forage for 300 kg heifer with an estimated gain of 0.5 kg⁻¹ day; ^b Required mineral concentrations in forage feed for 450 kg⁻¹ cow with an estimated milk yield of 10 kg⁻¹ day ARC, 1980).

Table 2. Content of micro-minerals (mg kg⁻¹ DM) in Bana (B) and French Cameroon (F) varieties of napier grass

Mineral	Stage of Maturity (weeks)														OVERALL				Required mg kg ⁻¹ DM Heifer ^a Cow ^b
	Wet Season							Dry Season							Mean	CV	SED		
	4	6	8	10	12	14	Mean	4	6	8	10	12	14						
Fe (x 10 ³)																			
B	2.5	2.4	2.0	2.3	2.1	2.0		2.4	2.3	2.1	2.4	2.2	2.0						
F	2.4	2.2	2.4	2.3	2.3	2.3		2.5	2.3	2.4	2.4	2.2	2.3						
Mean	2.5	2.3	2.2	2.3	2.2	2.2	2.3	2.6	2.4	2.3	2.4	2.2	2.3	2.4	2.4	8.5	0.14	3.0 4.0	
Cu																			
B	9.4	9.2	9.0	8.3	7.6	5.4		9.4	9.3	9.2	9.1	8.4	6.2						
F	9.1	9.0	9.0	8.0	7.2	5.6		9.2	9.3	9.3	9.0	8.3	6.2						
Mean	9.3	9.2	9.0	8.2	7.3	5.5	8.1	9.3	9.3	9.3	9.1	8.5	6.3	8.6	8.4	9.4	0.55	9 10	
Mn																			
B	8.2	7.4	6.8	6.4	5.6	5.1		8.4	7.1	7.0	6.7	6.1	5.5						
F	7.6	6.8	6.8	6.0	5.6	4.4		7.9	7.4	6.8	6.7	6.2	5.4						
Mean	7.9	7.1	6.8	6.3	5.8	4.6	6.4	8.2	7.3	6.9	6.7	6.2	5.5	6.8	6.6	4.6	0.21	10 16.21	
Co (x10 ⁻³)																			
B	2.1	2.1	1.9	2.1	1.8	2.1		2.2	2.2	2.0	1.9	2.1	2.0						
F	2.1	2.1	2.1	2.2	2.0	1.9		2.2	2.2	1.9	1.9	2.0	2.1						
Mean	2.1	2.1	2.0	2.2	1.9	2.0	2.1	2.2	2.2	2.0	1.9	2.1	2.1	2.1	2.1	7.2	0.10	.08.11 0.08-11	
Zn																			
B	9.6	9.0	7.5	7.3	6.7	4.6		9.9	9.6	8.6	8.2	7.4	6.8						
F	9.6	8.4	8.3	7.8	6.5	4.9		9.9	9.7	8.7	8.2	7.5	6.7						
Mean	9.6	8.7	7.7	7.6	6.6	4.8	7.5	9.9	9.7	8.7	8.2	7.5	6.8	8.4	8.0	5.3	0.30	30 28.48	

^aRequired forage levels for 300 kg heifer with an estimated gain of 0.5 kg⁻¹ day; ^b Required mineral concentration forage feed for 450 kg cow with an estimated milk yield of 10 kg⁻¹ day (ARC, 1980).

grazing condition', normally the early maturity of the grass. The level of $2.9 \text{ g P kg}^{-1} \text{ DM}$ was higher than the $2.5 \text{ g P kg}^{-1} \text{ DM}$ reported for Kenyan pastures (Mwakatundu, 1977) and $2.1 \text{ g P kg}^{-1} \text{ DM}$ for napier grass in western Kenya (Jumba *et al.*, 1995a). This is presumed to be partly due to the same reason advanced for Ca and partly to the nature of the soil at the study site, which was found to be inherently rich in available phosphorus (Jaetzold and Schimdt, 1983). The observed Ca : P ratio fell within the range of 1:1 and 1:2, assumed to be the ideal for growth and bone formation (Underwood, 1981). The Mg concentrations were high, concurring with reports that Mg may not be deficient in Kenyan pastures and fodders (Mwakatundu, 1977). The high levels of K are not surprising since K is abundant in many tropical forages in eastern Africa (Long *et al.*, 1970 ; Abate, 1994; Jumba *et al.*, 1995a,b).

The higher levels of micro-minerals, except for Cu, Mn and Zn, in the dry than in the wet season implies that the need for mineral supplements for dairy cattle fed on napier grass may not be dependent on season because in both cases, the concentrations were below requirements. The declining levels of Fe, Mn, Cu and Zn agree with previous observations that as grasses mature, the mineral content declines due to a natural dilution process and translocation of minerals to the roots (Minson, 1990; Underwood, 1981). The low levels of Zn, Mn and Co suggest that napier grass would be a poor source of these micro-minerals as noted with other Kenyan grasses (Long *et al.*, 1970; Jumba, *et al.*, 1995b), but is a relatively rich source of Fe as reported by Mwakatundu (1977) and Youssef (1988).

However, depending on stage of maturity and season, some major minerals such as P, Ca and Mg were found to be in concentrations that are likely to meet the needs of moderately growing dairy heifers which is consistent with previous findings by Kariuki *et al.*, (1998). Potassium (K) levels were above animal requirements whereas Na was at the threshold of meeting the requirements. However, Zn, Mn and Co concentrations were below animal requirements. Mineral deficiencies are likely to lead to depressed feed intake, forage utilization and subsequently poor animal performance (Underwood, 1981).

The mineral concentrations of napier grass presented in study should be considered as general guidelines because they indicate which minerals are likely to be deficient but more accurate data would be obtained by measuring mineral availability in animals. However, relatively high solubilization of forage minerals in the rumen have been reported suggesting that the release of minerals in the rumen may not limit their use by rumen microbes (Serra *et al.*, 1996; Van der Kamp, 1988).

Conclusion

It was concluded that some minerals in napier grass may be present at potentially limiting concentrations. The most critical in this category were microminerals whose concentrations were generally below those desired for optimum animal production.

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Chapter 6

Effect of feeding napier grass, lucerne and sweet potato vines as sole diets to dairy heifers on nutrient intake, weight gain and rumen degradation

J.N. Kariuki¹, C.K. Gachui², G. K. Gitau³, S.Tamminga⁴, J. van Bruchem⁴,
J.M.K. Muia¹ and K.R.G. Irungu⁵

¹National Animal Husbandry Research Centre, P.O. Box 25, Naivasha, Kenya.

²University of Nairobi, Department of Animal Production,
P.O. Box 29053, Nairobi, Kenya.

³International Livestock Research Institute (ILRI), P.O. Box 30709, Nairobi, Kenya.

⁴ Wageningen Agricultural University, Institute of Animal Sciences,
P.O. Box 338, 6700 AH, Wageningen, The Netherlands.

⁵ National Beef Research Centre, P.O. Box 1275, Nakuru, Kenya.

Effect of feeding napier grass, lucerne and sweet potato vines as sole diets to dairy heifers on nutrient intake, weight gain and rumen degradation

J.N. Kariuki, C.K. Gachuiiri, G.K. Gitau, S. Tamminga, J. Van Bruchem, J.M. K. Muia and K.R.G. Irungu

Abstract

Two experiments were conducted to assess the nutrient intake, weight gain (ADG) and degradation of napier grass (NG), lucerne (L) and sweet potato vines (SPV) fed to growing dairy heifers. In the first experiment, 33 heifers were randomly allocated to the three forages namely: napier grass, lucerne and sweet potato vines which were fed for 104 days. In the second experiment, degradation of the three forages was estimated using nylon bags incubated in two rumen fistulated steers. The mean chemical composition were: dry matter (DM), 155, 807 and 123 g kg⁻¹; organic matter (OM), 796, 854 and 852 g kg⁻¹ DM; crude protein (CP), 118, 167 and 135 g kg⁻¹ DM and neutral detergent fibre (NDF), 587, 408 and 506 g kg⁻¹ DM for NG, L and SPV, respectively. The mean daily DM intake was 5.0, 5.5 and 4.2 kg while the CP intake was 0.59, 0.96 and 0.57 kg for diets NG, L and SPV ($P < 0.05$). The ADG from NG, L and SPV were 0.50, 0.67 and 0.50 kg day⁻¹ respectively. The SPV diet showed higher effective degradation than L and NG ($P < 0.05$), while the latter two forages were not significantly different ($P > 0.05$). The young napier grass (0.5 m) was of better quality and resulted to higher animal performance than observed on smallholder farms where older napier grass (1.0 m) which is often used. It was concluded that NG, L and SPV contained sufficient nutrients to sustain acceptable growth in heifers and have the potential to improve dairy production for smallholders.

Key words: Napier, heifers, intake, gain, degradation.

Introduction

Smallholder dairy farmers in Kenya own approximately 80% of the estimated 3.5 million dairy cattle (MALDM, 1993). These farmers possess on average less than 2 hectares of land and have 2 to 3 lactating cows (Nyangito, 1992). The farmers practice zero or semi-zero grazing due to a shortage of land with napier grass being the main fodder source (Wouters, 1987; Boonman, 1993). Smallholder dairy production is characterised by inadequate and poor quality feeds (Wouters,

1987; Van der Valk, 1990) and replacement dairy heifers are underfed leading to poor performance and insufficient replacement stock for the dairy industry (MALDM, 1993).

It has been observed recently that napier grass fed at the recommended height of 1.0 m (MLD, 1991) is of low quality and has a mean crude protein (CP) content of 75 g kg⁻¹ DM at the farm level (Wouters, 1987) and 80 to 100 g CP kg⁻¹ DM under experimental conditions (Muinga *et al.*, 1995; Kariuki *et al.*, 1997). Napier grass of such a quality, however, would not sustain adequate performance in growing heifers since this class of cattle is rarely supplemented on the farms (Van der Valk, 1990). Recently, an average daily weight gain (ADG) of 0.25 kg has been reported on these smallholder farms for dairy heifers (Gitau *et al.*, 1994). This growth rate is relatively low compared to the expected ADG of 0.4 to 0.6 kg day⁻¹ for heifers fed exclusively on forage diets (Allen, 1993).

Many farmers have opted to feed other more nutritious forages or younger napier grass (0.5 m height) to their growing replacement heifers (Kariuki *et al.*, 1997). Two alternative forages that are commonly being used are lucerne (*Medicago sativa*) and sweet potato (*Ipomoea batatas*) vines (Woolfe, 1991; Boonman, 1993). Little information is available in Kenya on the use of lucerne for dairy production (Boonman, 1993). In temperate countries, lucerne is used as a high quality feed and is normally harvested and transported to dairy cattle in a "cut and carry" system or it is dried or ensiled (Douglas, 1986). Sweet potato vines are extensively used in South America and South-East Asia as feed for dairy cattle (Achata *et al.*, 1990; Woolfe, 1991). In Eastern and Central Africa, the vines have traditionally been used as livestock feed (Karachi, 1982). However, in Kenya, the expected animal responses when these forages are fed to dairy heifers have not been established. Rumen degradation data is essential for precise ration formulation (INRA, 1989; AFRC, 1992) but such information is limited for Kenyan forages (Muinga *et al.*, 1992; Abdulrazak *et al.*, 1996).

The objectives of this study were: (1) to determine the dry matter (DM) and nutrient intakes and the weight gains of dairy heifers fed on napier grass, sweet potato vines and lucerne as sole diets and (2), to determine the rumen DM degradation and *in vivo* digestibility of the three forages.

Materials and methods

Location and climate of the study area

The study was conducted at the National Animal Husbandry Research Centre, Naivasha, in the Kenyan Rift Valley (0° 40' S, 36° 26' E, 1900 m altitude). The mean annual rainfall for the study site is 620 mm with a mean annual temperature of 18°C (Jaetzold and Schimdt, 1983).

Management of forages

Napier grass (*Pennisetum purpureum*, variety Bana) and SPV (*Ipomoea batatas* variety Musinya) were grown using recommended cultural practices (MLD, 1991). The NG was harvested for feeding at 6 weeks (0.5 m high) while SPV were harvested at 12 weeks. The NG plot was sub-divided into 52 sub-plots and thus each sub-plot was harvested twice during the 104-day period. The harvesting of the sub-plots commenced 6 weeks before the start of the experiment to allow the napier grass to be 6 weeks old at the time. The sub-plots were harvested on successive days such that the sub-plot to be fed on day 1 of the experiment was cut 52 days before, that for day 2, 51 days before, and so on. This ensured that the napier grass fed during the entire experimental period was the same age.

The harvesting procedure for SPV was similar to that used for NG, except that the plot was sub-divided into 104 sub-plots and that the first sub-plot was harvested 104 days before the start of the experiment, the second sub-plot 103 days before, and so on to ensure that SPV fed to the heifers were of same age (12 weeks) throughout the experimental period.

Lucerne (*Medicago sativa*, variety Hunter River) was grown according to the recommended practices (MLD, 1991). The field from which L was obtained had grown the forage for two years. An initial harvesting of the entire field (2 ha) was done to dispose of all the forage. The L was allowed to grow and after 6 weeks, harvested, sun-dried, baled and stored as hay in a well ventilated barn.

Experiment 1 : Nutrient intake and weight gain and in vivo digestibility*Experimental procedure*

Thirty three Friesian heifers were selected from a large herd at the research centre on the basis of body weight and age. The heifers previously grazed a mixed pasture of rhodes grass (*Chloris gayana*), Kikuyu grass (*Pennisetum clandestinum*) and Kenya white clover (*Trifolium semipilosum*). At the beginning of the trial, the heifers were drenched with an antihelmintic and thereafter sprayed with an acaricide weekly to control ticks.

The heifers, were randomly divided into three groups of 11 each and the groups allocated to the three treatments namely; NG, L and SPV which were fed for 104 days (a 10-day adaptation period was allowed). The initial mean body weight and age for the heifers per group were as follows: NG treatment, 144.3 kg (s.d. = 4.07), 53 weeks; L treatment, 143.1 kg (s.d. = 3.51), 52 weeks and SPV treatment, 144.1 kg (s.d. = 3.24), 53 weeks. The weighing of the heifers was done before feeding on three consecutive days at the beginning of the trial and the procedure repeated fortnightly. The mean weight for the three weights was taken as each heifer's body weight.

Both NG and SPV were offered to the heifers fresh while L was given as hay. Napier grass (NG) was chopped into 2.5 cm pieces while the other two forages were offered whole as practiced by farmers (Van der Valk, 1990). The forages were available to the heifers at all times. The daily feed on offer was estimated using the previous day's intake and adding a 10% allowance. Half of the daily ration (weighed to the nearest 0.2 kg), was given early in the morning while the other half was given early in the afternoon. The feed refusals were collected and weighed each morning before offering fresh feed. Water and mineral licks were on offer at all times. Feed samples were collected daily and dried. Samples for each week were combined and taken to the laboratory for chemical analysis.

The feeding trial was followed by a 21-day digestibility trial using 12 Merino sheep (four sheep per diet) housed in metabolism cages. Sheep were given feed (at near maintenance level), water and minerals. The 14-day adaptation period was

followed by a 7-day collection period for each sheep, when complete collections of faeces and urine were carried out. During the digestibility trial, forages and refusals were sampled daily for the determination of dry matter and organic matter. Faeces were pooled for each animal and sub-sampled. The metabolisable energy (ME) for each diet was estimated using the equation of the Australian Agricultural Council (1990) for tropical forages:

$$\text{ME (MJ/kg DM)} = \text{DOM (g/kg DM)} \times 18.5 \times 0.81$$

Chemical analysis

Dry matter (DM) was determined using the methods of Association of Analytical Chemists (AOAC, 1990). The feed and faeces samples for chemical analysis were oven-dried at 70°C for 24 hours. The feed samples were then ground to pass through a 1 mm Wiley mill screen. Kjeldahl nitrogen and ash were determined according to AOAC (1990) standard procedures. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were obtained using the method of Van Soest and Robertson (1985). Calcium was determined by flame atomic absorption and phosphorus by spectrophotometry (AOAC, 1990). Silica was determined as the ash after the ADF ash was leached for one hour with 48% hydrobromic acid.

Experiment 2: Rumen degradation

Experimental animals

Two fistulated Friesian steers fitted with large (10 cm diameter) rumen fistulas were used for determination of rumen degradability. The steers were 18 months old with body weights of 426 and 437 kg respectively. The steers were housed individually and fed on a mixed diet of NG (33.3%), L (33.3%) and SPV (33.3%). Tick and helminth control were carried out as in experiment 1.

Rumen incubation

Rumen degradability of the three forages was estimated by incubation of a single composite sample obtained from dried daily samples of forages fed to the heifers in experiment 1. The samples were ground to pass through 3 mm sieve, and 5 g placed in nylon bags (Nybold Switzerland; polyimide, porosity 26%, mesh size 40 μ m). The bags were incubated for 0, 3, 6, 12 (in duplicate), 24, 48, and 96 hours (in triplicate) in each steer. After incubation, the bags were washed in tap water for 5 minutes after which they were oven-dried at 70°C for 48 hours. The zero hour residue was obtained by soaking the bags in water-bath at 38°C for 5 minutes after which they were oven-dried in the same way. The dried samples were then weighed to determine the extent of DM disappearance.

The disappearance of DM at the various stages of incubation were expressed as fractions of original amounts incubated and the results fitted to the Ørskov and McDonald (1979) exponential model:

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

where P is the DM disappearance at time t, 'a' the zero time intercept, 'b' the slowly degradable fraction and 'c' the rate of degradation. Potential degradation (PD) was estimated as (a+b) while effective degradation was calculated using Ørskov and McDonald (1979) equation:

$$ED = a + bc/(k + c)$$

where, an outflow rate (k) of 0.04 hour⁻¹ was assumed (Lechner-Doll *et al.*, 1990).

Statistical analysis

The average daily weight gain (ADG) over the experimental period was calculated by regressing body weight (kg) of individual heifers measured at 2-week intervals with time (in days). The general linear model (GLM) was used to compute analyses of variance (SAS, 1988) for DM intake, nutrient intake, organic matter (OM) digestibility and ADG. The least significant difference (LSD) test was used to compare statistical differences between the various treatment means.

Results

The mean dry matter (DM) content was 155, 807 and 123 g kg⁻¹ for NG, L and SPV, respectively (Table 1). The OM content for L and SPV were comparable while that of NG was lowest. The OM digestibility decreased from NG (571 g kg⁻¹), to L (543 g kg⁻¹) and SPV (501 g kg⁻¹) in that order.

Table 1. The dry matter (g kg⁻¹), organic matter (g kg⁻¹), OM digestibility and nutrient composition (with s.d) of the forages fed to heifers.

