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Energy deficiency in kikuyu grass containing high levels of nitrogen

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Elevated rumen ammonia levels in sheep on high nitrogen kikuyu (*Pennisetum clandestinum* Hochst) grass were indicative of a protein / energy imbalance in the grass. To correct the imbalance, grass containing 22% crude protein required maize meal supplementation of at least 20% on a dry basis. Unsupplemented high nitrogen kikuyu grass had a low dry-matter intake and digestibility. The efficiency of conversion of plant nitrogen into microbial protein in the rumen was probably poor and resulted in a large proportion of the ingested nitrogen being excreted in the urine. Maize meal supplementation improved the dry-matter intake and significantly increased the apparent retention of nitrogen and gross energy of the kikuyu grass.

Hoë peile rumenammoniak in skape op hoëstikstof-kikoejoegras (*Pennisetum clandestinum* Hochst) het op 'n proteïen / energie-wanbalans in die gras gedui. Om die balans te herstel, moes gras wat 22% ruproteïne bevat met ten minste 20% mieliemeel op 'n droë basis gesupplementeer word. Ongesupplementeerde hoëstikstof-kikoejoegras het 'n lae droëmateriaalinname en verteerbaarheid gehad. Die doeltreffendheid van die omskakeling van plantstikstof na mikrobeproteïen in die rumen was waarskynlik swak en het veroorsaak dat 'n groot hoeveelheid van die opgeneemde stikstof in die urine uitgeskei is. Mieliemeelsupplementering het die droëmateriaalinname verbeter en die skynbare retensie van stikstof en bruto-energie van die kikoejoegras betekenisvol verhoog.

Keywords: Digestibility, intake, maize meal supplementation.

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Kikuyu grass (*Pennisetum clandestinum* Hochst) often comprises the bulk of the summer pasturage for milk production in the high rainfall areas of Natal. Such pastures respond well to high levels of nitrogen fertilizer. However, due to the liberal application of fertilizer, or to accumulation of nitrogen in the soil as a result of the recycling of nitrogen and potassium by the grazing animal (Marais, Figenschou & Dennison, 1987), these pastures often attain crude protein levels in excess of 20%. Animal production on these pastures is lower than expected, when predictions are based on chemical analyses (Dugmore & Du Toit, 1988).

Kikuyu grass is generally low in digestible energy (Joyce, 1974; Mears & Humphreys, 1974), as well as in readily-digestible non-structural carbohydrates, such as starch, which have long been known to stimulate bacterial protein synthesis in the rumen (Pearson & Smith, 1943; Mathers & Miller, 1981). The efficient conversion of dietary protein into microbial protein in the rumen is energy dependent (Hogan, 1982). Synthesis of microbial biomass is curtailed by a low energy intake and the amino acid supply to the host animal from microbial protein is reduced. The growth rate and final carcass mass of lambs grazing kikuyu grass were significantly increased by maize meal or molasses supplementation (Van Ryssen, Short & Lishman, 1976).

Sub-clinical levels of anti-quality substances such as nitrate have been implicated in reducing rumen digestion of kikuyu grass high in nitrogen (Marais, Therion, Mackie, Kistner & Dennison, 1988). It therefore seems likely that the unsatisfactory animal production on kikuyu grass which is high in nitrogen could be due, not only to a protein / energy imbalance, but also to anti-quality components formed in such grasses.

This study investigated the protein / energy imbalance in high nitrogen kikuyu grass, as well as the effect of this imbalance on intake and utilization by sheep.

Materials and Methods

Kikuyu pasture

Kikuyu grass containing either 27 or 36 g nitrogen per kilogram dry matter was obtained from a long established pasture consisting of two areas previously shown to differ widely in nitrogen content. Each area was divided into strips which were cut over a period of time to provide regrowth at a four-week growth stage during the feeding period. Grass was cut into 5-cm lengths prior to feeding to sheep.

Experiment 1: Rumen ammonia production

During an adaptation period of ten days, two groups, each consisting of eight 12-month-old Döhne Merino wethers were fed either the low- or the high-nitrogen kikuyu grass. In order to ensure a constant intake, each sheep received 5 kg of fresh grass per day, fed in 1-kg portions at hourly intervals. On day four of the collection period, rumen fluid was withdrawn at 2,5, 4,5 and 6,5 h after the first daily feeding, using the suction strainer technique of Raun & Burroughs (1962). Rumen fluid samples were analysed for ammonia and the mean value of the three samples was taken as a measure of the overall rumen ammonia content. During the next four days of the collection period, the grass intake was supplemented with maize meal at a rate of 5,7% on a dry-matter basis, after which rumen fluid was sampled as before. The appropriate amount of maize meal was mixed in with fresh grass of predetermined dry-matter content. Grass was subsequently supplemented with maize meal at rates of 11,4, 22,7 and 34,0% of intake for periods of four consecutive days for each supplemental rate, respectively, and the ammonia concentration in the rumen was measured at the end of each four-day period.

