Effect of fibre and nitrogen content on the digestibility of Kikuyu (*Pennisetum clandestinum*)

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A series of 12 *in vivo* digestibility trials, using two-tooth Merino wethers were conducted on freshly-cut green kikuyu herbage. Samples of this herbage were analysed by proximate and acid-detergent analysis. A close relationship was found between crude fibre (CF) and acid-detergent fibre (ADF) (ADF = 20,06 + 0,56CF; r = 0,607; $P < 0{,}001$). An outstanding feature of these data is the positive correlation between the fibre fraction and digestible organic matter (DOM) as well as a negative correlation for the nitrogen fraction on DOM. The nitrogen fraction was found to be negatively associated with the digestibilities of the nitrogen-free extract and fibre fractions which comprise 75% of the herbage.
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'n Reeks van 12 *in vivo*-verteringsproewe met tweetand-Merinohamels is op vars, groen gesnyde kikoejoegras uitgevoer. Die Weende- en Van Soest-metodes is gebruik om die grasmonsters chemies te analiseer. 'n Noue verwantskap is tussen die ruvesel (RV) en suuronoplosbare vesel (ADF) gevind, (ADF = 20,06 + 0,56RV; r = 0,607; $P <$ 0,001). 'n Uistaande kenmerk van hierdie data is die positiewe verwantskap tussen die veselfraksies en verteerbare organiese materiaal (VOM), asook die negatiewe verwantskap tussen die stikstoffraksie en VOM. 'n Negatiewe verwantskap is tussen die stikstoffraksie en die verteerbaarheid van die stikstofvrye-ekstrak en veselfraksies waaruit 75% van die grasinhoud bestaan, verkry.
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The Weende system of proximate analysis of feeds was developed by Henneberg and Stohmann in about 1860 (Tyler, 1975; Fonnesbeck, 1976). The crude fibre (CF) and nitrogen-free extract (NFE) fractions separated by this system of analysis have been criticized as inadequate measures of the non-nutritive (CF) and highly digestible soluble carbohydrate (NFE) fractions of feedstuffs (Norman, 1935; Crampton & Maynard, 1938; van Soest & Robertson, 1980). This has led to the development of alternative methods of fibre analysis. Of these the detergent fibre system developed by van Soest (1963; 1964; 1966; 1967) has become widely used.

The objective of the present study was to compare the two methods of fibre analysis, the Weende CF and the van Soest acid-detergent fibre (ADF), commonly used by commercial and research laboratories even though ADF is not recognized as an official method of analysis. The approach used was to determine which fibre value would best predict the digestible organic matter (DOM) content of a tropical grass namely kikuyu (*Pennisetum clandestinum*; Hochst).

The investigation produced some unanticipated results pertaining to the relationship between the nitrogen fraction and the digestible organic matter (DOM) content of the kikuyu grass under test. The study was therefore expanded to include a study of the effects of the nitrogen content on the DOM value of kikuyu.

Material and Methods

A series of 12 *in vivo* digestibility trials were conducted over a 2-year period. Six two-tooth Merino wethers were used per digestibility trial. Fresh green kikuyu herbage was cut and fed daily to appetite, allowing approximately 20% orts. Herbage sampling and faecal collection were done for a 6-day period following a 10-day adaptation period. The kikuyu was fertilized at two nitrogen levels (200 and 400 kg N/ ha), and two stages of regrowth (3 and 6 weeks) within each fertilization treatment were compared.

All feed and faeces samples collected were analysed by proximate analysis (Schneider & Flatt, 1975) and from these data the DOM and total digestible nutrients (TDN) were calculated. Orts did not differ significantly from the feed samples and were therefore not used in the subsequent calculations. Subsequently, the samples were analysed for ADF, acid-detergent lignin (ADL), silica and nitrate nitrogen (NO_3-N). Nitrate nitrogen was measured by an Orion 'nitrate specific' ion activity electrode using the procedure described by Milham, Awad, Paul & Bull (1970). Acid-detergent fibre, lignin and silica analyses were carried out according to the procedure used by Holst (1973) with decalin omitted, as recommended by van Soest & Robertson (1980).

The accuracy with which the DOM value of the herbage could be predicted by the fibre measurement was used to establish the superior analytical technique. Regression analyses were used to measure the accuracy of fibre value as a predictor of DOM. The residual standard deviations (RSD) of the regression equations were used to determine the best fit (Minson, 1980).