Chemical composition	Forage					
	NG	s.d	L	s.d	SPV	s.d
DM(g kg ⁻¹)	55	9	807	23	123	9
OM (g kg ⁻¹ DM)	796	9	854	12	852	6
OM Digestibility (g kg ⁻¹ DM,) (using sheep)	571	18	543	5	501	17
ME (MJ kg ⁻¹ DM)	86	3	81	1	75	3
CP (g kg ⁻¹ DM)	118	6	167	9	135	6
NDF (g kg ⁻¹ DM)	587	15	408	10	506	14
ADF (g kg ⁻¹ DM)	301	6	347	5	339	7
Ash (g kg ⁻¹ DM)	204	06	156	6	148	5
ADL (g kg ⁻¹ DM)	47	4	64	3	35	3
Silica (g kg ⁻¹ DM)	53	3	21	2	12	1
Ca (g kg ⁻¹ DM)	3.4	0.2	7.6	0.4	5.0	0.3
Phosphorus (P)	3.4	0.2	4.0	0.4	2.8	0.3

NG = napier grass; L = lucerne; SPV = sweet potato vines; s.d. (mean values are for 13 samples); DM = dry matter; OM = organic matter; ME = metabolisable energy; CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre; ADL = acid detergent lignin; Ca = calcium and P = phosphorus.

Table 2. Nutrient intake, rumen degradation characteristics (using steers) and weight gains (ADG, kg⁻¹) of Friesian heifers given napier grass(NG), lucerne (L) and sweet potato vines (SPV)

	Treatments			S.E.D	Signif- cance	Heifer Need [®]
	NG	L	SPV			
DM intake (kg day ⁻¹)	5.0 ^{ab}	5.5 ^b	4.2 ^c	0.086	*	4.0
DM intake (g per kg ^{0.75})	106 ^a	118 ^b	89 ^c	2.10	*	-
OM intake (kg day ⁻¹)	4.0 ^a	4.7 ^b	3.6 ^c	0.070	*	-
Nutrient intake (kg day ⁻¹)						
CP	0.59 ^a	0.96 ^b	0.57 ^a	0.093	*	0.60
NDF	2.9 ^a	2.2 ^b	2.1 ^c	0.049	*	-
Ca	0.017 ^a	0.042 ^b	0.021 ^c	0.001	*	0.020
P	0.017 ^a	0.022 ^b	0.012 ^c	0.0005	*	0.012
Average gain (ADG,kg day ⁻¹)	0.50 ^a	0.67 ^b	0.50 ^a	0.041	*	-
Degradation characteristics (g kg ⁻¹ DM)						
soluble fraction (a)	255 ^a	215 ^b	276 ^a	10.3	*	
slowly degradable (b)	458 ^a	483 ^a	494 ^a	21.8	ns	
degradation rate (c)	0.04 ^{ab}	0.03 ^a	0.05 ^b	0.004	*	
PD	713 ^a	698 ^a	770 ^a	20.6	ns	
ED	498 ^a	468 ^a	587 ^b	9.3	*	

DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fibre; Ca = calcium; P = phosphorus; S.E.D = standard error of difference; PD = potential degradation; ED = effective degradation; ADG = average daily weight gain.

\$ Same superscripts (a, b and c) within row indicate no significance ($P < 0.05$)

® Requirements for a growing heifer, 150 kg liveweight with an ADG of 0.60 kg (NRC, 1989).

The metabolisable energy (ME) content of NG, L and SPV estimated from the *in vivo* OM digestibility were 8.6, 8.1 and 7.5 MJ kg⁻¹ DM respectively. Napier grass showed the lowest crude protein content (118 g kg⁻¹ DM) while the highest was that of L (167 g kg⁻¹ DM). Neutral detergent fibre (NDF) was highest for NG, followed by SPV with L having the lowest level. The levels of both calcium (Ca) and phosphorus (P) were higher in L compared to NG and SPV.

The heifers fed on L had the highest DM intake (5.5 kg) which was 24% greater than those on SPV and 9% more than those on NG (Table 2). These differences were significantly different ($P < 0.05$). When DM intake was expressed kg⁻¹ metabolic body weight ($W^{0.75}$), significant differences ($P < 0.05$) were also observed across the three diets. The OM intake showed a pattern similar to that of DM intake.

The CP intake from L was significantly higher than that of NG and SPV ($P < 0.05$) and was above the recommended requirements (NRC, 1989) for the heifers (Table 2). However, the mean CP intake for NG grass and SPV were not significantly different from each other ($P > 0.05$) and were at the threshold of meeting the recommended requirement. The NDF intake was significantly different between the three diets ($P < 0.05$), with NG grass having the highest NDF intake (2.9 kg day⁻¹) and SPV the lowest (2.1 kg day⁻¹). The Ca and P intake differed significantly between the three diets ($P < 0.05$). Calcium (Ca) intake from L was highest (42 g day⁻¹) and met the heifers requirements compared with 21 and 17 g day⁻¹ for SPV and NG respectively. The Ca intake from NG and SPV were at the threshold required to satisfy the heifer needs. Phosphorus (P) intake from all diets was above the heifer requirements.

The average daily weight gains (ADG) of heifers fed on the three forages are shown in Table 2. Heifers fed on L gained significantly ($P < 0.05$) more than those on NG and SPV (0.67 kg day⁻¹ for L versus 0.50 kg day⁻¹ for either NG or SPV).

The DM degradation for the three diets are shown in Table 2. The three diets differed significantly ($P < 0.05$) in rate of degradation (c), solubility (a) and effective degradability (ED) but not in slowly degradable fraction (b) and potential

degradation (PD). The ED between NG and L were not significantly different ($P < 0.05$). Lucerne (L) diet showed significantly lower ($P < 0.05$) soluble fraction (215 g kg^{-1}) and degradation rate. However, the PD was not significantly different among the diets ($P > 0.05$).

Discussion

This study showed that there were significant differences in nutrient intake and ADG when growing heifers were fed on sole diets consisting of NG, L and SPV. The DM and CP contents of NG, L and SPV were similar to those reported earlier in Naivasha (Kariuki *et al.*, 1997; Snijders *et al.*, 1992). The observed mean CP content for the three diets were also found to be in the range reported in the literature for NG (Muinga *et al.*, 1992; Snijders *et al.*, 1992), L (Leibholz, 1991; Broderick, 1995) and SPV (Karachi, 1982; Woolfe, 1990) and were considered adequate to meet heifer requirements and allow modest ADG (ARC, 1980; NRC, 1989). Low quality forages are defined as those with less than 80 g kg^{-1} DM CP (Leng, 1990) and such forage would adversely affect rumen microbial activity (Van Soest, 1982). Thus the forages fed in this study would be considered to be of medium to high quality.

The DMI was highest for heifers fed on L and lowest for those fed on SPV. The DMI was found to be positively associated with OM digestibility which was related to the energy available in the forage (Minson, 1990). The OM digestibility varies with the proportion of cell contents and cell wall constituents. The cell contents are very digestible, while cell wall digestion depends on the degree of lignification, the activity of rumen microbes and the time forage is retained in the rumen (Minson, 1990). Even when DMI was expressed per metabolic body weight, SPV still had the lowest DMI ($89 \text{ g kg}^{-0.75}$). The DMI for NG diet was comparable to the $100 \text{ g kg}^{-0.75}$ reported by Anindo and Potter (1986), although the NG fed to cattle in their study had a lower CP level (86 g kg^{-1} DM). This was a surprisingly high intake given the CP of napier grass in that study, a fact that the authors recognised. Leibholz (1991) observed comparable DMI of $119 \text{ g kg}^{-0.75}$ when Friesian heifers were fed on a L diet only.

The ADG obtained in this study for the three diets were higher than the mean 0.25 kg day⁻¹ observed earlier on smallholder farms in Kiambu, Kenya (Gitau *et al.*, 1994). Abou-Ashour *et al.*, (1984) reported ADG of 0.37 kg and recently Kariuki *et al.*, (1997) reported ADG of 0.32 kg when dairy heifers were fed on old napier grass (> 1.0 m) without supplementation. The ADG obtained in this study were comparable with the ADG estimates when older NG grass was fed to growing cattle given supplements (Dixon and Parra, 1984; Pachauri and Pathak, 1989) probably because the NG in this study was young and of better quality.

Adequate fibre which is measured as NDF and defined as total cell wall contents is necessary for rumination, saliva flow, rumen buffering and health of the rumen wall (Fox *et al.*, 1992). The lower NDF concentration in L and SPV was consistent with the general observation of lower NDF concentrations in legumes and non-grass fodders (Minson, 1990). Although napier grass was more fibrous than L and SPV, this factor did not seem to affect intake probably because the NDF concentration was still below 600 g kg⁻¹ DM usually considered as the threshold (Meissner *et al.*, 1991). Strasia and Gill (1990) have suggested that NDF should constitute at least 15% of the total DM intake for a growing heifer and this condition was fulfilled in this study.

The recommended Ca : P ratio is usually 1:1 to 2:1 and that ratio is most critical if P intake is marginal or inadequate (McDowell and Conrad, 1990). The ratios for the two minerals in all the forages used in this study were within this range. Lucerne provided a high Ca intake, a reflection of a high content and a high DM intake. However, the intake of the two minerals either met the heifer requirements or were slightly above the requirements. This was in contrast to the general perception that deficiencies of Ca and P are widespread in tropical areas where livestock depend solely on forage diets (McDowell and Conrad, 1990). The findings in the current study were probably because the forages were fed at a younger stage when the concentrations of the two minerals were high.

The study showed that there were variations in effective degradation across the diets. The differences in solubility and potential degradation are dependent on the cellular structure of the components being degraded (Hagerman, *et al.*, 1992)

and on inherent attributes of the NDF and CP present (Kaitho, 1997). For instance, microbial protein formation is influenced by feedstuff nitrogen that is soluble and degradable in the rumen and the energy available to fuel incorporation of ammonia and degradable protein into microbial protein (Preston and Leng, 1987). In this study lucerne and SPV were readily consumed although the ED values did not indicate extensive degradation in the rumen. The low solubility and degradation of L compared to either NG or SPV was probably caused by the higher lignin levels in lucerne. Lignin, which forms a complex with hemicellulose, also protects cellulose from enzymatic and microbial attack (Hartfield, 1993). However, since the OM and CP intake were relatively high, this effect was partly offset and the extra nutrient intake from lucerne resulted in a higher growth rate. The low performance associated with the SPV diet could be attributed mainly to low nutrient intake.

The results from the present study led to the conclusion that napier grass, lucerne and SPV contain satisfactory levels of CP, Ca and P that can sustain acceptable growth rates in dairy heifers. Lucerne, however, showed better performance than the other two forages. Further, the young napier grass (0.5 m) used in this study showed better quality and performance than the recommended napier (1.0 m) which is frequently used by farmers. Nevertheless, the three forages have a potential to improve dairy cattle production in Kenya.

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Chapter 7

Effect of supplementing napier grass with desmodium and lucerne on intake and weight gains in dairy heifers

J.N. Kariuki¹, G.K. Gitau², C.K. Gachui³, S. Tamminga⁴ and J.M. K. Muia¹,

¹ National Animal Husbandry Research Centre,
P.O. Box 25, Naivasha, Kenya.

² International Livestock Research Institute,
P.O. Box 30709, Nairobi, Kenya.

³University of Nairobi, Department of Animal Production,
P.O. Box 29053, Nairobi, Kenya.

⁴Wageningen Agricultural University, Institute of Animal Sciences,
P.O. Box 338, 6700 AH, Wageningen, The Netherlands.

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J.N. Kariuki, G.K. Gitau, C.K. Gachuri, S. Tamminga and J.M. K. Muia

Abstract

A study was conducted to investigate the effect of feeding napier grass (*Pennisetum purpureum*) with or without legume supplementation on nutrient intake and live-weight gains (LWG) in dairy heifers. In the first experiment, thirty-two, one year old Friesian and Sahiwal heifers were used. Eight heifers, four from each breed, were randomly allocated to the following four diets: napier grass alone (D1, control), napier/desmodium (D2, inter-cropped in the field), napier grass supplemented with lucerne hay (D3) and napier grass supplemented with desmodium hay (D4). Feed intake was recorded daily while LWG was measured fortnightly over the 120-day feeding period. The second experiment was conducted using two fistulated steers to estimate the rumen DM degradation of the diets. Heifers on diets D2, D3 and D4 showed significantly higher nutrient intake and LWG ($P < 0.05$) than those on D1. Heifers on D1 gained 0.41 kg day^{-1} , while those on D2, D3 and D4 gained 0.45 , 0.52 and 0.42 kg day^{-1} respectively. Diet D3 showed significantly higher ($P < 0.05$) solubility, degradation rate, potential and effective degradation compared to the other diets. Diet costs computed from forage production data, showed that D2 was the cheapest diet. Results from the study indicated that legume supplements enhanced animal performance and that the cost of live-weight gain is lower when the legume is grown as an inter-crop with napier grass.

Key words: Napier, desmodium, lucerne, heifers, intake, gains.

Introduction

In Africa, pasture grasses still remain the most important feed resources for cattle in different production systems. Beef cattle are predominantly reared on unimproved pastures in low rainfall areas while dairy cattle are fed on improved pasture grasses, fodders and farm by-products in the high and medium rainfall areas (Seré *et al.*, 1996). In Kenya, for instance, napier grass (*Pennisetum purpureum*) is the most common feed resource under the zero grazing system (Anindo and Potter, 1994).

Since the use of fertilizers in smallholder dairy system is limited (Valk, 1990), soil fertility continues to deteriorate leading to low quality napier grass (crude protein content $< 80 \text{ g kg}^{-1} \text{ DM}$) at the farm (Wouters, 1987). Such low crude protein (CP) levels cannot meet the requirements for growing dairy cattle (ARC, 1980). Commercial protein sources are rarely used (Valk, 1990) and therefore attempts have been made in the past to identify suitable legumes that could be inter-cropped with napier grass (Snijders *et al.*, 1992; Boonman, 1993) to improve its nutritive value. One of the legumes that has been identified is desmodium (*Desmodium intortum*) and is considered to have a great potential for use by smallholder dairy farmers in medium altitude regions (Boonman, 1993).

Although napier/desmodium inter-cropping has been adopted by smallholder farmers and integrated in their farming system (Snijders *et al.*, 1992; Boonman, 1993), the nutritive value, expected animal response and feed cost of napier/desmodium inter-crop have not been quantified in Kenya. Previous work has supplied adequate agronomic information on the effect of legume inclusion in pastures on yield and chemical composition (Thairu, 1972; Keya, 1974; Snijders *et al.*, 1992; Mureithi, 1992). It is, however, not documented how growing heifers perform on the napier/desmodium inter-crop compared with napier grass supplemented with well known forage supplements such as lucerne (*Medicago sativa*) or desmodium hay and which of the diets would be more cost effective.

The objective of this study was therefore to evaluate the effect of feeding dairy heifers napier/desmodium (intercropped) and napier grass supplemented with desmodium or lucerne hay on nutrient intake and live-weight gains and the comparative costs of these diets.

Materials and methods

Location and Climate of the study area

The study was conducted at the National Animal Husbandry Research Centre, Naivasha, Kenya ($0^{\circ} 40' \text{ S}$, $36^{\circ} 26' \text{ E}$, 1900 m altitude) between October, 1996 and February, 1997. The mean annual rainfall for the study site is 620 mm with a mean annual temperature of 18°C (Jaetzold and Schimdt, 1983).

Management of forages

A pure napier grass field (D1, variety Bana, about 2.5 ha) and another with napier/desmodium inter-crop (D2, about 0.4 ha) were grown at the research station using the recommended cultural practices (MLD, 1991; Snijders *et al.*, 1992). Each of the forage fields was sub-divided into 60 plots. The harvesting scheme ensured that the offered feed was the same age (8 weeks) during the whole experimental period (120 days). Lucerne and desmodium used as protein supplements in D3 and D4 were also grown according to the recommended cultural practices (MLD, 1991) and upon full establishment, a clearing cut was made. The forages were then allowed to grow for another 8 weeks, harvested, sun-dried for 3 days into hay, baled and stored.

Experiment 1: Dry matter intake and live-weight gain (LWG)

Experimental animals and feeding

Sixteen Friesian heifers (body weight = 181 kg; s.d. = 8.9) and sixteen Sahiwal (body weight = 163 kg; s.d. = 6.7) heifers were used in the feeding trial. The heifers were approximately one year old. Eight heifers, four from each breed, were randomly allocated to four diets: napier grass alone (D1, control), napier/desmodium (D2, inter-cropped in the field). The ratio of napier:desmodium in the inter-crop was found to be 7:3 (a result corroborated by Snijders *et al.*, (1992) at the same site). Subsequently, D3 (napier + lucerne hay) and D4 (napier + desmodium hay) were constituted such that the ratio of napier:legume on DM basis was 7:3. All diets were chopped into 2.5 cm pieces, mixed thoroughly and offered *ad libitum* in two equal portions, twice daily. The heifers were housed and fed individually and were allowed an initial adaptation period of 10 days. Clean water and mineral supplement were available to all heifers.

Live-weight and feed intake measurements

Feed intake was recorded daily while live-weight gains (LWG) were estimated fortnightly over the 120-day feeding period. The heifers were initially weighed at the beginning of the trial each morning on three consecutive days

before feeding and the three-day mean was taken as the initial weight. Thereafter, the heifers were weighed fortnightly. Feed refusals from the feed troughs were removed and weighed once a day before the morning ration was given. The daily feed on offer was 110% of the previous day's intake.

Experiment 2 : Rumen degradation

The rumen degradation of each diet was determined using the nylon bag method (Mehrez and Ørskov, 1977). The diet samples were milled through a 3 mm sieve, weighed into 5 g and placed in polyamide bags (Nybold, Switzerland, porosity 26% mesh size 40 μ m, size 6 cm x 12 cm). The bags were then incubated in the rumen of two fistulated steers (Friesians) for 3, 6, 12, 24, 48 and 96 hours. A zero hour residue was obtained by soaking the bags in water-bath at 38°C for 5 minutes. The incubated bags were then washed in tap water for 5 minutes after which they were oven-dried at 70°C for 48 hours. The dried samples were weighed to determine the amount of dry matter that disappeared in the rumen.

The degradation of DM at the various times of incubation were expressed as fractions of original amounts incubated and the results fitted to Ørskov and McDonald (1979) exponential equation:

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

where, P is the DM disappearance (%), at time t, 'a' the zero time intercept, 'b' the slowly degradable fraction and 'c' the rate of degradation. Potential degradation (PD) was estimated as (a + b) while effective degradation (ED) was calculated using the Ørskov and McDonald (1979) equation:-

$$ED = a + bc / (k + c)$$

where, an outflow rate (k) of 0.04 per hour was assumed (Lechner-Doll *et al.*, 1990).

Feed sampling and chemical analysis

Feed samples were collected daily before morning feeding and composited weekly. The samples were analysed for DM (105° C for 24 hours), organic matter (OM, ashing at 500° C) and Kjeldahl nitrogen (AOAC, 1990). Neutral detergent fibre (NDF) and acid detergent lignin (ADL) were analysed using the method of Van Soest and Robertson (1985).

Statistical analysis and economic calculations

The live-weight gain (LWG) over the experimental period was calculated by regressing body weight (kg) of individual heifers measured at 2-week intervals with time (in days). Feed efficiency (FE) was calculated as gain per intake. The general linear model (GLM) was used to compute analyses of variance (SAS, 1988) for nutrient intake, LWG and FE. The least significant difference (LSD) test was used to compare differences between diets means. The cost of diets were calculated using mean DM yields recorded previously at the study site and at farms (Wouters, 1987; Kariuki, 1989; Snijders et al., 1992; Boonman, 1993) divided by the total production cost. The costs taken into account were the current costs of land preparation, seeds, fertilizer, weeding, harvesting, labour, chopping and feeding (Nijssen and Waithaka, 1992).