Experiment 2: Digestibility trial

Fresh kikuyu grass containing a relatively high nitrogen level (35 g/kg) was fed to appetite, either on its own or supplemented with maize meal, at 20,4% of intake on a dry-matter basis, to two groups each consisting of six 14-month-old Döhne Merino wethers. Following an adaptation period of ten days, herbage intake and faecal and urine excretion were measured during a seven-day collection period. Samples of herbage and maize meal, as well as faeces and urine samples, were collected for chemical analyses. Animals were maintained on these rations for a further seven days after which the mass of each animal was recorded.

Chemical analyses

Total nitrogen was determined by the macro-kjeldahl method. Nitrate-nitrogen was measured by the method of Cataldo, Haroon, Schrader & Young (1975) and rumen ammonia by the method of Weatherburn (1967). Total non-structural carbohydrates were determined by the procedure described by Marais (1969) and gross energy was determined by means of bomb calorimetry.

Results

Chemical composition of feed

The chemical composition of kikuyu grass and maize meal used in this study is given in Table 1. Dry-matter content of the grass used in either experiment was about 131 g/kg fresh grass. Nitrogen contents of the low- and high-nitrogen kikuyu grass were 27 and 36 g/kg dry matter respectively, equivalent to crude protein contents of 16,9 and 22,5%, respectively. Maize meal contained 14 g kjeldahl-nitrogen per kilogram dry matter, whereas the nitrate-nitrogen content of low- and high-nitrogen grass was about 2 and 5 g/kg, respectively. The total non-structural carbohydrate content of both the low- and high-nitrogen grass was lower than 50 g/kg, as compared to 808 g/kg in maize meal.

Effect of maize meal on rumen ammonia level

In order to establish whether the rumen microbes could adapt to changes in maize meal concentration over such short periods (four days), the animals were fed progressively lower levels of maize meal at the end of the supplementation study. Results obtained were similar to those obtained during the period of progressive maize meal increments, suggesting that adaptation was sufficiently rapid.

The effect of maize meal on the ammonia level in the rumen is presented in Figure 1. Maize meal supplementation had little effect on rumen ammonia levels of animals fed on grass which contained 27 g nitrogen per kilogram dry matter. The rumen ammonia level of sheep on unsupplemented high-nitrogen grass was about twice that of sheep on low-nitrogen grass. Supplementation of the high-nitrogen grass with about 20% maize meal or more, decreased the level of ammonia in the rumen to that measured when low-nitrogen kikuyu grass was fed.

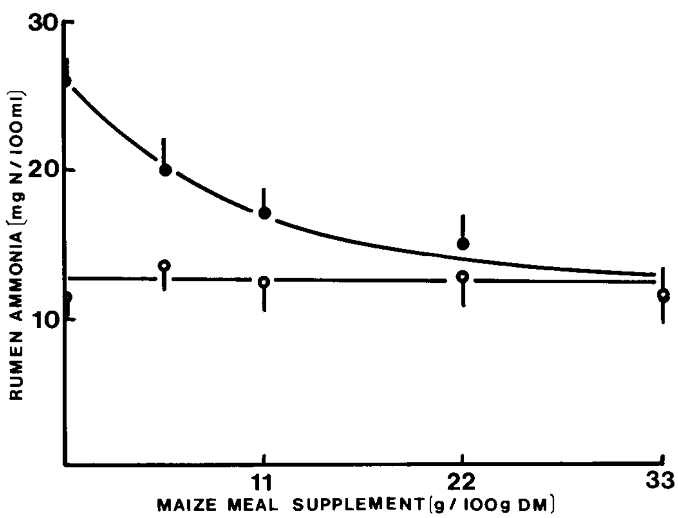

Figure 1 Effect of maize meal supplementation (0—33 g maize meal to fresh grass containing 100 g of dry matter) on the rumen ammonia level of sheep fed kikuyu grass containing either 36% (●) or 27% (○) nitrogen per kilogram dry matter.