Results and Discussion

Chemical composition

The range of TDN values (52 – 64%) presented in Table 1 compares favourably with TDN values reported in the literature (48 – 66%) (Todd, 1956; Butterworth, 1967; Campbell, Sherrod & Ishizaki, 1969; Joyce, 1974; van Ryssen, Short & Lishman, 1976). No DOM values for kikuyu were found in the literature, though the relationship between DOM and TDN values has been found to be very close for roughages (Swart & Joubert, 1964; Armstrong, 1982) as confirmed for kikuyu in this study, viz. TDN = 4,66 + 0,94 DOM and r = 0,991 ($P < 0,001$).

Table 1 The mean composition, digestibility coefficients, DOM and TDN value of the kikuyu grasses under test (mean ± *SD*, *n* = 12)

Component	Composition (%) (DM = 100)	Digestibility coefficients (%)
ADF	34,8 ± 1,97	56,6 ± 6,13
ADL	6,6 ± 1,32	7,8 ± 20,5
NFE	47,7 ± 3,05	58,3 ± 6,09
CF	26,0 ± 2,31	61,9 ± 5,53
CP	17,4 ± 3,66	65,0 ± 3,82
Silica	0,94 ± 0,28	–
NO_3-N	0,70 ± 0,50	–
DOM	–	56,4 ± 4,06
TDN	–	57,6 ± 3,84

The CF and ADF values measured (Table 1) compare well with the range of values for kikuyu cited by Moore & Mott (1973) viz. 25 – 36% CF and 32 – 38% ADF. Kim, Gillingham & Loadholt (1967) reported a close correlation between CF and ADF. The association between CF and ADF for the present data was calculated to be ADF = 20,06 + 0,56 CF (n = 70), r = 0,607 ($P < 0,001$). The CP values for kikuyu cited in the literature vary from 10 to 30% (Taylor, 1939; Todd, 1956; Jeffery, 1971; Joyce, 1974; van Ryssen, *et al.*, 1976) and those of the present study fall within this range. The digestibility of the CF fraction in the kikuyu was higher than that of its NFE (Table 1), a phenomenon observed in tropical grass species (Lander & Dharmani, 1931; French & Rogerson, 1955; Quarterman, 1961), which is contrary to the accepted view that NFE is the highest digestible and CF the least digestible fraction in grass (Schneider & Flatt, 1975).

Fertilizer treatment effects

Owing to the few samples per treatment, especially the 400 N treatment, the effect of fertilizer treatments (Table 2) on chemical composition and the digestibilities of nutrients should be considered only as indicative of trends. The DOM values of the kikuyu tended to increase from a 3-to 6-week regrowth stage for the 200 N treatment, whereas the DOM values declined over this period for the 400 N treatment. Minson (1971) reported that the rate of decrease in DOM of tropical grasses with age was generally about 0,1 digestibility unit per day as opposed to 0,5 units reported for temperate species (Minson, Raymond & Harris, 1960; Reid & Jung, 1965). Increases in the dry matter (DM) and gross energy digestibilities of tropical grasses with maturity have been recorded previously (Grieve & Osbourn, 1965), but only in regrowths of 5 weeks and less. Jeffery (1971) observed a similar increase in the DM digestibility of kikuyu between regrowths of 23 and 37 days ($P < 0,05$), but by 52 days the digestibilities had returned to the 23-day level. Mears (1970) cited maximum DM digestibility values for kikuyu occurring at 36 days regrowth in New South Wales, 42 days in Hawaii and at 20 days in Queensland.

Table 2 The mean chemical compositions (%) and DOM values (%) of the different fertilizer treatments on kikuyu herbage (dry matter basis)

Chemical fraction	Treatment: 200 kg/N ha, 3 week cut	200 kg/N ha, 6 week cut	400 kg/N ha, 3 week cut	400 kg/N ha, 6 week cut
n	3	4	2	3
ADF	34,4 ± 3,0	35,5 ± 2,1	33,9 ± 1,8	34,7 ± 1,5
ADL	6,3 ± 0,4	6,3 ± 1,3	7,6 ± 3,0	6,3 ± 0,8
Silica	1,02 ± 0,4	0,88 ± 0,3	0,78 ± 0,4	1,06 ± 0,2
CF	26,0 ± 2,7	27,1 ± 2,9	24,4 ± 2,5	25,3 ± 0,8
NFE	48,4 ± 2,6	48,8 ± 3,8	45,4 ± 0,6	47,1 ± 3,7
CP	16,2 ± 4,6	16,2 ± 4,4	20,8 ± 2,3	18,2 ± 1,8
Nitrate	0,68 ± 0,5	0,54 ± 0,4	0,94 ± 0,9	0,78 ± 0,6
DOM	54,4 ± 3,1	57,8 ± 4,2	59,0 ± 4,2	55,3 ± 5,0