Results

The chemical composition and rumen DM degradation of the diets are shown in Table 1. Diets D2 and D3 showed significantly higher ($P < 0.05$) CP than D1 and D4. The napier:legume ratio in D2, D3 and D4 were comparable on DM basis. The NDF significantly differed between the diets ($P < 0.05$) with D1 having the highest content (559 g kg⁻¹ DM) and D2 the lowest (504 g kg⁻¹ DM). The ADL was significantly different ($P < 0.05$) across the diets with D2 and D3 showing no significant difference ($P > 0.05$). The solubility (a) of D3 was significantly higher ($P < 0.05$) than that of the other diets. The observed values for solubility ranged from 241 g kg⁻¹ DM (D3) to 185 g kg⁻¹ DM (D4). However, no significant differences were noted for the slowly degradable fraction ($P > 0.05$) across the

Table 1. Mean chemical composition (g kg⁻¹ DM) and rumen degradation constants (g kg⁻¹ DM) of the diets fed to heifers.

	D1	D2	D3	D4	S.E.D
Chemical composition					
DM (g kg ⁻¹ DM)	149 ^a	157 ^b	351 ^c	344 ^c	0.8
DM composition (g kg ⁻¹ DM)					
OM	815 ^a	861 ^b	833 ^c	842 ^d	4.2
CP	117 ^a	142 ^b	137 ^{bc}	131 ^c	3.0
NDF	559 ^a	504 ^b	536 ^c	534 ^c	4.1
ADL	31 ^a	52 ^b	49 ^b	59 ^c	3.3
Degradation characteristics (g kg ⁻¹ DM)					
(a)	219 ^a	187 ^a	241 ^b	185 ^a	3.1
(b)	485	478	474	469	4.4
(c)	0.07 ^a	0.08 ^a	0.09 ^b	0.08 ^{ab}	0.002
PD	704 ^a	664 ^b	735 ^a	653 ^b	5.4
ED	550 ^a	524 ^b	611 ^c	520 ^b	4.7

D1 = napier grass; D3 = napier/desmodium; D4 = napier + lucerne hay; D4 = napier + desmodium hay; SED=standard error of difference; DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fibre; ADL = acid detergent lignin; (a) = soluble fraction; (b) = slowly degradable fraction; (c) = degradation constant; PD = potential degradation; ED = effective degradation; ^{a, b}Between feeds, means not sharing a common superscript differ significantly ($P < 0.05$).

diets. Similarly, D3 showed significantly higher ($P < 0.05$) PD and ED compared to the other diets.

The mean nutrient intake, LWG and feed efficiency of the four diets fed to the heifers are shown in Table 2. The DMI was highest for D3 and lowest for D1. A similar trend was observed for OM, CP and NDF intake. Diets D1 and D4 showed

Table 2. Mean intake of dry matter (DM), organic matter (OM), crude protein (CP), the live-weight gains (LWG) and feed utilisation efficiency of the diets fed to heifers.

Diet		Intake					LWG	FE
		DM	DM	OM	CP	NDF		
		kg d ⁻¹	(g kg ^{0.75})			kg d ⁻¹		
<hr/>								
D1								
	Friesian	6.0 ^a	113 ^a	100 ^a	12.8 ^a	69 ^a	0.39 ^a	0.065 ^a
	Sahiwal	5.6 ^b	114 ^a	107 ^b	14.6 ^b	74 ^b	0.42 ^a	0.074 ^b
	Mean	5.8 ^A	114 ^A	104 ^A	13.7 ^A	72 ^A	0.41 ^A	0.070 ^A
D2								
	Friesian	7.0 ^a	135 ^a	123 ^a	19.1 ^a	71 ^a	0.42 ^a	0.061 ^a
	Sahiwal	6.8 ^b	138 ^b	130 ^b	21.6 ^b	80 ^b	0.47 ^b	0.069 ^b
	Mean	6.9 ^B	135 ^B	127 ^B	20.4 ^B	76 ^B	0.45 ^B	0.065 ^B
D3								
	Friesian	7.4 ^a	137 ^a	128 ^a	23.2 ^a	82 ^a	0.52 ^a	0.070 ^a
	Sahiwal	6.8 ^b	138 ^a	134 ^b	23.8 ^b	86 ^b	0.52 ^a	0.076 ^b
	Mean	7.1 ^A	138 ^C	131 ^B	23.6 ^B	84 ^C	0.52 ^C	0.073 ^A
D4								
	Friesian	6.7 ^a	126 ^a	114 ^a	18.8 ^a	72 ^a	0.40 ^a	0.060 ^a
	Sahiwal	6.2 ^b	128 ^a	118 ^b	21.8 ^a	79 ^b	0.44 ^b	0.072 ^b
	Mean	6.4 ^C	127 ^D	116 ^C	20.3 ^C	76 ^B	0.42 ^A	0.066 ^C
	S.E. D	0.2	2.0	1.94	0.47	0.80	0.01	0.002

D1 = napier grass; D3 = napier/desmodium mixture; D4 = napier + lucerne hay; D4 = napier + desmodium hay; , BW = body weight; S.E.D = standard error of difference.

^{a,b} Between breeds, means not sharing a common superscript differ significantly ($P < 0.05$)

^{A,B} Between diets, means not sharing a common superscript differ significantly ($P < 0.05$)

Table 3. Dry matter (DM) yields, cost of production (Ksh 100 kg⁻¹ DM), carrying capacity (heifers ha⁻¹ year⁻¹), heifer gain (kg ha⁻¹ day⁻¹) and the cost of gain (Ksh kg⁻¹) for the diets

	DM yield ⁺ (t ha ⁻¹ y ⁻¹)	DM Cost ⁺⁺ (Ksh) 100 kg ⁻¹ DM	Carrying ⁺⁺⁺ capacity (heifers ha ⁻¹ y ⁻¹)	Heifer gain (kg ha ⁻¹ d ⁻¹)	Cost of Gain (Ksh kg ⁻¹)
D1	12.3	330	5.8	2.4 ^a	46.9 ^a
D2	17.4	270	6.9	3.1 ^b	41.3 ^b
D3	15.8	362	6.1	2.8 ^b	49.6 ^c
D4	13.5	385	5.8	2.4 ^a	58.5 ^d

⁺ Sources : Wouters, 1987; Kariuki, 1989; Snijders *et al.*, 1992; Boonman, 1993.

t ha⁻¹ y⁻¹ = metric tonnes per hectare per year; ⁺⁺ Exchange rate 1US\$ = Ksh. 60; ⁺⁺⁺ For heifers weighing 180 kg gaining 0.41, 0.45, 0.52 and 0.42 kg day⁻¹ for D1, D2, D3 and D4, respectively; ^{a,b,c,d} Between breeds, means not sharing a common superscript differ significantly (P<0.05); D1 = fresh napier grass; D2 = napier/desmodium mixture; D3 = napier + lucerne hay; D4 = napier + desmodium hay.

relatively lower nutrient intake in comparison to D2 and D3. Heifers that consumed legume containing diets D2 and D3 gained more weight than those that consumed napier alone (D1).

However, no significant difference was observed in LWG between D1 and D4. Heifers on D3 showed significantly higher (P<0.05) feed utilization efficiency (gain/intake) than heifers on D1, D2 and D4. There were significant differences in nutrient intake, LWG and FE (P<0.05) between the two breeds, with the Sahiwal

having a higher intake per metabolic body weight, higher LWG and FE than the Friesian.

Table 3 shows the DM yield and cost of production of the diets assuming that both napier grass and legume were obtained from the same hectare to produce a diet with a napier:legume ratio of 7:3. The carrying capacity, weight gain expected from a hectare and the cost per kg of weight gain are also shown in Table 3. Due to the high yields of D2 when grown as a mixture, this diet translated to significantly higher ($P < 0.05$) body weight gain per hectare and the lowest cost ($P < 0.05$).

Discussion

The current study assessed the potential of supplementing napier grass with desmodium and lucerne to improve the performance (LWG) of dairy heifers. The parameters studied such as intake (DMI, OMI, CPI and NDFI) and rumen degradation, indicated that supplementation with legumes improved the quality of diets and subsequently resulted to higher animal performance. The observed mean CP level of 117 g kg^{-1} DM for D1 (napier grass alone) from this study was higher than 64 and 79 g kg^{-1} DM reported recently by Muinga *et al.*, (1995) and Abdulrazak *et al.*, (1996) respectively in the coastal Kenya region but was comparable to 110 g kg^{-1} DM observed by Anindo and Potter (1994) in the Kenyan highlands. However, lower CP levels for on-farm napier grass at 76 g kg^{-1} DM have been reported (Wouters, 1987). According to Leng (1990), low-quality forages are considered as those having less than 80 g CP kg^{-1} DM. Napier grass in this study had CP level above this threshold, and was therefore considered as medium quality forage. Despite, the relatively high CP content of napier grass in this study, it could not meet requirements for the heifers (ARC, 1980). Lucerne and desmodium were included in the diets as protein supplements to improve the quality.

Based on the data from this study, the variations in DM, OM and CP intake in the heifers were influenced by diet composition. Heifers offered napier grass with legumes showed increased DMI, OMI, CPI and NDFI. The legumes are known to have higher degradation than grasses and this coupled with high CP could have

increased the concentration of rumen ammonia (McMeniman *et al.*, 1988). The latter resulted to increased population of rumen cellulolytic microbes and subsequently the rate of digestion (Preston and Leng, 1987; Osuji *et al.*, 1995), as was observed for the legume containing diets. The higher DM, OM and CP intake in the lucerne based diet compared to desmodium, could be attributed partly to the presence of tannins in desmodium (Reed, 1995; Kaitho, 1997). Tannins are anti-nutritional factors that reduce intake, decrease palatability and negatively affect digestion (Reed, 1995; Kaitho *et al.*, 1998). Tannins also bind proteins and inhibit the fermentation of structural carbohydrates in the rumen (D'Mello, 1992). Desmodium was associated with the highest levels of lignin which may have formed undegradable ligno-cellulose complexes with cellulose and hemicellulose (Minson, 1990).

The Sahiwal heifers showed relatively higher DMI per unit body weight than Friesian heifers. The Sahiwals were previously reared under range conditions where feed quality and quantity were likely to have been limiting while the Friesians were raised on well-irrigated improved pastures. Cattle previously on restricted nutrition eat more per unit body weight during re-alimentation than those on unrestricted nutrition (Ehoche *et al.*, 1992) and this could have explained the differences in performance observed between the two breeds.

Feeding of napier grass in smallholder farms in Kenya has been associated with low LWG of about 0.21 kg day^{-1} recorded on youngstock fed on napier grass with CP of less than $80 \text{ g kg}^{-1} \text{ DM}$ (Gitau *et al.*, 1994; Wouters, 1987). However, the current study demonstrated that legume supplements improved DM intake and the subsequent LWG from 0.41 kg day^{-1} on napier grass alone with a CP of $117 \text{ g kg}^{-1} \text{ DM}$ without legume to between 0.42 and 0.52 kg day^{-1} when the grass is supplemented. These observations concur with the results of Krischke and Voigtlander (1986) and Kariuki *et al.*, (1997) who demonstrated that supplementing napier grass basal diets with legumes improved LWG of heifers. According to ARC (1980), a diet with a CP concentration of $120 \text{ g kg}^{-1} \text{ DM}$ would meet the requirements for rumen degradable protein for a 180 kg heifer gaining 0.5 kg day^{-1} . The ARC (1980) recommendation assumes that CP degradation would be optimal

which may not have been the case in this study. However, such a gain was not observed for D1 which had a comparable CP level, and even with the other three diets which had higher CP, the resultant LWG were below expectations. The ARC (1980) requirements are based on temperate forages with higher digestibility and energy content than tropical forages (Minson, 1990) and this may partly explain this observation. The presence of anti-nutritional factors in desmodium contained in D2 and D4 may also partly explain the low LWG. The results in this study therefore suggest that feeding standards for temperate regions may not be appropriate under tropical conditions.

From the biological perspective, the diets containing lucerne and desmodium hay supplements showed higher weight gains. However, napier/desmodium diet (grown as an inter-crop) would be more appealing from the farmers point of view due to its higher carrying capacity and low cost. Besides giving higher yields than napier grass alone, the napier/desmodium inter-crop has previously been found to smother annual weeds and the field requires no nitrogen fertilization (Snijders *et al.*, 1992). These factors made the inter-crop the cheapest diet and the one that gave the highest total gain per hectare. It was nevertheless surprising that the difference in the cost of weight gains between napier grass alone and napier supplemented with either lucerne hay or desmodium hay were smaller than expected. This could be attributed to the high costs of maintaining pure stands in terms of fertilizers, weeding and absence of beneficial effects of grass/legume symbiotic relationship.

Conclusions

Although the highest LWG were obtained from D3, diet costs computed from forage production data, showed that D2 was the cheapest diet and that the latter diet had the highest LWG per hectare. The results therefore indicated that though all legume supplements enhanced performance, the cost of live-weight gain is lower when the legume is grown as an inter- with napier grass and fed thus.

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Chapter 8

Performance of Sahiwal and Friesian heifers fed on napier grass supplemented with graded levels of lucerne

J.N. Kariuki¹, S. Tamminga², G. K. Gitau³, C.K. Gachui⁴ and J.M.K. Muia¹

¹National Animal Husbandry Research Centre, P.O. Box 25, Naivasha, Kenya.

² Wageningen Agricultural University, Institute of Animal Sciences,
P.O. Box 338, 6700 AH, Wageningen, The Netherlands.

³International Livestock Research Institute (ILRI), P.O. Box 30709, Nairobi, Kenya.

⁴University of Nairobi, Department of Animal Production, P.O. Box 29053, Nairobi,
Kenya.

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Abstract

Two experiments designated A and B were conducted to evaluate the effect of supplementing napier grass with lucerne on dry matter intake (DMI) and weight gain (ADG) of Friesian and Sahiwal heifers. In experiment A which lasted 92 days, twenty four heifers from each of Sahiwal and Friesian breeds were blocked by breed and randomly allocated to the following treatments: young napier + 0 kg lucerne (T1); young napier + 1.5 kg lucerne (T2); old napier + 0 kg lucerne (T3); old napier + 1.5 kg lucerne (T4); old napier + 2.5 kg lucerne (T5); old napier + 3.5 kg lucerne (T6) heifer⁻¹ day⁻¹. Supplementation significantly ($P < 0.05$) increased DMI from 4.3 to 6.7 kg day⁻¹ in Sahiwals and 5.2 to 7.8 kg day⁻¹ in Friesians ($P < 0.05$). Similarly, supplementation positively influenced ADG which significantly ($P < 0.05$) improved from 0.29 to 0.64 kg day⁻¹ for Sahiwals and 0.30 to 0.65 kg day⁻¹ for Friesians. In Experiment B, diets from experiment A were incubated in the rumen for 0, 3, 6, 12, 24, 48, 96 and 336 hours using four steers to estimate degradation. The rumen degradation of lucerne containing diets were significantly ($P < 0.05$) higher than those with napier grass alone. It was concluded from the study that lucerne has a great potential to improve animal performance in smallholder dairy farms.

Key words: Napier, lucerne, heifers, intake, weight gain, degradation.

Introduction

In the tropics, the majority of dairy cattle depend on low quality natural pastures and crop residues (Preston and Leng, 1987; Minson, 1990). In Kenya, dairy cattle under zero grazing system are mainly fed on napier grass (*Pennisetum purpureum*) which has been adopted due to its high dry matter (DM) yields and palatability (Anindo and Potter, 1986; Boonman, 1993). Napier grass has a mean crude protein (CP) of 76 g kg⁻¹ DM at the farms (Wouters, 1987). However, this level is below the ARC (1980) recommended dietary CP levels for growing heifers of 10 to 12 g kg⁻¹ DM CP and as a result, the reported average weight gains for

heifers fed on napier grass was less than 0.25 kg day^{-1} (Gitau *et al.*, 1994). The subsequent result is lack of good replacement heifers.

The use of commercial protein sources on the farms is limited by high costs and unavailability (Valk, 1990). Therefore, to improve the performance of heifers, cheap and easily grown protein sources such as legumes need to be identified. It is established that legume inclusion in ruminants diets could improve animal nutrition (Minson and Milford, 1967; Posler *et al.*, 1993) in addition to enhancing soil fertility through nitrogen fixation (Tothill, 1987; Mureithi, 1992). Zero grazing farmers in central Kenya region grow lucerne (*Medicago sativa*), as a protein source to supplement napier grass (MALDM, 1994). Of the legumes studied in Kenya, the highest DM yields have been recorded with lucerne both at the farms (Boonman, 1993) and under research conditions (Snijders, 1989). During the dry season when there is little growth at the farms, lucerne is purchased from commercial stores (Boonman, 1993). Thus, if napier grass and lucerne are both grown on the farm high nutrient yields and therefore high animal output are likely to be achieved. Unfortunately, farmers lack specific guidelines on how to combine napier grass with lucerne for dairy heifers and the effect of lucerne supplement on performance is not documented.

The objective of this study was therefore to investigate the effect of supplementing napier grass with graded levels of lucerne on rumen degradation, feed intake and weight gain of Sahiwal and Friesian heifers.

Materials and Methods

Location of the study area

The study was conducted between January and May 1995 at the National Animal Husbandry Research Centre, Naivasha, in the Kenyan Rift Valley ($0^{\circ} 40' \text{ S}$, $36^{\circ} 26' \text{ E}$, 1900 m altitude). The mean annual rainfall for the study site is 620 mm and the mean annual temperature 18°C (Jaetzold and Schimdt, 1983).

Experiment A : Feed intake and growth experiment***Management of forage feeds***

An existing napier grass (variety Bana) field measuring about 3.5 hectares (ha) was sub-divided into two equal plots, P1 and P2. Plot P1 was used for 6 week old napier grass while P2 was used for 12 week old one. Plot P1 was further subdivided into 42 sub-plots and P2 into 84 sub-plots. In January, 1995 a clearing cut and weeding were done followed by fertilizer application at the recommended rates of 100, 100 and 150 kg ha⁻¹ of nitrogen (N), phosphorus (P₂O₅) and potassium (K₂O) respectively (MLD, 1991). During the period the total rainfall received was 352 mm. January and February were very dry (mean rainfall 29 mm per month, mean temperature 24.6°C) whereas the mean for March to May were 101 mm per month with a mean temperature of 21.8°C. Thus during dry periods, when rainfall was not adequate, the plots were irrigated weekly to ensure continuous forage growth.

The harvesting of the sub-plots commenced 6 (42 days) weeks before the start of the experiment to allow the napier grass to be 6 weeks old at the start of the feeding experiment. The sub-plots were harvested on successive days such that the sub-plot to be fed on day 1 of the experiment was cut 42 days before, that for day 2, 41 days before, and so on. The P1 plot was harvested twice during the period. The adopted harvesting schedule ensured that the napier grass fed during the entire experimental period was 6 weeks.