Table 1 Mean chemical composition, expressed on a dry matter basis, of kikuyu grass and maize meal

	Experiment 1		Experiment 2	
	Low N grass	High N grass	High N grass	Maize meal
Dry matter (g/kg fresh grass)	131 ± 2	129 ± 2	127 ± 4	865 ± 0
Total nitrogen (g/kg)	27 ± 1	36 ± 1	35 ± 2	14 ± 0
Nitrate nitrogen (g/kg)	2,3 ± 0,1	5,0 ± 0,1	5,2 ± 0,2	
Total non-structural carbohydrates (g/kg)	48 ± 2	49 ± 2	49 ± 2	808 ± 2
Gross energy (MJ/kg)			17,44 ± 0,03	17,57 ± 0,06

Table 2 Daily intake and utilization of high nitrogen kikuyu grass on its own or supplemented with maize meal

	Kikuyu grass only (a)	Kikuyu grass + 20% maize meal: Kikuyu portion (b)	Level of significance (a *vs* b)	Total (c)	Level of significance (a *vs* c)
Dry matter intake (g/kg $W^{0,75}$)	32,9	39,2	NS [a]	47,3	**
Nitrogen intake (g/kg $W^{0,75}$)	1,2	1,4	NS	1,5	*
Dry matter digestibility (%)	50,6	61,1	*	64,4	**
Nitrogen retention (%)	13,7	35,2	**	39,2	**
Urine excretion (l/d)	2,49			1,86	**

[a] Non significant.
* $P < 0,05$.
** $P < 0,01$.

Feed intake and utilization

The daily intake and utilization of high-nitrogen kikuyu grass with and without maize meal (20% of intake) are given in Table 2. The dry matter and nitrogen intake per kilogram metabolic mass of the unsupplemented grass was 32,9 and 1,2 g, respectively, per day.

Maize meal supplementation significantly increased the total daily feed intake. However, increased intake of the kikuyu portion of the diet was not statistically significant.

The apparent digestibility of dry matter and the retention of nitrogen of unsupplemented grass was 50,6 and 13,7%, respectively.

A total digestible nutrient value of 80,1% and a crude protein digestibility value of 77% for maize meal was assumed (Morrison, 1957). The digestibility of the grass portion of the total (supplemented) diet was calculated and is also presented in Table 2. Compared to unsupplemented high-nitrogen grass, kikuyu grass supplemented with maize meal had a significantly higher dry-matter digestibility and nitrogen retention than kikuyu grass alone (Table 2). This observation applied to the total intake as well as to the kikuyu portion of the diet. The volume of urine excreted by the animals fed on grass supplemented with maize meal was significantly ($P <$ 0,01) lower than that for animals fed on grass alone.

Excretion of nitrogen and energy

Results presented in Table 3 show that the loss of nitrogen in urine and faeces of sheep fed high-nitrogen kikuyu grass supplemented with maize meal was 30 and 32%, respectively. On unsupplemented grass, nitrogen excretion in the urine increased to 50% of the total nitrogen intake. Compared to the faeces, little energy was lost in the urine. About 39% of the gross energy consumed was excreted in the faeces of sheep fed on grass supplemented with maize meal. On grass alone, energy excretion in both the faeces and urine was significantly ($P < 0,01$) higher than on the supplemented diet.

Live mass change

The change in live mass of sheep over the 14-day experimental period is presented in Table 4. The initial live mass of the sheep was about 42 kg. Sheep on the unsupplemented high-nitrogen kikuyu grass lost mass at a rate of 186 g/d, while the animals on the maize meal supplemented diet gained mass at a rate of 149 g/d.

Table 3 Excretion of nitrogen and energy by sheep fed on high-nitrogen kikuyu grass only or on kikuyu grass supplemented with maize meal

	Excretion (% of total intake): Kikuyu grass only	Kikuyu grass + 20% maize meal	Level of significance
Nitrogen			
Urine	50,4	29,8	**
Faeces	35,3	32,0	NS [a]
Energy			
Urine	3,3	1,2	**
Faeces	52,9	38,9	**

[a] Non significant.
** $P < 0,01$.

Table 4 Mean live mass change over a 14-day experimental period of sheep fed high-nitrogen kikuyu grass alone, or grass supplemented with 20% maize meal

Ration	Initial mass (kg)	Daily mass change (g)
Kikuyu grass only	42,9 ± 2,2	−186 ± 114
Kikuyu grass + maize meal	42,1 ± 2,7	+149 ± 72

Discussion

While the level of ammonia in the rumen reflects protein intake (Weston & Hogan, 1968), it is also markedly affected by the amount of energy released from organic matter during rumen fermentation (Walker, 1965;

Hogan & Weston, 1967). Hogan (1982) stated that as the ratio of digestible organic matter to crude protein in a feed decreases towards 3:1, the ammonia level in the rumen increases gradually. However, a further decrease in the ratio causes a sharp rise in ammonia level due to the rapid deamination of protein which displaces carbohydrates as the main source of energy for microbial protein synthesis.