The harvesting procedure for P2 field was similar to that used for P1, except that the plot was sub-divided into 84 sub-plots and that the first sub-plot was harvested 84 days before the start of the experiment, the second sub-plot 83 days before, and so on to ensure that the napier was same age (12 weeks) throughout the experimental period.

A clearing cut was also done for a 1 ha two-year old lucerne field (variety Hunter River). Fertilizer was applied at the rate of 100 and 100 kg ha⁻¹ of phosphorus (P₂O₅) and potassium (K₂O) (MLD, 1991) and the lucerne allowed to grow again for 6 weeks. Irrigation was regularly done as for napier grass. The

lucerne was then harvested using a mower, sun-dried for 60 hours, baled and stored in a well ventilated hay shed.

Napier grass was harvested in the afternoon, chopped into 25 mm pieces and spread in an open shed until the following morning. Lucerne hay was similarly chopped.

Experimental animals, diets and housing

Twenty four heifers from each of two breeds, Sahiwal (*Bos indicus*; 124.1 kg LW, SD = 1.92; average age of 15.3 months) and Friesian (*Bos taurus*; 170.1 kg LW, SD = 1.69; average age of 15.5 months) were selected from two large herds in the research station. Friesians were previously grazing an irrigated predominantly Kikuyu grass (*Pennisetum clandestinum*) and Kenya white clover (*Trifolium semipilosum*) mixed sward while Sahiwals were grazing a non-irrigated Naivasha star grass (*Cynodon plectostachyus*) pasture.

Since heifers within breeds had similar weights, they were blocked by breed. The 24 heifers of each breed were then randomly allocated to the six dietary treatments as follows: young napier + 0 kg lucerne (T1); young napier + 1.5 kg lucerne (T2); old napier + 0 kg lucerne (T3); old napier + 1.5 kg lucerne (T4); old napier + 2.5 kg lucerne (T5); old napier + 3.5 kg lucerne (T6) heifer⁻¹ day⁻¹. Therefore each diet was offered to four Sahiwal and four Friesian heifers. Napier grass was given *ad libitum*. The heifers were housed and fed individually. A month prior to the start of the experiment, the heifers were treated against helminths. Spraying with acaricide to control ticks was carried out weekly. Water and licks were provided at all times.

Feeding , feed sampling and weighing procedures

Each morning the chopped feed (Napier grass and lucerne) to be offered to each heifer were weighed. This was divided into in two equal portions and offered twice daily. The supplement was always given first. Feed to be offered (napier grass) was adjusted daily such that the refusals were not more than 10% of the feed offered.

Feed samples were obtained by regularly taking samples as the chopping progressed (about 10 kg). Sub-sampling was done by spreading the bulked sample on a polythene sheet to form a ridge and taking four segments of the ridge for each of the samples taken for DM, chemical analysis and rumen incubation. Samples of offered feed and refusals were collected daily and oven-dried and stored. Samples for each week were then composited for analysis. The weighing of the heifers was done before feeding on three consecutive days at the beginning of the trial and the procedure repeated fortnightly. The mean weight for the three weights was taken as each heifer's body weight at that time.

Experiment B: Rumen degradation

Four rumen fistulated steers (two of each breed) approximately 18 months old with mean body weights of 295 kg (Sahiwal) and 340 kg (Friesian) were used. These steers were also individually housed and fed on a mixed diet of napier grass (75%) and lucerne (25%) *ad libitum*. Tick and helminth control were carried out as reported earlier in Experiment A.

Feed samples for rumen incubation were ground to pass through 5 mm sieve, 5 g weighed and placed in nylon bags (Nybold Switzerland; polyimide, porosity 26%, pore size 40 μ m). The bags were incubated for 0, 3, 6, 12 (duplicate), 24, 48, 96 (triplicate) and 336 (quadruplicate) hours in each animal. After incubation, the bags were washed in tap water for 5 minutes after which they were oven-dried at 70°C for 48 hours. The dried samples were then weighed to determine dry matter residue.

Chemical analysis

Feed samples were collected daily before morning feeding and composited weekly. The DM was determined by oven-drying at 105°C for 24 hours. Feeds samples for chemical analysis were, however, oven-dried at 70°C for 24 hours. The latter were then ground using a Wiley mill to pass through a 1 mm screen before analysing for organic matter (OM, ashing at 500°C) and Kjeldahl nitrogen (AOAC,

1990). Neutral detergent fibre (NDF) and acid detergent lignin (ADL) were analysed using the method of Van Soest and Robertson (1985). Calcium and magnesium were determined by flame atomic absorption and phosphorus by spectrophotometry (AOAC, 1990). Silica was determined as the ash after the ADF ash was leached for one hour with 48% hydrobromic acid.

Calculations and statistical analysis

The average daily gains (ADG) over the experimental period was calculated by regressing body weight (kg) of individual heifers measured fortnightly on time (in days). The average daily gains (ADG), DM degradation and feed intake were subjected to analysis of variance using the general linear model procedure (GLM) available in SAS (1988). The treatment effects were further partitioned into single degree of freedom orthogonal contrasts. Residual DM at the various incubation times were expressed as fractions of original amounts incubated and the results analysed by non-linear regression (SAS, 1988) according to the model of Robinson *et al.*, (1986):

$$R_t = U + (100 - S - U) * e^{-k_d * t}$$

where; R_t is residue at time t (%), U is rumen undegradable fraction (336 hour incubation, %), S is water soluble fraction (0 h incubation, %) and k_d is fractional rate of degradation ($\% h^{-1}$). The rumen degradation results of the individual diet ingredients were used to calculate the degradation of treatment diets by the method of de Visser (1993) as follows:

$$\text{Diet degradation} = (\text{napier DMI/Total DMI}) \times \text{napier degradation} + (\text{lucerne DMI/Total DMI}) \times \text{lucerne degradation}$$

The substitution rate was estimated using the following formula: $r = [(a-b)-c]/d \times 100$, where, r is substitution rate (%), a is total DM intake (kg), b is DM in

supplement (kg) and *c* is DM intake of basal feed without supplement (kg). Feed efficiency was calculated as gain per feed intake (OM).

Results

Chemical composition

The composition of napier grass and lucerne are shown in Table 1. As expected, napier grass had lower DM content (173 and 185 g kg⁻¹ DM, respectively for 6 and 12 weeks) than the lucerne hay (845 g kg⁻¹ DM). The CP content of lucerne hay (190 g kg⁻¹ DM) was more than twice that of napier grass (85 and 63 g kg⁻¹ DM for 6 and 12 week old napier grass). However, neutral detergent fibre (NDF) was higher for napier grass than it was for lucerne. Lucerne showed higher OM content since its ash content was lower compared to napier grass. The mean silica levels for napier grass were higher than lucerne whilst the latter showed a higher ADL level. Lucerne was richer in calcium than napier grass although its phosphorus levels were lower. However, the magnesium levels in napier grass and lucerne showed little variation.

Table 1: Chemical composition of napier grass (6 and 12 week old) and lucerne used as ingredients in the heifer diets (treatments).

Component	Napier (6 weeks)	Napier (12 weeks)	Lucerne
Composition (g kg ⁻¹ DM basis)			
DM %	173	185	847
OM	788	797	847
CP	85	63	190
NDF	593	611	455
ADF	336	384	447
EE	15	13	16
ADL	3.7	4.5	6.6
Total ash	212	203	153
Residue ash	74	94	34
Silica	72	86	23
Calcium	2.9	2.5	7.5
Phosphorus	5.4	4.4	3.8
Magnesium	1.9	2.1	1.9

DM = dry matter, OM = organic matter, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, EE = ether extract, ADL = acid detergent lignin.

Table 2: Mean daily total intake of organic matter (OM), neutral detergent fibre (NDF), crude protein (CP), dry matter (DM), average daily weight gains (ADG), substitution rate (SR) and feed efficiency (FE) for Friesian and Sahiwal heifers consuming 6 or 12 weeks Napier grass (*ad libitum*) supplemented with graded levels of lucerne.

Treatment	Intake					ADG (kg)	SR (%)	FE %
	DMI (kg)	g DM kg ^{0.75}	OM (kg)	NDF (kg)	CP (kg)			
T1 Napier (6 weeks) + 0 kg lucerne								
Friesian	5.4 ^a	97 ^a	4.3 ^{ab}	3.2 ^a	0.46 ^a	0.34 ^a	0.00	0.06
Sahiwal	4.7 ^b	118 ^b	3.7 ^b	2.8 ^b	0.40 ^b	0.29 ^b	0.00	0.06
mean	5.1	114	4.0	3.0	0.43	0.31	0.00	0.06
T2 Napier (6 weeks) + 1.5 Kg lucerne								
Friesian	6.4 ^a	118 ^a	5.2 ^a	3.6 ^a	0.68 ^a	0.52 ^a	0.23	0.08
Sahiwal	5.3 ^b	131 ^b	4.3 ^b	3.0 ^b	0.59 ^b	0.40 ^b	0.53	0.08
mean	5.9	125	4.8	3.3	0.64	0.46	0.38	0.08
T3 Napier (12 weeks) + 0 kg lucerne								
Friesian	5.2 ^a	97 ^a	4.2 ^a	3.2 ^a	0.33 ^a	0.35 ^a	0.00	0.08
Sahiwal	4.3 ^b	111 ^b	3.5 ^b	2.1 ^b	0.27 ^b	0.30 ^b	0.00	0.07
mean	4.8	104	3.9	2.7	0.30	0.32	0.00	0.07
T4 Napier (12 weeks) + 1.5 kg lucerne								
Friesian	6.1 ^a	119 ^a	5.8 ^a	4.3 ^a	0.61 ^a	0.52 ^a	0.34	0.09
Sahiwal	5.3 ^b	134 ^b	4.6 ^b	3.4 ^b	0.52 ^b	0.42 ^b	0.22	0.08
mean	5.7	126	5.2	3.9	0.57	0.47	0.26	0.09
T5 Napier (12 weeks) + 2.5 kg lucerne								
Friesian	7.5 ^a	141 ^a	6.1 ^a	5.2 ^a	0.75 ^a	0.65 ^a	0.07	0.09
Sahiwal	6.3 ^b	147 ^b	5.2 ^b	3.6 ^b	0.67 ^b	0.61 ^a	0.08	0.10
mean	6.9	144	5.7	4.1	0.71	0.63	0.08	0.10
T6 Napier (12 weeks) + 3.5 kg lucerne								
Friesian	7.8 ^a	147 ^a	6.4 ^a	4.4 ^a	0.87 ^a	0.66 ^a	0.10	0.09
Sahiwal	6.7 ^b	157 ^b	5.5 ^b	4.7 ^b	0.80 ^b	0.64 ^a	0.21	0.10
mean	7.3	152	6.0	5.0	0.84	0.65	0.16	0.10
S.E.D (n=8)	0.116	1.420	0.103	0.102	0.008	0.037	0.06	0.01
Significance								
T1 vs T2	***	**	***	***	***	***	***	***
T1 vs T3	***	***	ns	**	***	ns	ns	***
T1 and T2 vs T3, T4, T5 and T6	***	***	***	***	***	***	ns	***
T3 vs T4, T5 and T6	***	***	***	**	***	***	***	ns

ns (not significant), $P > 0.05$; ** $P < 0.01$ and *** $P < 0.001$

^a Within treatments, figures bearing different superscripts differ significantly ($P < 0.05$).

Nutrient intake and weight gain (ADG)

The results indicated that lucerne supplementation positively influenced ($P < 0.05$) DM, OM, CP, and NDF intake (Table 2). Friesian heifers showed higher DM and OM intake than the Sahiwal heifers ($P < 0.05$) but the reverse was true when the intake was expressed per metabolic weight. Heifers under supplementation (T2, T4, T5 and T6) gained significantly ($P < 0.05$) more weight than those on napier grass alone (Table 2). However, the means for T1 and T3 showed no significant ($P < 0.05$) difference. Treatment T5 and T6 had the highest gains of over 0.60 kg per day for both breeds. Except for T2 and T4, the substitution rates for the supplement were generally low.

Table 3. Rumen degradation of the napier grass diets supplemented with varying levels of lucerne

	Fraction			k_d
	S	D	U	
Treatment				
T1 Napier (6 weeks) + 0 kg lucerne	27.2	51.2	22.6	3.3
T2 Napier (6 weeks) + 1.5 Kg lucerne	27.7	55.9	21.9	3.4
T3 Napier (12 weeks) + 0 kg lucerne	21.7	45.7	25.3	2.7
T4 Napier (12 weeks) + 1.5 kg lucerne	27.1	48.2	23.9	3.0
T5 Napier (12 weeks) + 2.5 kg lucerne	27.7	50.9	23.1	3.1
T6 Napier (12 weeks) + 3.5 kg lucerne	28.4	53.1	22.6	3.3
S.E	2.3	3.1	2.9	0.6

S = soluble; D = slowly degradable; U = undegradable fraction (U); k_d = rate of degradation (% per hour); S.E. = of diets offered to Friesian and Sahiwal heifers.

Rumen degradation

The lucerne supplement significantly ($P < 0.05$) improved degradation. Generally, the higher the proportion of supplement in the diet, the higher the degradation (Table 3). The fractions S, D, U and the rate of degradation, k_d of the diets are shown in Table 3. Napier maturity was also observed to have a negative influence on degradation. At same levels of supplementation, diets containing 12 week old napier showed a lower degradation as the respective S, D and U fractions showed.

Discussion

Tropical forages support lower levels of animal production than temperate grasses due to low CP and digestibility (Minson, 1990). Napier grass in this study had a CP content of $85 \text{ g kg}^{-1} \text{ DM}$ (6 weeks) and $63 \text{ g kg}^{-1} \text{ DM}$ (12 weeks) and may be considered to represent what is available in smallholder dairy farms. However, according to the definition of Leng (1990) that low quality forages as those with less than $80 \text{ g kg}^{-1} \text{ DM CP}$, the 6 weeks napier grass had marginal CP content while the 12 weeks one would clearly be low quality feed. Nevertheless, lucerne ($190 \text{ g kg}^{-1} \text{ DM CP}$) would be an excellent supplement since it is easily grown by the smallholders. Legume supplements to low quality tropical grasses improve rumen microbial activity (Minson and Milford, 1967; Reed *et al.*, 1990). Indeed such supplementation increases both energy and protein supply leading to enhanced animal performance (Norton and Poppi, 1995a). This has been demonstrated using other legumes in cattle (Muinga *et al.*, 1995; Abdulrazak, *et al.*, 1996) and goats (Richards *et al.*, 1994; Van Eys *et al.*, 1986).

In this study, supplementing napier grass with lucerne increased the crude protein content of the diet leading to enhanced nutrient intake. Across the four levels of supplementation, the difference in intake was about 1.0 kg DM per day. The heifers receiving lucerne supplements consumed slightly less napier grass but total DM intake was higher. This could partly be attributed to the substitution effect. The DMI of Friesian was higher than the Sahiwal heifers an observation that may be explained by the fact that, within the same treatments, Friesians had

heavier body weights. However, intake per metabolic weight was higher for the Sahiwals. This observation tends to support the proposition that *Bos indicus* breeds are better adapted to tropical feeds than *Bos taurus* (Cunningham and Syrstad, 1987). It is also probable that there was some compensatory growth in the Sahiwals because they were previously on a relatively low plane of nutrition (Ehoche *et al.*, 1992).

The increase in weight gain on lucerne supplementation could be explained by improvement in nutrient intake and degradation. It was unexpected that weight gains from 6 and 12 weeks napier would be similar and this could not be easily explained. However, the low gains observed on these diets have been recorded previously on sole napier grass diets (Moran, 1983, Pachauri and Pathak, 1989).

The rates of substitution observed in the study were generally low, a fact that could be attributed to the relatively low levels of lucerne supplement though Sahiwal heifers in T2 showed significantly higher substitution rate for unexplained reasons. The little substitution effect of lucerne contrasts with the effect of concentrate supplements on the intake of basal grass diets. Nevertheless, these results correspond with Van Eys *et al.*, (1986) who found little or no substitution when goats fed on napier grass as a basal diet were supplemented with *Leucaena*. Certain protein-rich supplements demonstrate substitution effect (Mosi and Butterworth, 1985; Norton and Poppi, 1995b) while others show no such characteristic (McMeniman *et al.*, 1988; Ash, 1990) and hence the results from this study were not surprising. It has also been observed that the extent of substitution depends on the rate of degradation (Khalili, 1993).

Most legumes are more lignified than grass (Smith *et al.*, 1972), a phenomenon that was observed in this study. Despite this, lucerne containing diets were degraded more than the napier grass-only diets. This could be explained by high protein content in the supplemented diets and the high silica content associated with napier grass. Silica bind cellulose and hemicellulose in a manner similar to lignin and thus reducing digestion (Van Soest, 1982). Studies with other legumes have also attributed high degradation to the fragility of cell walls, good

buffering capacity and readily degraded mesophyll and phloem tissues (Ndlovu, 1992; Broderick, 1995).

The efficiency with which napier grass was utilized tended to increase with the level of supplement. The supplemented 6 weeks napier grass was more efficiently used than the unsupplemented one. For the 12 weeks napier grass, the highest efficiency occurred at 2.5 kg lucerne supplementation level. It may be possible that at the higher supplementation level, energy became a limiting factor and hence no further improvement in the efficiency of utilization could be gained.

Conclusion

The improved protein status of the diet increased supply of protein to the rumen, making the rumen microbes to proliferate enhancing microbial activity. This consequently led to higher nutrient intake and weight gains. Therefore, the results from this study suggest that lucerne supplementation would greatly improve animal production in smallholder dairy farms.

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Chapter 9

Effect of *Desmodium*, *Sesbania* and *Calliandra* supplementation on growth of dairy heifers fed napier grass basal diet

R.J. Kaitho¹ and J.N. Kariuki²

¹ International Livestock Research Institute, P.O. Box 30709, Nairobi, Kenya.

² National Animal Husbandry Research Centre, P.O. Box 25, Naivasha, Kenya.

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R.J. Kaitho and J.N. Kariuki

Abstract

The effect of feeding heifers young napier grass (7-weeks regrowth) or old napier (16-weeks regrowth) supplemented with either wilted *Desmodium intortum*, *Sesbania sesban* or dried *Calliandra calothyrsus* leaves on intake and live weight changes was evaluated in a 67-day trial. Thirty-two Friesian heifers with an average live weight of 271 kg and 16.8 months old were randomly allocated to the four diets. The diets were either *ad libitum* young napier grass or old napier grass supplemented with 25% each of *Sesbania*, *Desmodium* or *Calliandra*. There was a significant difference in chemical composition between the young and old napier grass. Significant differences ($P < 0.05$) were also observed on intake of dry matter (DM), organic matter (OM), crude protein (CP) and neutral detergent fibre (NDF). The total DM intake were 2.77, 2.86, 2.62 kg per 100 kg live weight (LW) for *Desmodium*, *Calliandra* and *Sesbania* supplemented diets respectively. A DM intake of 3.11 kg per 100 kg LW was observed on the heifers fed young napier grass. The mean weight gains were 369 g per day for young napier grass and 235, 270 and 224 g per day for old napier grass supplemented with *Desmodium*, *Calliandra* and *Sesbania* respectively. It was concluded that supplementing old napier grass prevented loss of weight and sustained some weight gain.

Key words: Forage supplementation, intake, growth, napier, heifers.

Introduction

In developing countries, feeding of dairy cattle is often based on crop residues and low quality native hay or pasture. Since these are often low both in protein and energy there is a need for supplementary feeding to meet nutrient requirements. As supplies of commercial concentrate, agro-industrial by-products or domestic cereals are limited and consequently expensive, other supplementary feeds produced on-farm are needed for cattle feeding. Forage legumes are endowed with high nitrogen content and can be used as protein supplements to poor quality

grasses and cereal by-products. Their use has resulted in some dramatic increases in animal performance (Stobbs and Thompson, 1975) which have encouraged their widespread adoption.

A large number of shrubs and tree legumes have been documented as useful livestock fodders (Kaitho, 1997; Topps, 1992). For example, *Leucaena leucocephala* and *Gliricidia sepium*, have been particularly used as supplements to a wide range of forages and agricultural by-products. *Leucaena leucocephala* inclusion improved performance of sheep (Kaitho *et al.*, 1997), goats (Van Eys *et al.*, 1986), dairy heifers (Thirumalai *et al.*, 1991), and calves (Pachauri and Pathak, 1989) on a number of different grass basal diets. *Calliandra calothyrsus*, *Sesbania sesban* and *Desmodium intortum* have been adopted as protein supplements to poor quality grasses and cereal by-products in the cut-and-carry feeding systems. *Desmodium* is inter-cropped with napier grass, while *Sesbania* and *Calliandra* browses are established as hedge rows or alleys. These forage legumes are hardy and have favourable chemical composition, with a nitrogen content of 3-5% in dry matter (edible leaves and stem). As napier grass matures, the nutrient content decreases, while dry matter content and yield increases. Therefore farmers can either feed young napier grass if land and labour is not a constraint, or feed old napier grass which requires supplementation to maintain the same level of production. Therefore this experiment was designed to investigate the effect of feeding Friesian heifers young napier grass (7-weeks regrowth) or old napier grass (*Pennisetum purpureum*) grass (16-weeks regrowth) supplemented with either wilted *Desmodium intortum*, *Sesbania sesban* or dried *Calliandra calothyrsus* leaves on intake and live weight changes.

Materials and methods

Napier grass, *Sesbania* and *Desmodium* were grown under irrigation at the National Animal Husbandry Research Centre, Naivasha, while *Calliandra* leaves were harvested and dried at Kisii Farmers Training centre. Thirty-two heifers (271 kg, 16.8 months old) selected from the centre herd were blocked on weight and age into four groups and allocated to the experimental diets in a completely

randomized block design. They were housed in cubicles with individual feeding facility and offered their corresponding diets for 67 days. The diets were either *ad libitum* young napier grass or old napier grass supplemented with 25% of either *Sesbania*, *Desmodium* or *Calliandra*. Water was provided *ad-libitum*. The supplements were fed prior to feeding of napier grass in the morning. Fresh napier grass was harvested and transported to the stable daily and chopped to particles size of about 2 cm. Feeding was such that 30, 25, 25 and 20% of the basal diet was fed in the morning, noon, evening and at night, respectively. The amount of offer was adjusted daily to allow a left-over of 10-15%. The heifers were weighed weekly and underwent routine spraying and animal health care similar to all cattle in the research centre.

Four rumen-fistulated Friesian steers (451 kg; SD = 8.2) were used for rumen degradation studies using the nylon bag technique (Mehrez and Ørskov, 1977). Each steer was fed napier grass supplemented with 1 kg concentrate (CP = 12.6%, NDF = 46.9%). The feed samples were ground through 2.5 mm screen, weighed into nylon bags (12 cm X 14 cm; 41 μ m pore size; Polymide, Switzerland) and incubated for 0, 3, 6, 12, 24, 48, 72, 96, 120 and 336 h. After incubation, the bags were washed in a washing machine (set temperature 30°C) without spinning. The bags were dried in a forced-air oven at 60°C for 48 h, cooled in a desiccator, and weighed.

Sample preparation and chemical analysis

Feed samples were obtained by regularly taking samples as the chopping progressed (6-8 kg). Sub-sampling was done by spreading the bulked sample on a polythene sheet to form a ridge and taking four segments of the ridge for each of the samples taken for dry matter and chemical analysis. The chemical analysis samples were bulked for every three consecutive days after drying at 60°C. Similarly, the individual heifer dietary feed left-overs were daily sampled for dry matter determination.

Samples of feeds and refusals were ground to pass a 1.0 mm screen using a Wiley mill, while rumen incubated residues were ground using a mortar and

pestle. Dry matter was assayed on the offered and refused feed using the method described by the AOAC (1990). All other analyses were determined using air-dried feed samples and oven-dried (60°C) rumen incubated residues. Analyses for ash and Kjeldahl nitrogen (N) in forages were according to AOAC (1990) standard procedures. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin were analysed using the method of Van Soest and Robertson (1985).

Data and statistical analysis

Live weight gain (LWG) over the experimental period was calculated by regressing body weight (kg) of individual animals measured weekly on time (in days). Residual DM at the various stages of incubation were expressed as fractions of original amounts incubated and the results analysed by non-linear regression (SAS, 1988) based on the following model (Robinson *et al.*, 1986):

$$R_t = U + (1000-S-U) * e^{-kd(t-L)}$$

Where R_t = residue at time t

U = truly indigestible residue (336 h incubation)

S = water soluble fraction (0 h incubation)

Kd = rate of degradation (% / h)

L = lag phase.

Different rates of degradation were obtained by fitting the model with ($Kd1$) and without ($kd2$) lag phase.

Results

Chemical composition of napier grass and supplements offered is given in Table 1. There was significance difference ($P < 0.05$) on dry matter, crude protein, neutral detergent fibre and ash content of napier grass and the supplements. The legume supplements had higher ($P < 0.05$) crude protein content than the napier grass, however napier grass had higher ash and neutral detergent fibre levels than the legumes. The old napier grass was in the late vegetative growth stage and had

Table 1. Chemical composition (%) and rumen degradability of napier and legume supplements fed to heifers

Component (%)	Young Napier	Old Napier	<i>Desmodium</i>	<i>Calliandra</i>	<i>Sesbania</i>	SED
DM	16.6	23.7	29.6	90.9	29.0	0.82
ASH	19.8	16.5	10.8	7.8	7.3	0.37
CP	8.5	6.4	12.7	21.2	15.5	0.22
NDF	62.7	67.5	59.9	49.5	55.1	0.64
ADF	29.0	34.4	35.2	29.7	10.6	0.97
ADL	2.6	3.1	8.9	13.3	2.9	0.14
S (%)	28.4	18.5	19.3	28.7	31.6	
U (%)	17.4	23.7	28.9	22.3	3.0	
L (h ⁻¹)	0.2	1.6	1.5	3.4	1.5	
Kd1 (% h ⁻¹)	3.5	2.6	2.9	1.6	5.8	
Kd2 (% h ⁻¹)	3.1	2.5	2.7	1.2	5.3	

DM: dry matter (%); CP: crude protein (%); NDF: neutral detergent fibre (%); ADF: acid detergent fibre (%); ADL: lignin (%); S: water soluble fraction, U: undegraded residue; L: lag phase; Kd1: degradation rate from a model including lag phase, Kd2: degradation rate from model excluding lag phase; SED: standard error of difference (n = 20).

a crude protein content of 6.4% which was significantly lower than crude protein of the young napier grass (8.5). The young napier grass had relatively higher solubility and degradability than the old napier, while among the supplements, *Sesbania* had higher solubility and degradability than *Calliandra* and *Desmodium*.

Table 2 shows mean nutrient intake and live weight gain of heifers fed young napier grass or old napier grass supplemented with forage legumes. Significant differences ($P < 0.05$) were observed on intake of dry matter, organic matter, crude protein and neutral detergent fibre. Animals fed young napier grass had significantly

Table 2. Nutrient intake (kg per 100 kg LW) and body weight gain (g per day) of heifers fed young napier grass or old napier grass supplemented with forage legumes.

	Young	Old Napier supplemented with			SED
	Napier	<i>Desmodium</i>	<i>Calliandra</i>	<i>Sesbania</i>	
DMI Napier	3.11	2.31	2.43	2.28	0.037
DMI supplement	-	0.46	0.43	0.34	0.017
Total DMI	3.11	2.77	2.86	2.62	0.039
CPI	0.24	0.21	0.25	0.20	0.005
NDFI	1.95	1.83	1.85	1.73	0.065
OMI	2.49	2.34	2.43	2.22	0.033
Weight gain	369	235	270	224	10.8

LW: live weight; DMI: dry matter intake (kg per 100 kg LW); CPI: crude protein intake (kg per 100 kg LW); NDFI: neutral detergent fibre intake (kg per 100 kg LW); OMI: organic matter intake (kg per 100 kg LW); SED: standard error of difference (n = 8).

($P < 0.05$) higher dry matter intake and live weight gain than those fed old napier grass. The total dry matter intake was 2.77, 2.86, 2.62 kg per 100 kg live weight for *Desmodium*, *Calliandra* and *Sesbania* supplemented diets respectively. A dry matter intake of 3.11 kg per 100 kg live weight was observed on the heifers fed young napier grass. Heifers on young napier grass gained 369 g day⁻¹ while the mean daily gains were 235, 270, and 224 g day⁻¹ for old napier grass supplemented with *Desmodium*, *Calliandra* and *Sesbania* and respectively.

Discussion

The pattern of growth and nutrient intake observed in this study indicate that supplementation of poor quality napier grass with legumes had a positive impact on daily gains. Legume supplementation of grass diets with less than 7% CP has been shown to increase dry matter intake and animal performance (Minson and Milford, 1967). In many parts of tropics, there are regular feed shortages and droughts and therefore under such conditions subsistence feeding, mainly poor quality grasses and crop by-products, results in reduced live weight and low animal livestock productivity. The old napier (6.4% CP) could at best only maintain the animals but lactating cattle would most likely lose body weight. The severe nutritional limitations in growing heifers are further associated with delayed age at first calving, increased interval between parturitions, increased non-productive life of animals and herd wastage. Therefore, during times of feed shortage, forages from shrubs and especially trees have a great value as they supply dietary nitrogen, energy, minerals and vitamins.

Most investigations of intake response to protein supplementation have been conducted with concentrate supplements. Previous research indicates that browses will support similar level of animal performance when fed to provide similar amounts of CP (Khalili and Varvikko, 1992; Varvikko and Khalili, 1993; Richards *et al.*, 1994). In this study, animals on young napier grass gained more weight than those fed old napier grass and supplemented with the forage legumes. In a previous study, Kaitho and Kariuki (1990) observed that heifers fed old napier grass sustained a growth of 320 g per day while those fed young napier grass gained over 484 g per day. Legume supplementation of grass-only diets has been observed to improve animal performance (Chadhokar and Kantharaju, 1980; Reed *et al.*, 1990). These responses have typically been attributed to the legume overcoming the depressing effect that the low N concentration grass has on intake (Minson and Milford, 1967), and by the legume providing ruminally degradable N (Van Eys *et al.*, 1986) or ruminally escape N (Flores *et al.*, 1979).

Most of the forage legumes contain biochemically active materials, such as cyanogenic glycosides, tannins, goitrogenic and allergenic substances that affect

metabolism. When livestock are on free range pasture, as in an extensive production systems, they are hardly affected. This may be because of the animals have a variety of forage material to select from. Under zero grazing system, the farmer hardly provides variety, hence incidences of toxicity are more likely. It is known that high levels of tannin are present in *Calliandra* and *Desmodium*, and both have a low digestibility (Kaitho, 1992) while *Sesbania* has high levels of saponins (Kaitho *et al.*, 1997). Forage legumes containing moderate levels of phenolic compounds are promising protein supplements (Kaitho *et al.*, 1997). Although the phenolics in these species reduce nitrogen availability, the negative effect is partially offset by lower urinary loss of nitrogen, allowing adequate animal performance (Woodward and Reed, 1989).

Increased attention must be given to include potentially important shrubs and trees into native pastures, alley farming and agroforestry systems. Research on management and use of shrub and tree fodders is limited, although their potential is increasingly being recognized. There are however outstanding gaps in present knowledge concerning browse productivity and its measurement. The most important problem that urgently requires solution is how to increase the availability of browse to grazing and stall fed animals through improved management taking into consideration seasonal changes in plant productivity and the feed requirements of the animals. The nutritional value of browse has long been underestimated with the result that only limited data on intake, digestibility, utilization and the value of shrubs in dry seasons have been reported. Well designed studies need to be carried out to establish optimum levels of supplementation with various combinations of forages and by-products typical of particular areas.

Conclusion

It is clear that forage legumes have a distinct advantage over tropical grasses in terms of their superior nutritional value, particularly as supplements to poor quality roughages. Supplementation of old napier grass with legumes prevented weight loss and sustained some weight gain.

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Chapter 10

General Discussion

General Discussion

Introduction

Constraints to the smallholder dairy farming in high potential areas of Kenya are related to high human population and the subsequent pressure on land. As a result dairy cattle are reared under zero or semi-zero grazing and napier grass, because of its relatively high dry matter yields compared to other fodders is the most important fodder. However, the use of fertilizers on napier grass to improve its quality or concentrate supplementation to dairy cattle fed on napier grass are limited because most farmers cannot afford these inputs. The practical option, therefore, is to develop technologies that rely on home-made feeds.

Fortunately, a number of protein-rich forages (PRF) have been identified as possible supplements to napier grass. These options are attractive because PRF can be easily grown by farmers and are therefore sustainable and would lower the overall costs of raising replacement heifers. If used appropriately, they would serve two essential functions namely (i) to promote efficient microbial growth in the rumen and (ii) to increase protein supply for digestion in the small intestine (bypass protein). Lack of sufficient information on the nutritive value of napier grass and the PRF has limited their utilization because it is difficult to formulate diets and predict potential production from napier grass in combination with other feeds.

There are many interacting factors at the farm and in order to develop feasible improvements for the particular farming system it is important to understand these factors. Feed type, composition and availability vary between seasons and within the farm and therefore animal production target is normally adjusted to fit the feed available. This smallholder farmers' practice is in sharp contrast to the high input dairy production systems in the western world where feed is adjusted to meet the target animal production level (Schiere and De Wit, 1993).

Opportunities for improving quality

Animal performance from napier grass on the smallholder farms is low, with milk yield well below 2000 kg year⁻¹ (Abate and Abate, 1991) and weight gain does not exceed 0.25 kg day⁻¹ (Gitau *et al.*, 1994). The review in Chapter 2 gives

an appraisal on the current knowledge on the nutritive value of napier grass and proposes low cost strategies for small scale dairy farmers to improve animal production from napier grass. The results presented showed that napier grass has high a DM production potential but is deficient in crude protein (CP), is low in some minerals and has a high degree of indigestibility. The first requirement for any improvement should therefore attempt to increase the absolute levels of major nutrients such as protein in napier grass diets in order to improve animal production at the farm level. It was noted that there is little information on animal performance from napier grass and it is therefore not well defined what supplement types and levels should be included in napier grass based diets.

To improve the quality of napier grass only diets, it was suggested that the use of easily grown PRF offers a better option to the resource poor smallholder dairy farmer. It was, however, pointed out that the CP content and digestible CP systems in Kenya do not fully account for the protein value in napier grass and the PRF. Unfortunately available information on Kenyan forages including napier grass is largely derived by the Weende proximate analytical system (Gohl, 1981; Abate *et al.*, 1984; Wandera, 1997). Indeed, CP content on its own is hardly linked to the digestion process in the animal while DCP neglects protein degradation and microbial protein production in the rumen (Tamminga *et al.*, 1994). The system currently being used in the country is therefore unsatisfactory to assess the nutritional adequacy of napier grass and other forages. Factors such as nitrogen (N) degradation in the rumen and the digestion of bypass protein are of paramount importance. It was subsequently concluded that assessment of Kenyan forages using the newer and more accurate methods of feed evaluation are necessary to conform with the current international practices.

Rumen degradation and intestinal protein digestion

Napier grass and PRF were evaluated in terms of rumen degradation and intestinal protein digestion (Chapter 3). Three other grasses which are possible substitutes to napier grass were also studied. In order of importance, these were Kikuyu grass (*Pennisetum clandestinum*), Guinea grass (*Panicum maximum*),

Rhodes grass (*Chloris gayana*) and Guatemala grass (*Tripsacum daniellii*). The seven PRF considered were lucerne (*Medicago sativa*), Kenya white clover (*Trifolium semipilosum*), sweet potato vines (*Ipomoea batatas*), desmodium (*Desmodium spp.*), banana stems and leaves (*Musa sapienta*), edible canna (*Canna edulis*), *Leucaena leucocephala*, *Sesbania sesban*, *Calliandra calothyrsus* and *Acacia xanthophloea*. Grasses had <100 CP g kg⁻¹ DM while the other forages except banana leaves/stems and edible canna had >170 CP g kg⁻¹ DM which was comparable to the reported ranges for tropical grasses and legumes (D'Mello and Devendra, 1995; Minson, 1990).

Results from ruminal degradation (in situ) as well as intestinal digestion (MNB) varied among forages. For instance *D. uncinatum* and *A. xanthophloea* had the lowest slowly degradable (D) of fraction of CP at 355 and 308 g kg⁻¹ and also lowest total tract digestibility of CP 575 and 261 g kg⁻¹ respectively. In contrast, *T. semipilosum*, *M. sativa* and *S. sesban* underwent rapid and extensive degradation in the rumen leading to low bypass protein (BP). The forages studied in this trial provided levels of BP ranging from 374 to 713 g kg⁻¹ with apparent digestibility of ranging from 18 about to 80%. The mean apparent digestibility was much lower than those reported for temperate forages (Van Bruchem et al., 1989; Valk et al., 1996; Van Straalen et al., 1995) but comparable to Kaitho et al., (1998) for tropical forages.

It was suspected that the low degradation in *D. uncinatum* and *A. xanthophloea* compared to other forages was caused by tannins in these species (Kiura, 1992; Kaitho et al., 1998). When tannins exceed 4%, they depress feed intake due to their astringency and anti-microbial characteristics (Susmel and Filacorda, 1996). Tannins are also negatively associated with feed utilization efficiency because they form complexes with feed proteins, enzymes and polysaccharides (Leinmueller et al., 1991). However, other reports indicated that low quantities of tannins (3-4% of DM) show positive effects by preventing excessive rumen degradation of dietary protein and reduce the risk of bloat (Mangan, 1988; Leinmueller et al., 1991; D'Mello, 1992).