By varying the energy level (maize meal supplementation), while maintaining a constant protein intake, the rumen ammonia level in Experiment 1 provided some measure of the efficiency of protein conversion in the rumen. Lack of an effect of maize meal supplementation on rumen ammonia level, in the case of low-nitrogen grass, suggested a satisfactory protein/energy balance for bacterial protein synthesis. The initial high level and subsequent rapid drop in rumen ammonia concentration on supplementing the high-nitrogen grass (22,5% crude protein) with maize meal, suggests that the digestible energy in the grass alone could not sustain an efficient conversion of plant nitrogen into microbial protein. The severe protein/energy imbalance could be corrected by maize meal supplementation at a concentration of at least 20% on a dry-matter basis.

By comparing the nutritional value of high-nitrogen kikuyu grass with the kikuyu grass supplemented with 20% maize meal (Experiment 2) it was shown that, in spite of its relatively high crude protein content, the apparent nitrogen retention of the kikuyu grass fed alone was extremely low (13,7%). This amounted to a daily nitrogen retention of only 2,7 g per sheep. The daily nitrogen requirement for the maintenance of body protein is about 0,35 g N/kg metabolic mass (Rowett Research Institute, 1986), which amounts to about 5,8 g N/d for the 42 kg animals used in the present experiment. Therefore, although the unsupplemented animals received kikuyu grass containing almost 23% crude protein, these animals were in negative nitrogen balance. This was reflected in the loss of body mass during the short duration of the experiment (Table 4). Differences in rumen fill probably also contributed to the observed changes in live mass. Poor retention of protein is attributed to a lack of metabolizable energy in the high-nitrogen grass. Maize meal supplementation significantly increased the retention of nitrogen in the kikuyu portion of the diet to 35,2%. The animals which received maize meal retained 9,3 g N/d and were in a positive nitrogen balance, gaining body mass during the experimental period.

The poor nitrogen retention in sheep on high-nitrogen grass was largely due to excessive ammonia loss from the rumen. This is reflected by the excretion of 50,4% of the consumed nitrogen in the urine, compared to the 29,8% excreted in the urine of sheep supplemented with maize meal (Table 3). The removal of excess ammonia from the rumen and small intestine by the portal circulation and its conversion to less toxic urea by the Krebs–Henseleit pathway, impose a considerable energy drain upon animals (Hibbett, 1984), already stressed by an energy-deficient high-nitrogen diet. To eliminate the high levels of nitrogen from the body, these animals excreted 34% more urine than animals given the maize meal supplement. The large volume of urine excreted by the sheep on the unsupplemented kikuyu grass must have led to a concomitant increase in water intake. However, the low dry-matter content (131 g/kg) of lush kikuyu grass probably imposed a restriction on intake. Therefore, additional intake of water could have partly accounted for the low voluntary dry-matter intake (32,9 g DM/kg metabolic mass) by the sheep fed grass only. Jeffery (1971) reported intakes of 51,2 g/kg metabolic mass for fertilized kikuyu grass, whereas Joyce (1974) quoted values of 53,5 to 54,3 g/kg metabolic mass. In the present investigation maize meal supplementation slightly, but not significantly, increased the consumption of the grass portion of the diet.

The dry-matter digestibility of 50,6% obtained for the grass alone (Table 2) does not compare favourably with values of 61 to 64%, reported by Jeffery (1971) and Joyce (1974). The reason for the low digestibility and the high percentage (52,9%) of gross energy excreted in the faeces in the present investigation is not clear. It is tentatively suggested that anti-quality factors, such as the high nitrate level (5 g/kg) in the high-nitrogen grass, could have reduced the digestion of structural carbohydrates (Marais *et al.*, 1988). The grass investigated by Jeffery (1971) and Joyce (1974) contained only moderate levels (< 17%) of nitrogen and probably did not accumulate such anti-quality substances. The low digestibility may largely explain the low dry-matter intake of kikuyu grass in the present experiment.

The kikuyu grass used in the present study was cut at 08h00, at a time when the level of readily-digestible carbohydrate reserves in the leaves and stems was found by this laboratory to be at its lowest (4,9%). Better protein utilization could be expected in the grazing situation, where the animal could benefit from the accumulation of photosynthate in the plant during the course of the day. However, results obtained in this laboratory showed that peak levels of non-structural carbohydrates in the leaves of kikuyu grass seldom exceed 9%, which is still far below the required level suggested by the maize meal supplementation study.

This study clearly showed that excessive nitrogen levels in kikuyu grass cause protein/energy imbalances which markedly reduce the nutritional value of the grass, and that supplementation with maize meal can be beneficial under certain circumstances.

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