This trial further investigated whether an *in vitro* (IV) method could be used to estimate intestinal protein digestion. The pepsin/pancreatin method accounted for 97% of the variations in mobile method. Generally, the IV method slightly overestimated undegradable protein (UDP) digestibility compared to MNB method. This corresponds to the findings of Van Straalen (1995) for temperate forages. It was concluded from Chapter 3 that CP content alone could not fully account for the nutritive value of forages especially some PRF. Protein degradation in the rumen and post-ruminal digestion of bypass protein portrayed a better assessment of nutritive value. However, the MNB could be considered laborious, costly and requires surgically prepared animal. A cheaper and easier such as the *in vitro* method would be highly favourable in the tropics where a large number of feeds have not been assessed for their protein value.

It was concluded from Chapter 3 that protein supplementation strategies for low CP tropical grasses should firstly target at satisfying the protein requirements of rumen microbes. Protein supplements containing a combination of ruminally degradable and bypass protein could then be considered for high animal performance. Using protein-rich forages which showed favourable RDP/DOMR ratios as supplements on grass diets would improve the animals metabolic capacity which would subsequently enhance voluntary intake and animal performance. Further research is necessary to determine how animal performance is influenced when the protein-rich forages are included in napier and other grass diets.

Effect of supplements on rumen fermentation

The nutrients the ruminant receives are not those chemically determined in the feed but are products of a variable fermentation process in the rumen and of intestinal digestion following thereafter. During microbial fermentation in the rumen, structural polysaccharides and other feed components are converted into volatile fatty acids (VFA), microbial biomass, heat and methane (Tamminga and Van Vuuren, 1988). The VFA are important sources of energy for the host animal, whereas microbial mass is an important source of required nutrients such as essential amino acids, phosphorus and B vitamins. Acetate, propionate and

butyrate, the key VFA formed in the rumen during fermentation are estimated to supply 70-90% of the animal energy requirements (AFRC, 1992; Nagaraja *et al.*, 1997). In addition to the VFA, rumen fermentation also provides about 70-100% of the ruminants amino acid supply (AFRC, 1992). Protein fermentation further leads to production of branched-chain fatty acids which are essential growth factors in cellulolytic bacteria (Chikunya *et al.*, 1996; Nagaraja *et al.*, 1997).

The major VFA differ in nature and therefore the ratio in which they are formed and supplied to the host animal is important. Acetate and butyrate are ketogenic while propionate is the main glucogenic precursor in ruminants (Van Houtert, 1993). The frequently reported ratio for forage based diets for acetate:propionate:butyrate is approximately 70:20:10 (Nagaraja *et al.*, 1997). However, the actual concentrations and proportions of VFA in the rumen will depend on feed intake (Sutton *et al.*, 1988; Van Houtert, 1993) and the composition of the diet (Dijkstra *et al.*, 1993). For instance forage diets typically result in a high proportion of acetate at the expense of propionate (Van Houtert, 1993). Quantitatively, rumen fermentation may be characterised by the amount of organic matter fermented (DOMR), concentrations and relative proportions of fermentation products and the amount and efficiency of microbial protein synthesis (Nagaraja *et al.*, 1997).

However, the effect of supplements on VFA concentrations and proportions was somewhat obscure (Chapter 4) because VFA production and absorption is a dynamic process. Indeed VFA concentrations in the rumen fluid are the result of rates of production, absorption and utilization as well as a function of total liquid available as a diluent (Robinson, *et al.*, 1986; Dijkstra, 1994).

The recommended $\text{NH}_3\text{-N}$ concentration that allows maximum microbial protein production in the rumen for tropical roughages is 150 mg l^{-1} (Preston and Leng, 1987). Rumen $\text{NH}_3\text{-N}$ concentration is a function of production by the microbes, $\text{NH}_3\text{-N}$ from urea recycling on one hand and utilisation by microbes, rate of passage to omasum and absorption through the rumen wall (Bosch *et al.*, 1991) on the other hand. Results in Chapter 4 indicated that at all supplementation levels, $\text{NH}_3\text{-N}$ concentration was raised above the minimum requirement reflecting

improved CP status of the diet and subsequent fermentation. However, napier grass only diets had $\text{NH}_3\text{-N}$ levels below requirements implying that such diets are likely to be inefficiently utilized. However, the optimum rumen $\text{NH}_3\text{-N}$ concentration for maximum microbial protein production has remained a subject of debate with Satter and Slyter (1974) giving 50 mg l^{-1} , Hoover (1986), 80 mg l^{-1} and Dixon (1987) indicating that as high as 200 mg l^{-1} may be necessary for low quality roughages.

The quantity of microbial protein (MP) produced in the rumen is influenced by the amount of organic matter fermented in the rumen (DOMR). The rumen MP production has been estimated as 150 g kg^{-1} DOMR (Brun-Bellut *et al.*, 1990;

Table 1. Contribution of supplements to improved to DMI and DOMR

Parameter	Proportion supplementation			
	0	10%	20%	30%
(a) Napier + desmodium				
OMI ($\text{g kg}^{-0.75}$)	74 ^a	76 ^{ab}	83 ^b	90 ^c
ED	468 ^a	533 ^b	543 ^c	584 ^c
DOMR intake ($\text{g kg}^{-0.75}$)	34.6	40.5	45.1	52.6
Increase in DOMR (%)	0	17.1	30.3	52.0
(b) Napier + sweet potato vines				
OMI ($\text{g kg}^{-0.75}$)	78 ^a	80 ^{ab}	86 ^b	94 ^c
ED*	465 ^a	515 ^b	541 ^c	553 ^c
DOMR intake ($\text{g kg}^{-0.75}$)	36.3	41.2	46.5	52.0
Increase in DOMR (%)	0	13.5	28.1	43.3

ED = effective degradation; DOMR = rumen fermentable organic matter; OMI = organic matter intake.

*The ED quantifies the proportion of consumed feed that is available for microbial fermentation (Ørskov and McDonald, 1979).

Tamminga *et al.*, 1994). Therefore deficiency of either rumen degradable protein (RDP) or DOMR would negatively affect MP production. The results indicate that PRF supplements had very profound effects on fermentation and greatly improved DOMR by up to 50% whereas intake of undegradable organic matter (OM) remained almost constant (Table 1). The latter observation suggest that rumen fill could limit intake in ruminants fed on tropical forages. Indeed, Norton and Poppi (1995) have recently reported that legumes have the greatest potential to improve the protein:energy ratios in tropical grass diets because of their inherently higher crude protein.

Mineral composition

In many regions in the tropics, forages are deficient in one or more minerals and supplementation is necessary for optimal animal performance and (or) health (McDowell and Conrad, 1990). A number of minerals are required by rumen microorganisms for their normal growth and metabolism (Durand and Kawashima, 1980; Spears, 1994). Low concentrations of these elements in forage may impair the ability of microorganisms to digest fibre and synthesize protein. Since the concentration of minerals in forages are affected by stage of maturity, climatic and seasonal changes (Minson, 1990) regular analysis has been recommended for formulating appropriate mineral supplementation schedules (Spears, 1994).

The concentrations of Ca, P, Mg, K, Cu and S are higher in legumes than in grasses (Fleming, 1973, Underwood, 1981; Minson, 1990). In Chapter 6, for instance lucerne diet had Ca, P and Mg levels that could meet the requirements of growing heifers. Therefore, the use of legumes as supplements can reduce mineral deficiencies to some extent. Sulphur (S) in the legumes and other plant protein is mainly in the form of S-containing amino acids. The content of S in the forage would therefore vary with forage CP content and the extent of protein degradation. Diets containing $> 150 \text{ g CP g}^{-1} \text{ DM}$ are likely to supply adequate S (Norton and Poppi, 1995). In this respect, PRF supplements in napier grass would greatly raise diet S-levels.

Results in Chapter 5 show that some minerals in napier grass may be present at potentially limiting levels for optimum animal performance. However, depending on stage of maturity and season, some major minerals such as P, Ca and Mg were found to be in concentrations that are likely to meet the needs of moderately growing dairy heifers. Potassium (K) was very abundant in the grass whereas Na was at the threshold of meeting animal requirements. However, Zn, Mn and Co concentrations were below animal requirements. Mineral deficiencies are likely to lead to depressed feed intake, forage utilization and subsequently poor animal performance (Underwood, 1981).

However, the mineral concentrations of napier grass given in study should be considered as general guidelines because they only indicate which minerals are likely to be deficient without measuring availability in animals. The observed trends would need to be confirmed by studies focusing on factors affecting mineral availability in cattle. For instance, relatively high solubilization of forage minerals in the rumen have been reported (Serra *et al.*, 1996; Van der Kamp, 1988) suggesting that the release of minerals in the rumen may not limit their use by rumen microbes.

Inter-cropping napier grass with legumes

The concept of grass/legume mixture as an attractive option to dairy farmers is based on the benefit derived by the grass from the symbiotic nitrogen fixed by the associated legume, and the better balanced diet with respect to both protein and energy. Numerous grazing trials world-wide have shown considerable improvements in weight gains when cattle were grazed on grass/legume compared to pure grass pastures (Butterworth; 1985). However, hardly any work on animal performance is reported for the "cut-and-carry" systems in Kenya. Inter-cropping napier grass with tree legume hedge-rows has been introduced in western (Semenye *et al.*, 1989) and coastal Kenya (Mureithi *et al.*, 1995). In the

Table 2. Dry matter (DM) yield, OM digestibility (% in vitro), CP content (g kg⁻¹ DM), N-fixed, carrying capacity (CC) and estimated animal performance from napier/desmodium mixture

Forage	DM yield ¹ t/ha	CP	in vitro OMD	est.N fixed	est. CC ²	Gain ¹ kg d ⁻¹	Gain ² kg d ⁻¹	³ Cost of gain Ksh d ⁻¹
Mean cutting height = 79 cm								
Napier	14.7	117	550	0	5.8	0.41	2.4	46.9
Mixture	19.3	103	524	190	7.6	0.45	3.1	41.3

¹ = weight gain per heifer per day; ² = total weight per hectare per day.

³The CC is determined by using the mean DM intake of heifers in Chapter 7; ⁴ Exchange rate 1US\$ = Ksh.60; DM yield data from Snijders *et al.*, (1992).

highland regions, napier/desmodium has been successfully grown (Snijders *et al.*, 1992). Napier/desmodium mixture can form a stable mixture that persists for up to 10 years (Kariuki, unpublished). Recent trials on napier/desmodium mixture indicated clear advantages of the mixture in terms of nutrient yields (Table 2). The study (Chapter 7) showed that these results can be translated into improved animal performance.

Napier/desmodium inter-crop is a more economically attractive option than growing the forages separately. Besides giving higher yields (higher gains per unit land) than napier grass alone, the inter-crop smothers annual weeds, and as shown in Table 2 nearly 200 kg hectare⁻¹ year⁻¹ atmospheric nitrogen fixed could be fixed into the soil (Snijders *et al.*, 1992).

As only napier/desmodium inter-crop was evaluated in relation to animal response from this study, there is need to assess other options for different agro-ecological zones. For example results from agronomic trial proposed napier/stylosanthes for western Kenya (Orodho, 1990) while napier/clitoria was suggested for the coastal region (Mureithi, 1992) but animal responses from these feeds have not been documented.

Effect of supplements on animal performance

The animal growth and intake responses from the forage diets are reported in Chapters 6, 7, 8 and 9. The study in Chapter 6 compares responses from sole diets of napier grass, lucerne and sweet potato vines. The positive animal performance upon supplementation reported in Chapter 7, 8 and 9 were attributed to the abilities of the PRF supplements to overcome protein deficiency in napier grass by providing more ruminally degradable protein and/or bypass protein. It was remarkable from these results that performance from good quality napier grass gave similar or even better performance than the supplemented poor quality napier grass. It was evident that the ADG observed was dependent upon napier grass maturity, type and level of supplement and the quality of the constituted diet (Table 3). Even when supplemented, weight gain from napier grass were usually below 0.5 kg day^{-1} . This is not surprising and indeed agrees with Stobbs and Thompson (1975) who reviewed animal performance from tropical pastures and concluded that observed weight gains were often between 0.4 to 0.5 kg day^{-1} . However, poor quality, and unsupplemented napier grass can be associated with restriction to DM intake and low or negative weight gains, whereas good quality napier could result to weight gains beyond these limits as this study showed.

In Chapter 6 napier, lucerne and sweet potato vines (SPV) were evaluated as sole diets to growing heifers. Heifers gained 0.67 kg day^{-1} on lucerne and 0.50 kg day^{-1} on napier grass and SPV respectively. However, the napier grass was harvested at a height about 0.5 m suggesting that it is possible to manipulate the cutting interval to the farmers advantage and obtain much higher gains than would be normally possible from overgrown napier grass. However, farmers do not usually have adequate quantities of lucerne and SPV to feed as sole diet to all stock but the forages could be excellent for the calves. At the farm level, the forage supplements are offered irregularly and in small quantities during certain seasons (Mertz, 1994) and under such circumstances, responses in performance may not be noticeable.

In Chapter 7 and 8, the similar diets were offered to both Friesian and Sahiwal heifers. It was interesting to observe that the Sahiwals consumed more

feed on metabolic weight basis than the Friesians. This observation conformed with the fact that species that have low body weights show higher DM intake per metabolic weight. Weight gains for the Sahiwal showed different patterns in the two experiments. In Chapter 7 (Napier/desmodium), Sahiwals gained slightly more body weight than the Friesians contrary to expectations, whereas in Chapter 8, the reverse was observed. These differences could be attributed to the differences in the plane of nutrition between the two breeds prior to experimentation. At the research site (Naivasha), Friesians were previously reared on irrigated pastures. Sahiwal were on rangelands, with a dry season preceding in Chapter 7 (June-September) while a wet season preceded the experiment reported in Chapter 8. It is established that restricted nutrition (dry season) in growing animals leads to sub-optimal weight gains (Owens, *et al.*, 1993). For such animals, weight gain during compensatory growth is usually greater than for those that were never restricted. This growth rebound presumably represents rapid hypertrophy of muscle tissue (Douillard *et al.*, 1991).

In the study described in Chapter 9, Friesian heifers were offered either young quality napier grass (CP=85 g kg⁻¹ DM) with no supplementation or old quality napier grass (CP=64 g kg⁻¹ DM) supplemented with 25% of each of the legumes *Desmodium intortum*, *Calliandra calothyrsus* and *Sesbania sesban*. The observed DM intake were: 3.1, 2.8 and 2.9 kg⁻¹ 100 kg body weight; and weight gain: 0.37, 0.24, 0.27 and 0.22 kg day⁻¹, respectively for the four diets. The results indicated that the quality of napier grass had significant effect on animal performance suggesting that unsupplemented good quality napier may give better performance than very poor napier grass even when the latter is supplemented. This concurred with the view that responses in DM intake and weight gain by ruminants fed on tropical grasses supplemented with legumes is related to the quality of the basal diet (Norton and Poppi, 1995). Indeed, our results agreed with recent findings in which sheep fed on mature *Andropogon gayanus* grass supplemented with *Desmodium ovarium* or *Stylosanthes capitata* improved neither DM intake nor weight gain (Lascano and Palacios, 1993). It was concluded from our study that supplementation of poor quality napier grass may prevent weight loss but could sustain only low weight gain in heifers.

Table 3. Summary of intake, weight gain and feed conversion efficiencies (FE) of heifers fed on napier grass and PRF

Napier Suppl.		Diet	Heifer	Breed	Exp	DMI	CPI	NDFI	ADG	FE
		CP	weight		period	kg day ⁻¹				
			(kg)		(days)					
(a) Good napier										
NG	nil	118	144	Friesian	104	5.0	0.59	2.9	0.50	0.10
NG	nil	117	181	Friesian	120	6.0	0.70	3.4	0.39	0.07
NG	nil	117	163	Sahiwal	120	5.6	0.66	3.1	0.42	0.08
(b) Poor napier										
NG	nil	85	340	Friesian	92	5.4	0.46	3.2	0.34	0.06
NG	nil	85	295	Sahiwal	92	4.7	0.40	2.8	0.29	0.06
NG	nil	63	340	Friesian	92	5.2	0.33	3.2	0.35	0.07
NG	nil	63	295	Sahiwal	92	4.3	0.27	2.1	0.30	0.07
NG	nil	85	271	Friesian	67	8.4	0.24	2.0	0.37	0.04
(c) Napier + 20-30% supplement										
NG/D mixture		142	181	Friesian	120	7.0	0.99	3.5	0.42	0.06
NG/D mixture		142	163	Sahiwal	120	6.8	0.97	3.4	0.47	0.07
NG	30%DD	131	181	Friesian	120	6.7	0.88	3.6	0.40	0.06
NG	30%DD	131	163	Sahiwal	120	6.2	0.81	3.3	0.44	0.07
NG	30%L	137	181	Friesian	120	7.4	1.01	4.0	0.52	0.07
NG	30%L	137	163	Sahiwal	120	6.8	0.93	3.6	0.52	0.08
NG	1.5 kg L	110	340	Friesian	92	6.4	0.68	3.6	0.35	0.06
NG	1.5 kg L	115	295	Sahiwal	92	5.3	0.59	3.0	0.40	0.08
NG	1.5 kg L	94	340	Friesian	92	6.1	0.61	4.3	0.52	0.09
NG	1.5 kg L	109	295	Sahiwal	92	5.3	0.52	3.4	0.42	0.08
(d)Poor napier + 20-30% supplement										
NG	25%D	93	271	Friesian	67	7.5	0.70	1.83	0.24	0.03
NG	25%C	101	271	Friesian	67	7.8	0.78	1.85	0.27	0.04
NG	25%S	86	271	Friesian	67	7.1	0.61	1.73	0.22	0.03
(e) Napier + 30-50% supplement										
NG	2.5 kg L	120	340	Friesian	92	7.5	0.75	5.2	0.65	0.09
NG	2.5 kg L	127	295	Sahiwal	92	6.3	0.67	3.6	0.61	0.10
NG	3.5 kg L	120	340	Friesian	92	7.8	0.87	4.4	0.66	0.09
NG	3.5 kg L	129	295	Sahiwal	92	6.7	0.80	4.7	0.64	0.10
(e) Other diets										
L	nil	167	143	Friesian	104	5.5	0.96	2.2	0.67	0.12
SPV	nil	135	144	Friesian	104	4.2	0.57	2.1	0.50	0.12

PRF=protein-rich forages; CP=crude protein (g kg⁻¹ DM); DMI=dry matter intake (kg day⁻¹); CPI=crude protein intake; NDFI=neutral detergent fibre intake; ADG=average daily weight gains; Suppl.=supplement type; NG=napier grass; D=desmodium; DD=dried desmodium; L=lucerne; C=calliandra; S=sesbania; SPV=sweet potato vines.

Optimum levels of supplementation

A number of experiments have been done to determine the optimum levels of legume supplementation to low quality tropical roughages. In cattle, 16% *Leucaena* inclusion in grass hay converted weight loss to gain (Wahyuni *et al.*, 1982). Similarly, Doyle *et al.*, (1986) concluded that 33% *Gliricidia* was sufficient to prevent weight loss in cattle. Devendra (1995) has recommended that the optimum dietary level of legumes should be approximately 30-50% of the ration on DM basis or 0.9 to 1.5 kg⁻¹ 100 kg body weight. Results from this study indicated similar optima depending on supplement type because within the range, the highest mean FE were observed (Table 4). In practice, however, farmers feed the legumes according to availability (Mertz, 1994).

Improvement in DM intake was less than the proportion of supplement in the diet indicating that some substitution occurred. When a supplemented animal reduces its intake of napier grass, this substitution effect lowers the value of the combination. Substitution has been variously ascribed to intra-ruminal effects such as pH changes affecting fibre digestion rates, greater transient rumen load, and improved nutrient intake resulting in reduced intake drive for the least acceptable dietary component (Egan, 1997).

Proposed feeding strategies for replacement heifers

Proper feeding of dairy heifers from weaning to 24 months of age is often a challenge in many smallholder farms. This class of cattle is in practice given less attention compared to other classes of cattle like the calf which if ignored is more vulnerable to nutritional stress or the lactating cow from which the farmer derives immediate benefits (milk). Inadequately fed heifers grow poorly and do not reach breeding weight at the desired age (Heinrichs, 1996). As a result, such heifers would calve down much later than 24 months and produce considerably less milk during their life-time than do well-fed heifers. In addition, undersized heifers have more difficulty at calving than do well-grown heifers. However, attaining first calving at about 24 months is much more difficult to achieve in Africa due to differences in feed composition, availability and genetic differences between animals.

Supplementation with PRF could be a sustainable way of improving the feeding value of poor quality grasses and other crop residues for the resource poor smallholder farmers. The protein that the supplements meet are necessary for proper functioning and development of reproductive organs and growth rate. Many heifers receiving inadequate protein nutrition or energy for prolonged periods have underdeveloped ovaries and uteri and often experience delayed sexual maturity (Heinrichs, 1996). Table 4 gives a summary of the observed animal performance stratified according to napier grass quality and the level of supplementation and the expected age at which the heifers would attain puberty.

With the diversity of PRF, there are several possibilities of devising napier/PRF mixtures to get the desired weight gain from heifers. Attention should be paid to the quality of both napier grass and PRF (e.g. anti-nutritional factors) because these can lead to a deviation from the expected performance. Napier grass may be offered to heifers free-choice without fear of animals overeating. However, caution needs to be exercised in feeding the PRF because in some instances there are health risks when inclusion rates go beyond 50% (Devendra, 1995). Since nutrient requirements of heifers change as they mature and therefore dietary allowance should take this into consideration. It is important that all heifers have free access to clean water, minerals and that the necessary disease control measures taken.

However, since these were short-term experiments, further work is required to fully understand the long term effects of protein supplementation of replacement heifers from weaning to first lactation.

Practical implications and conclusions

This study has showed that there is considerable potential to improve napier grass utilization using PRF. Unfortunately this option appears to have been underestimated by both researchers and other development agents probably due to lack data on the PRF potential such as the one now available from this study. However, to be of value, these results need to be translated on the farm into improved productivity. The growing of napier/legume as an inter-crop has been

Table 4. Expected period to attain puberty based on diet choice

Diet	Weight gain	FE	Age at Puberty	Age at first calving
1. Poor napier	-	0.06	-	-
2. Poor napier + 20-30% PRF	0.24	0.03	39 months	48 months
3. Good napier	0.44	0.08	23 months	31 months
4. Fair napier + 20-30% PRF	0.45	0.07	22.5 months	31.5 months
5. Fair napier + 30-50% PRF	0.64	0.10	17 months	26 months
6. PRF only	0.59	0.12	18 months	27 months

Very poor napier = < 60 g CP kg⁻¹ DM; Good napier = > 10 g CP kg⁻¹ DM; Fair napier = 8-10 g CP kg⁻¹ DM; PRF = protein-rich forage (mean CP 150 g CP kg⁻¹ DM).

FE = feed efficiency (gain/intake)

recommended on the basis of higher economic returns compared to the situation where the forages are grown separately. The benefit of this mixture could be direct through the consumed legume which improves dietary protein levels and hence rumen fermentation or by atmospheric nitrogen fixation into the soil. Undoubtedly, significant improvement in animal performance is unlikely when the napier grass quality is very low or when quantities of PRF offered are too small. Efforts should firstly be directed at improving the quality of napier grass itself through use of appropriate cutting regimes, manure application and, where possible, use of commercial fertilizers.

It is difficult, perhaps impossible to make generalised practical recommendations regarding the use of PRF as supplements to napier grass. Sound, realistic recommendations can only be made in the context of specific, individual region or farming system where a whole range of interacting factors must be taken into account. The minimum external input technologies suggested in this study for example would apply for smallholder dairy farmer practising zero or semi-zero grazing in high potential areas of Kenya, but not for the large scale farmer in the same region who uses concentrates and fertilizers and aims at high milk yields and weight gains.

In conclusion, translation of research results into practice present formidable challenges. It is important to develop technologies that are simple, practical, affordable and effective. It is hoped since the technologies tested in this study are easy to apply, their adoption would fit into farmers goals and resource capability and bring tangible benefits to his dairy enterprise.

Further research

Further research is necessary to resolve the following issues:-

- evaluation and response tests including practical and economic benefits at the farm level. The small scale farmers and farming systems ought to be kept as the central point, while their potential and limitations should be understood by scientists.
- Napier/legume mixtures. The benefits of such diets have not been adequately quantified and demonstrated to farmers and efforts in this area should be vigorously intensified.
- Assess the possible effects of including some energy sources together with these supplements on performance.
- Influence of genetic differences between local and exotic cattle breeds on replacement heifer growth requires further elucidation. For example effect of compensatory growth in Sahiwal cattle.
- Anti-nutritional factors. A number of possible protein-rich forages contain harmful chemical substances that influence animal performance negatively. Little is known on the long term and short term effects.

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Summary

Summary

Dairy farming is the main livestock enterprise in the mixed crop/livestock farming system in high potential areas of Kenya. These areas are characterised by a high human population density and small farm sizes (less than 2 hectares). As a consequence, napier grass has been widely adopted due to its relatively high dry matter (DM) yield and its suitability as a cut fodder for zero and semi-zero grazing systems. The conventional methods of improving napier grass quality through fertilization or use of concentrates to supplement napier grass diets is limited because most farmers cannot afford these inputs. This has led poor animal performance mostly attributed to low protein in napier grass. The most vulnerable group is heifers which receive far less attention compared to calves and cows. This is reflected by low weight gain (less than 0.25 kg day^{-1} on the farms) and poor reproductive and life-time performances.

Fortunately several protein-rich forages (PRF) have been introduced to farmers to improve the quality of napier grass-based diets. Since PRF can be easily grown on the farm, they are sustainable and would enable the farmer to reduce production costs. However, neither the napier grass nor the PRF are adequately understood with respect to their nutritive value making it difficult to formulate diets and predict the subsequent animal performance on the farms. The overall objective of the study was therefore to evaluate the nutritive value of napier grass and determine the potential for improvement using PRF.

Chapter 1 gives an overview of the importance of the smallholder dairy farming in Kenya in the context of both the whole agricultural industry and the livestock sector in particular. Recent developments within smallholder dairying and problems associated with the use of napier grass as the main feed resource have been highlighted. Chapter 2 reviews the chemical composition and other nutritional factors known to limit napier grass utilization in smallholder dairy farms in Kenya, and the potential for improvement. It was noted that napier grass has a high DM yield potential but is deficient in protein and has low digestibility which lead to poor animal performance. To improve the quality of napier grass only diets, it was suggested that the use of easily grown PRF offers a better option to the resource

poor smallholder dairy farmer because they are sustainable. However, available data on nutritive value such as crude protein (CP) content and digestible CP (DCP) systems in Kenya are largely derived by the Weende proximate analytical system. In this analytical system, CP is not linked to the digestion process in the animal while DCP neglects protein degradation, microbial protein (MP) production in the rumen and the digestion of bypass protein. The system is therefore unsatisfactory to assess the nutritional adequacy of napier grass and other forages and it was subsequently concluded that assessment of napier and PRF using the newer and more accurate methods of feed evaluation was necessary to conform with the current international practices. Availability of such information would facilitate the development of suitable feeding strategies for the resource poor dairy farmer.

In Chapter 3, rumen degradation, intestinal and whole tract protein digestion in napier grass and 17 other forages used by smallholders were determined using mobile nylon bag (MNB) and pepsin/pancreatin *in vitro* techniques (IV). The CP soluble fraction (W) differed significantly among forages ($P < 0.05$) although the mean for grasses ($245 \text{ g kg}^{-1} \text{ CP}$) and non-grasses ($242 \text{ g kg}^{-1} \text{ CP}$) were comparable. However, the rate of degradation (k_d) and bypass protein (BP) were significantly greater ($P < 0.05$) in non-grasses than in grasses. The highest BP ($P < 0.05$) were estimated for *Desmodium spp.* and *Acacia xanthophloea* which were reflected in their lower rumen degradable protein (RDP). The ratio between RDP and rumen fermentable organic matter (DOMR) in grasses was too low to allow optimum production of microbial protein. The mean total tract protein digestion for grasses ($721 \text{ g kg}^{-1} \text{ CP}$) was greater than for non-grasses ($686 \text{ g kg}^{-1} \text{ CP}$) indicating that the grass protein was of high quality. The results of intestinal digestion showed that digestibility coefficients obtained by the IV method were slightly higher than those for the MNB procedure but there was a strong relationship between the MNB and IV results implying that intestinal CP digestion could be estimated by *in vitro* methods ($R^2 = 0.97$, $P < 0.001$). This would reduce the need for surgery and elaborate procedures involved in the MNB technique. It was concluded from the study that protein supplementation strategies for low CP tropical grasses should firstly target at optimising MP production and then consider supplements containing a combination of ruminally degradable and bypass protein for high animal performance.

In Chapter 4, the effect of varying the levels of PRF supplements in napier grass on DM intake, degradation and rumen fermentation was assessed. Diets were constituted to contain napier grass with 0, 10, 20 and 30% desmodium or sweet potato vines (SPV). The organic matter (OM) and CP intake increased significantly ($P < 0.05$) with increase in the level of supplements ranging from 74 and 94 g kg^{-0.75} for OM and 7.6 to 13.0 g kg^{-0.75} for CP, respectively. The supplements significantly increased ($P < 0.05$) DM degradation, rumen ammonia nitrogen (NH₃-N) and volatile fatty acids (VFA) concentrations. Supplementation raised the NH₃-N concentration to above the minimum levels necessary for optimum microbial function in contrast to napier grass only diets. The PRF supplements had very profound effects on fermentation and greatly improved the OM fermented in the rumen (DOMR) by between 43 and 52% at the highest levels of supplementation. It was concluded that PRF could play an important role in improving utilization of napier grass and the subsequent animal performance.

In Chapter 5, the influence of stage of maturity and season on the mineral concentration of 5 micro and 5 macrominerals in Bana and French Cameroon varieties of napier grass were examined. Deficiency of minerals in forage diets may impair the ability of microorganisms to digest fibre and synthesize protein and therefore regular analysis has been recommended to enable appropriate formulation of mineral supplements. The results from this experiment indicated that some minerals in napier grass were present at potentially limiting levels for optimum animal performance. The effect of variety was significant for calcium, phosphorus, potassium, iron and manganese. Season significantly influenced the levels of magnesium, copper, manganese and zinc. The mineral content declined significantly with maturity except for cobalt. It was concluded that the levels of micro-minerals were below those desired for optimum animal performance and supplementation would be necessary. However, these results indicated general trends and for more precise information on adequacy, measurement of mineral availability to the animals was recommended.

Chapter 6 evaluated napier grass (NG), lucerne (L) and sweet potato vines (SPV) as sole diets to growing heifers with respect to intake, weight gain (ADG)

and rumen degradation. The mean chemical composition of the forages were: OM, 796, 854, 852, CP, 118, 167, and 135 g kg⁻¹ DM and NDF, 587, 408, and 506 g kg⁻¹ DM for NG, L and SPV respectively. The mean DM intake was 5.0, 5.5 and 4.2 while CP intake was 0.59, 0.59 and 0.57 kg for diets NG, L and SPV ($P < 0.05$). The ADG from NG, L and SPV were 0.67, 0.50 and 0.50 kg day⁻¹, respectively. The effective degradability (PD) was highest for SPV ($P < 0.05$) while that of L and NG were similar ($P > 0.05$). The results showed that farmers can obtain much higher gains from young napier grass than would be normally possible from overgrown napier grass. However, farmers do not usually have adequate quantities of lucerne and SPV to feed as sole diet to all stock but the forages could be excellent for the calves. It was concluded from the study that NG, L and SPV contained sufficient nutrients to sustain acceptable weight gains for young heifers.

Chapters 7, 8 and 9 studied the effects PRF supplements on nutrient intake and weight gains of growing heifers fed on napier grass basal diets. Inadequately fed heifers grow poorly and show poor reproductive performance. Such heifers would calve down much later than 24 months and produce considerably less milk during their life-time than do well-fed and well grown heifers. Supplementation would improve protein nutrition of the heifers ensuring increased weight gains and proper functioning and development of reproductive organs. The positive responses obtained from the supplemented heifers were attributed to the abilities of PRF to overcome protein deficiency in napier grass by providing more RDP and/or bypass protein.

In Chapter 7, animal performance from napier/desmodium grown as an inter-crop was evaluated. This was compared with the conventional practice of growing napier grass and PRF separately and adding the latter to the basal grass diet. Four diets were tested using 32 Friesian heifers: napier grass alone (D1, control), napier/desmodium (D2, inter-cropped in the field), napier grass supplemented with lucerne hay (D3) and napier grass supplemented with desmodium hay (D4). Heifers on diets D2, D3 and D4 showed significantly higher nutrient intake and ADG ($P < 0.05$) than those on D1. Heifers on D1 gained 0.41 kg day⁻¹, while those on D2, D3 and D4 gained 0.45, 0.52 and 0.42 kg day⁻¹ respectively. Diet D3 showed

significantly higher ($P < 0.05$) solubility, degradation rate, potential and effective degradabilities compared to the other diets. However, diet costs computed from forage production data, showed that napier/desmodium (D2) was economically more attractive because it showed the highest weight gain per unit land, a limiting resource for the smallholders.

In chapter 8, the effect of supplementing napier grass with graded levels of lucerne on DM intake (DMI) and weight gain (ADG) using Friesian and Sahiwal heifers was evaluated. Twenty four heifers from each of Sahiwal and Friesian breeds were blocked by breed and randomly allocated to the following treatments: young napier + 0 kg lucerne (T1); young napier + 1.5 kg lucerne (T2); old napier + 0 kg lucerne (T3); old napier + 1.5 kg lucerne (T4); old napier + 2.5 kg lucerne (T5); old napier + 3.5 kg lucerne (T6) heifer⁻¹ day⁻¹. Supplementation significantly ($P < 0.05$) increased DMI from 4.3 to 6.7 kg (Sahiwal) and 5.2 to 7.8 kg (Friesians) day⁻¹ ($P < 0.05$). Similarly, supplementation positively influenced ADG which significantly ($P < 0.05$) improved from 0.29 to 0.64 kg day⁻¹ for Sahiwal and 0.30 to 0.65 kg day⁻¹ for Friesians. Using nylon bags, the diets were incubated in the rumen of four steers to estimate rumen degradation. The rumen degradation of lucerne containing diets were significantly ($P < 0.05$) higher than that of napier grass alone. It was concluded that lucerne supplement improved utilization of napier grass and hence animal performance.

In the study described in Chapter 9, Friesian heifers were offered either good quality napier grass (7 weeks, CP = 85 g kg⁻¹ DM) with no supplementation or poor quality napier grass (16 weeks, CP = 64 g kg⁻¹ DM) supplemented with 25% of each the legumes *Desmodium uncinatum*, *Calliandra calothyrsus* and *Sesbania sesban* in a feeding experiment lasting 67 days. Significant differences ($P < 0.05$) were observed on intake of DM, OM, CP and NDF. The observed DM intake were: 3.1, 2.8, 2.9 and 2.6 kg⁻¹ 100 kg body weight; and weight gain: 0.37, 0.24, 0.27 and 0.22 kg day⁻¹, respectively for the four diets. The results indicated that the quality of napier grass had significant effect on animal performance suggesting that unsupplemented good quality napier may give better performance than very poor napier grass even when the latter is supplemented. It was concluded that

supplementation of poor quality napier grass may prevent weight loss but could only sustain low weight gain in heifers.

In the General Discussion, the contributions and conclusions of the results described in previous chapters are discussed with respect to practical implications for the smallholder dairy farmer. The summary of observed animal responses when napier grass supplemented at different levels is presented and this gives good indications of expected performance. Napier grass may be offered to heifers free-choice but caution needs to be exercised in feeding the PRF because levels beyond 50% may lead to ill-health. Undoubtedly, improvements in animal performance are unlikely to be noticed when the napier grass quality is very low or when quantities of PRF offered are too small. Although it is difficult, perhaps impossible to make generalised practical recommendations for all regions regarding the use of PRF as supplements to napier grass, the data provided by this study on the nutritive value of these forages will facilitate making of appropriate choices for diet formulation at the farm level. Nevertheless, long-term experiments are required to fully understand effects of PRF supplementation on heifers from weaning to first lactation.

Samenvatting

SAMENVATTING

Kleinschalige gemengde landbouwbedrijven in de vruchtbare en intensief bebouwde delen van Kenya hebben hoofdzakelijk melkkoeien als tak van veehouderij. Een belangrijk kenmerk van die vruchtbare gebieden is een hoge bevolkingsdichtheid en kleine bedrijfsgroottes (< 2 ha). De hoge droge stof (DS) opbrengst en haar geschiktheid als snijgewas heeft tot gevolg gehad dat napier gras op uitgebreide schaal is gebruikt gaan worden als bron van veevoer. De mogelijkheden van elders met succes beproefde methoden om met kunstmest of krachtvoer ter aanvulling van napier de kwaliteit van op napier gras gebaseerde rantsoenen te verbeteren, is beperkt omdat de meeste boeren zich de kosten van deze inputs niet kunnen permitteren. De productiviteit blijft derhalve laag, voornamelijk als gevolg van een tekort aan eiwit in het rantsoen. De meest kwetsbare groep zijn de pinken omdat die beduidend minder aandacht krijgen dan kalveren en melkgevende koeien. Het gevolg is een lage groei (< 0.25 kg/dag), slechte vruchtbaarheidsresultaten en lage levensproducties.

Gelukkig zijn er verscheidene eiwitrijke ruwvoerders beschikbaar en ook geïntroduceerd bij boeren om de kwaliteit van de op napier gebaseerde rantsoenen te verbeteren. Omdat bedoelde eiwitrijke ruwvoerders op de bedrijfjes zelf verbouwd kunnen worden, mogen ze als duurzaam worden beschouwd en maken ze het voor de boer mogelijk zijn productiekosten te verlagen. Echter, de juiste voederwaarde van zowel napier gras als de eiwitrijke ruwvoerders zijn onvoldoende bekend, waardoor het moeilijk is om rantsoenen samen te stellen en een voorspelling te maken van de te bereiken productiviteit op de bedrijven. Het hoofddoel van dit onderzoek was dan ook om enerzijds de voederwaarde van napier gras nauwkeuriger vast te stellen en anderzijds om de potentiële waarde van eiwitrijke ruwvoerders als supplement naast napier gras nader te bepalen.

Begonnen wordt met het in hoofdstuk 1 geven van een overzicht van het belang van de kleinschalige melkveehouderij in Kenya, zowel in het algemeen als onderdeel van het totale landbouwsysteem als in het bijzonder als onderdeel van de dierlijke productie sector. Met name recente ontwikkelingen binnen de kleinschalige melkveehouderij en de problemen die samenhangen met het gebruik

van napier gras als voornaamste voedergewas worden toegelicht.

Hoofdstuk 2 geeft een overzicht van de chemische samenstelling en andere voedingsfactoren waarvan wordt aangenomen dat ze de benutting van napier gras in de kleinschalige melkveehouderij in Kenya beperken, en wordt aandacht geschonken aan de mogelijkheden om hierin verbetering te brengen. Geconcludeerd wordt dat napier gras een potentiëel hoge DS opbrengst heeft, maar dat zowel het eiwitgehalte als de verteerbaarheid van de organische stof (OS) te wensen overlaten, met als gevolg een lage productiviteit in termen van dierlijke productie. Om de kwaliteit van op alleen napier gras gebaseerde ransoenen te verbeteren wordt beargumenteerd dat het aanwenden van gemakkelijk te verbouwen eiwitrijke ruwvoerders een goede optie is voor de over weinig middelen beschikkende kleinschalige melkveehouder, ook al omdat de productie van dit soort voeders als duurzaam bestempeld mag worden. De beschikbare gegevens over de voederwaarde in termen van ruw eiwit (RE) en verteerbaar ruw eiwit (vre) in Kenya zijn grotendeels afkomstig van de resultaten van de klassieke Weender analyse. In de benadering door het Weender analyse systeem wordt RE helemaal niet in verband gebracht met het verteringsproces in het dier, terwijl vre, dat dit wel doet toch volledig voorbijgaat aan zowel het belang van eiwitafbraak en de productie van microbiëel eiwit in de pens, als de vertering van eiwit dat aan afbraak in de pens ontsnapt. Deze beperkingen maken het Weender systeem daarom minder geschikt om de veevoedkundige waarde van napier gras en andere voeders op hun juiste waarde te schatten. Vervolgens wordt geconstateerd dat het nodig is om de veevoedkundige waarde van napier gras en andere ruwvoerders nader te onderzoeken volgens de nu internationaal geldende inzichten en meetmethoden voor voederwaardeschatting. De beschikbaarheid van dit soort informatie zou het ontwikkelen van passende voerstrategieën voor de kleinschalige melkveehouder mogelijk maken.

In hoofdstuk 3 worden de resultaten gerapporteerd van een onderzoek naar de pensafbraak, darmverteerbaarheid en verteerbaarheid in het totale maagdarmkanaal van napier gras en 17 andere ruwvoerders die gebruikt worden door de kleinschalige melkveehouders. Gebruik werd gemaakt van nylon zakjes

incubaties in de pens, de mobiele nylon zakjes (MNB) techniek en een *in vitro* (IV) techniek gebaseerd op het gebruik van pepsine/pancreatine. De omvang van de uitwasbare (W) fractie van het RE verschilde significant ($P < 0.05$) tussen ruwvoerders, ofschoon het gemiddelde voor grassen ($245 \text{ g kg}^{-1} \text{ RE}$) en niet-grassen ($242 \text{ g kg}^{-1} \text{ RE}$) vergelijkbaar was. De snelheid van afbraak (k_a) en het aandeel eiwit dat aan pensafbraak ontsnapt (bypass proteïne of BP) waren significant hoger ($P < 0.05$) in de niet-grassen in vergelijking met de grassen. Het hoogste BP ($P < 0.05$) werd vastgesteld voor *Desmodium spp.* en *Acacia xanthophloea*, voornamelijk als gevolg van hun lage pensafbraak (RDP). De verhouding tussen pensafbreekbaar RE en pensafbreekbare OS (RDP/DOMR) was in de onderzochte grassen te laag om een optimale activiteit en productie van microbiële eiwit mogelijk te maken. De gemiddelde verteerbaarheid van eiwit in het totale maagdarmkanaal was voor grassen ($721 \text{ g kg}^{-1} \text{ RE}$) hoger dan voor niet-grassen ($686 \text{ g kg}^{-1} \text{ RE}$), wat gezien werd als een aanwijzing dat het eiwit in gras op zich van goede kwaliteit is. De resultaten van de darmverteerbaarheid gaven aan dat de met de IV methode bepaalde verteerbaarheden weliswaar iets hoger uitkwamen dan die met de MNB methode, maar dat er een hoge correlatie bestond tussen de uitkomsten van beide methoden ($R^2 = 0.97$; $P < 0.001$). Geconcludeerd werd dat met de gebruikte *in vitro* methode de darmverteerbaarheid goed geschat kan worden, wat de noodzaak van arbeidsintensieve meetmethoden met geopereerde dieren zoals bij de MNB methode aanzienlijk kan verminderen. De eindconclusie van het onderzoek was dat strategieën voor eiwitsupplementatie bij tropische grassen met een laag RE gehalte zich allereerst dienen te richten op het optimaliseren van microbiële activiteit en eiwitproductie in de pens en dat pas daarna aandacht nodig is voor het verstrekken van extra bestendig eiwit.

In hoofdstuk 4 worden de resultaten van onderzoek naar het effect op de opname van DS en snelheid en mate van pensafbraak van oplopende hoeveelheden eiwitrijke ruwvoerders als supplement naast napier gras gerapporteerd. Rantsoenen werden samengesteld op basis van napier gras met toegevoegd 0, 10, 20 of 30% desmodium of het loof van zoete aardappelen (sweet potato vines of SPF). De opname aan OS en RE namen significant toe ($P < 0.05$), voor respectievelijk de OS

met een toenemend aandeel supplement toenemend van 74 tot 94 g kg^{-0.75} en voor RE van 7.6 tot 13.0 g kg^{-0.75}. Door de supplementen nam de DS afbraak, en de gehalten aan ammoniak (NH₃-N) en vluchtige vetzuren (VFA) in de pens significant ($P < 0.05$) toe. Door de supplementen nam de concentratie aan NH₃-N toe tot boven het niveau dat als minimum wordt beschouwd voor een optimale microbiële activiteit, dit in tegenstelling tot rantsoenen op basis van alleen napier gras. De eiwitrijke ruwvoerders hadden een groot effect op de pensfermentatie en leidden tot een sterke verhoging van de opname aan DOMR. Bij het hoogste niveau van supplementatie was de verhoging respectievelijk 43 en 52% bij desmodium en SPV. Geconcludeerd werd dat eiwitrijke ruwvoerders een belangrijke rol kunnen spelen bij het verbeteren van de benutting van napier gras en de daaruit voortvloeiende verbetering van de dierlijke productiviteit.

In hoofdstuk 5 wordt de invloed van groeistadium en seizoen op de gehalten aan 5 mineralen en 5 spoorelementen in de Bana en Frans Cameroun variëteiten van napier gras nader onderzocht. Omdat een mineralentekort in op ruwvoerders gebaseerde rantsoenen het vermogen van de micro-organismen in de pens om ruwvezel af te breken en eiwit te synthetiseren zou kunnen aantasten, wordt aangeraden de voeders regelmatig op hun gehalten aan mineralen te onderzoeken. De resultaten van dit onderzoek gaven aanwijzingen dat de gehalten van sommige in napier gras aanwezige mineralen zo laag waren dat ze als limiterend beschouwd moeten worden voor een optimale dierlijke productiviteit. De variëteiten verschilden significant voor wat betreft hun gehalten aan calcium (Ca), fosfor (P), kalium (K), ijzer (Fe) en mangaan (Mn). Het seizoen had een significante invloed op de gehalten aan magnesium (Mg), koper (Cu), Mn en zink (Zn). Uitgezonderd voor cobalt (Co), namen de gehalten aan alle mineralen en spoorelementen af met een toename van het groeistadium. Geconcludeerd werd dat met name de gehalten aan spoorelementen te laag waren voor een optimale dierlijke productie en dat supplementatie gewenst zou zijn. Echter de resultaten geven slechts algemene trends aan en gepleit wordt voor het verzamelen van meer informatie over met name de beschikbaarheid van mineralen voor het dier.

In hoofdstuk 6 wordt een vergelijking gemaakt tussen jong napier gras (NG),

lucerne (L) en loof van zoete aardappelen (SPV) als enig voer voor jonge groeiende pinken (144 kg lichaamsgewicht). Vergeleken werden de opname, dagelijkse groei en pensafbraak. De gemiddelde chemische samenstelling van de ruwvoerders was OS: 796, 854 en 852; RE: 118, 167 en 135; NDF: 587, 408 en 506 g kg⁻¹ DS voor respectievelijk NG, L en SPV. De gemiddelde dagelijkse opname was significant ($P < 0.05$) verschillend tussen voeders en bedroeg voor DS 5,0; 5,5 en 4,2 kg voor RE 0,59; 0,59 en 0,57 kg van op NG, L en SPV gebaseerde rantsoenen. De dagelijkse gewichtstoename bij NG, L en SPV was respectievelijk 0,67; 0,50 en 0,50 kg. De effectieve pensafbraak was het hoogste voor SPV ($P < 0.05$) terwijl die van L en NG gelijk waren. De resultaten lieten zien dat veehouders een veel hogere groei met jong napier gras kunnen bereiken dan ze doorgaans doen met meer uitgegroeid napier gras. Hoewel boeren in Kenya normaal gesproken niet de beschikking hebben over voldoende lucerne of SPV om ze als enkelvoudig voer aan al hun dieren te kunnen verstrekken, zouden L en SPV uitstekende voeders voor jonge kalveren zijn. Geconcludeerd werd dat NG, L en SPV voldoende voedingsstoffen bevatten om in jonge pinken een zeer acceptabele dagelijkse groei te bereiken.

In de hoofdstukken 7, 8 en 9 worden de resultaten gerapporteerd van studies naar de effecten van supplementen van eiwitrijke ruwvoerders op de voeropname en de groei van pinken, gevoerd met napier gras als basisrantsoen. Slecht gevoerde pinken groeien slecht en hebben een lage vruchtbaarheid. Zulke pinken kalven veel later voor de eerste keer af dan op een leeftijd van 24 maanden en hun levensproductie aan melk is ook aanzienlijk lager dan pinken die goed gevoerd zijn en een goede jeugdgroei hebben laten zien. Een juiste supplementatie zou de eiwitvoorziening van zulke pinken kunnen verbeteren en zorgen voor een betere groei en een normale ontwikkeling en functioneren van de geslachtsorganen. De positieve effecten die werden gevonden bij gesupplementeerde pinken werden toegeschreven aan de eigenschappen van eiwitrijke ruwvoerders die er zorg voor droegen dat de tekorten van napier grass werden aangevuld, door hetzij te voorzien in pensafbreekbaar, hetzij in pensbestendig eiwit.

Hoofdstuk 7 beschrijft de waarde van een als menggewas verbouwd

napier/desmodium mengsel. Dit menggewas werd vergeleken met de normale praktijk van het gescheiden verbouwen van napier gras en eiwitrijke ruwvoerders en het bij het voeren aanvullen van napier gras met het supplement. In een proef met 32 pinken werden vier verschillende rantsoenen met elkaar vergeleken, namelijk alleen napier gras (D1, controle), napier/desmodium (D2, menggewas), een mengsel van napier gras en lucerne hooi (D3) en tenslotte een mengsel van napier gras met desmodium hooi (D4). Pinken gevoerd met de rantsoenen D2, D3 en D4 hadden een significant hogere voeropname en gemiddelde dagelijkse groei ($P < 0.05$) dan de met D1 gevoerde dieren. De groei van pinken op rantsoen D1 was $0,41 \text{ kg dag}^{-1}$, de met de rantsoenen D2, D3 en D4 gevoerde dieren groeiden respectievelijk $0,45$; $0,52$ en $0,42 \text{ kg dag}^{-1}$. Vergeleken met de andere rantsoenen had D3 een significant hogere ($P < 0.05$) uitwasbaarheid, afbraaksnelheid en potentiële en effectieve pensafbreekbaarheid. Echter, de op basis van productiegegevens berekende kosten lieten zien dat het napier/desmodium menggewas (D2) economisch gezien het meest aantrekkelijk was, omdat er per oppervlakte eenheid land, een beperkende factor voor kleine veehouders in Kenya, de hoogste dierlijke groei mee kon worden bereikt.

In hoofdstuk 8 wordt de invloed gerapporteerd van het supplementeren van napier gras met toenemende hoeveelheden lucerne op DS opname en groei bij pinken van de rassen Friesian en Sahiwal. Van beide rassen werden 24 pinken geblokt per ras en bij toeval verdeeld over de navolgende behandelingen: jong (6 weken) napier gras zonder lucerne (T1), jong napier gras met $1,5 \text{ kg}$ lucerne (T2), oud (12 weken) napier gras zonder lucerne (T3), oud napier gras met $1,5 \text{ kg}$ lucerne (T4), oud napier gras met $2,5 \text{ kg}$ lucerne (T5) en oud napier gras met $3,5 \text{ kg}$ lucerne (T6) per pink per dag. Het supplementeren gaf een significante ($P < 0.05$) verhoging van de dagelijkse DS opname van $4,3$ naar $6,7 \text{ kg}$ (Sahiwal) en van $5,2$ naar $7,8 \text{ kg}$ (Friesians). Op overeenkomstige wijze beïnvloedde het supplementeren de groei, welke significant ($P < 0.05$) toenam van $0,29$ tot $0,64 \text{ kg dag}^{-1}$ bij de Sahiwal en van $0,30$ tot $0,65 \text{ kg dag}^{-1}$ bij de Friesians. Om de pensafbreekbaarheid te bepalen werden de rantsoenen in nylon zakjes geïncubeerd in de pens van vier ossen. De pensafbraak van de rantsoenen met lucerne was significant ($P < 0.05$)

hoger dan die van alleen napier gras. Geconcludeerd werd dat een supplement met lucerne de benutting van napier gras en dus de dierlijke productie aanzienlijk kon verbeteren.

In het experiment beschreven in hoofdstuk 9, werd aan pinken van het ras Friesian in een 67 dagen durende voederproef hetzij een goede kwaliteit napier gras (7 weken oud, 85 g RE kg⁻¹ DS) zonder supplement dan wel een slechte kwaliteit napier gras (16 weken oud, 64 g RE kg⁻¹ DS), gesupplementeerd met 25% van één van de vlinderbloemige planten *Desmodium uncatum*, *Calliandra calothyrsus* of *Sesbania sesban* verstrekt. Er werden significante ($P < 0.05$) verschillen vastgesteld voor de opname aan DS, OS, RE en NDF. DS opnames waren respectievelijk 3,1; 2,8, 2,9 en 2,6 kg⁻¹ 100 kg lichaamsgewicht; en groei 0,37; 0,24, 0,27 en 0,22 kg dag⁻¹ voor de vier rantsoenen. De resultaten geven aan dat de kwaliteit van napier gras van beslissende invloed is op de productiviteit van de dieren, en dat goede kwaliteit napier een zonder supplement een betere groei kan geven dan slechte kwaliteit napier, zelfs als dat wordt gesupplementeerd met eiwitrijk ruwvoer. Geconcludeerd werd dat het supplementeren van slechte kwaliteit napier gewichtsverlies kan voorkomen, maar dat het slechts een beperkte groei in pinken mogelijk maakt.

In de Algemene Discussie worden de resultaten, beschreven in de voorgaande hoofdstukken, in de algemene context van hun praktische toepasbaarheid door de kleinschalige melkveehouder in Kenya besproken. De gevonden positieve effecten op de dierlijke productiviteit wanneer napier gras met verschillende doseringen van eiwitrijke ruwvoerders wordt gesupplementeerd, worden nog eens samengevat en een schatting wordt gemaakt van de omvang van de te verwachten positieve effecten op groei. Napier gras kan onbeperkt aan pinken worden verstrekt, maar bij het verstrakken van eiwitrijke supplementen is enige voorzichtigheid geboden. Bij een aandeel van >50% bestaat er gevaar voor het optreden van gezondheidsproblemen. Verder wordt opgemerkt dat bij napier gras van een te lage kwaliteit of wanneer slechts geringe hoeveelheden supplement worden verstrekt, verbeteringen in de dierlijke productiviteit onopgemerkt kunnen blijven. Hoewel het moeilijk, zo niet onmogelijk is om algemeen geldende praktische

aanbevelingen te doen voor alle omstandigheden waaronder eiwitrijke ruwvoerders als supplement naast napier gras verstrekt worden, kunnen de gegevens verzameld in het in dit proefschrift beschreven onderzoek een waardevolle bijdrage leveren in het maken van de juiste keuzes voor wat betreft het in de praktijk samenstellen van rantsoenen. Om de effecten van het aan pinken tussen het spenen en het begin van hun de eerste lactatie verstrekken van eiwitrijke ruwvoerders als supplement volledig te begrijpen zijn nog lange termijn studies nodig.

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John Ndiritu Kariuki

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About the Author

John Ndiritu Kariuki was born on November 9, 1958 in Nyeri District, Kenya. His parents migrated and settled in the newly created smallholder farms in Nyandarua District in the 1960's. John's involvement in farm activities made a lasting impression on him and were to greatly influence his choice of a future career. He attended Karagoine Primary School and, later, Nyahururu and Kagumo High Schools for his secondary school education. In 1979, he was employed as a teacher and posted to Salient Secondary School in Nyandarua District. He also briefly worked for the Ministry of Water Development in Nairobi in 1981. He studied at the University of Nairobi for a Bachelor of Science degree in agriculture and after graduation was employed as a research officer by the Ministry of Agriculture (Scientific Research Division) and posted in 1985 to Western Agricultural Research Station, Kakamega.

Between 1986 and 1988 he studied for a Master of Science degree in animal production at the University of Nairobi. His thesis topic was "Evaluation of two cultivars of napier grass at different stages of growth". He joined the Kenya Agricultural Research Institute (KARI) in 1988 and was transferred to the National Animal Husbandry Research Centre, Naivasha in 1989. Between 1989 and 1991 he was attached to the Research Unit of the National Dairy Development Project. This period provided the opportunity to meet with a cross-section smallholder dairy farmers in different parts of Kenya. The many discussions with farmers during farm visits, on-farm trials and diagnostic surveys enabled the author to appreciate the major constraints encountered by smallholders. Initiation of this study project was therefore greatly influenced by these contacts and experiences on the farms.

In 1994, he was one the nine Task Force members appointed by KARI to formulate the National Dairy Cattle Research Framework for National Agricultural Research Project. Since 1994, he has been registered for a PhD programme at Wageningen Agricultural University. The research culminated in this thesis entitled, "The potential of improving napier grass under smallholder farmers' conditions in Kenya". It is the author's small contribution to the efforts geared toward improving the welfare of the smallholder farmers in Kenya. During his research career, the author's work has appeared in scientific journals, conference proceedings, research reports and farmers magazines.