The levels of the various chemical fractions in the kikuyu did not vary appreciably over the different treatments (Table 2). The CP levels in the 200 N treatment remained constant at the different stages of regrowth whilst the CP levels in the 400 N treatment declined slightly with age of regrowth. This is in agreement with the conclusion of Norton (1982) that kikuyu was a notable exception in grasses, in that protein levels remained high throughout growth and maturity, as previously shown by Milford & Haycock (1965), Colman & Holder (1968) and Aii & Stobbs (1980).

Effect of the chemical fractions on digestibility

The relationships between the various chemical components of kikuyu and its DOM content are given in Table 3. A striking feature of the correlation of the chemical components on DOM is the positive correlation for the fibre components on DOM and the negative correlation for nitrogen on DOM. Both these correlations are contrary to the accepted negative correlation for fibre on DOM or the positive correlation for protein on DOM (Schneider & Flatt, 1975). Pattinson (1981)

Table 3 Linear regression equations for the chemical fractions on the DOM content of kikuyu herbage

Chemical fraction	Regression eqn.	Correlation coefficient	RSD
CF	Y^a = 29,18 + 1,05 CF	0,566 (NS)	4,35
NFE	Y = 17,69 + 0,81 NFE	0,610*	3,58
ADF	Y = 5,21 + 1,47 ADF	0,717**	3,02
ADL	Y = 46,0 + 1,67 ADL	0,519 (NS)	10,22
Silica	Y = 48,46 + 8,47 (SiO_2)	0,578*	14,78
CP	Y = 67,96 – 0,66 CP	–0,594*	15,04
NO_3-N	Y = 60,1 – 5,18 (NO_3-N)	–0,634*	37,07

[a] Y = DOM; $^*P < 0,05$; $^{**}P < 0,01$

found that the dry matter digestibility (DMD) of kikuyu using *in situ* nylon bags was positively correlated with ADF content, whilst for coastcross 11, grown in the same vicinity, the expected negative relationship was found between fibre and digestibility. Milford (1960) and Butterworth (1967) observed that the CF content of subtropical and tropical grasses was not related to the nutritional value of the plant. This could be due to the higher digestibility value of CF compared to that of NFE, as recorded by Lander & Dharmani (1931), French & Rogerson (1955), French (1957) and Milford (1960), and observed in the present study.

The positive but non-significant correlation between ADL and DOM in kikuyu (Table 3) was contrary to the expected negative relationship between lignin and digestibility in grasses (Schneider & Flatt, 1975). On tropical grasses in Indonesia, Parakaksi, Satter, Pope, Djojosoebagio & Nasoetion (1976) similary found positive correlations for lignin on dry matter digestibility in two trials (r = 0,48; r = 0,83) with a negative correlation (r = −0,50) in a third trial. In two trials where the positive correlations were recorded, the grasses had low lignin levels (4,5 – 6,2% of the DM) whereas the grass in the trial with the negative correlation contained 7,2 – 15,9% lignin. In the present data the ADL levels ranged from 4,8 – 9,8%, intermediate to those of Parakaksi, *et al.* (1976). A significant positive relationship was found between the silica levels in the kikuyu and its DOM value. Research by van Soest & Jones (1968) indicated that silica could be an important contributing factor to the low digestibilities of grasses. The positive correlation between both lignin and silica on DOM in the present study is most probably due more to their positive association with the ADF fraction in the herbage (ADL on ADF, r = 0,270, Silica on ADF, r = 0,615) than to direct effects of lignin or silica on the herbage digestibility *per se*.

The digestibility of the ADL in the present trial varied from negative to highly positive values (Table 1). These results agree with other published results on lignin digestibility. Galyean, Wagner & Owens (1979) reported that lignin digestibilities of a selection of feeds ranged from 27,9 to 53,3% whilst Hale, Duncan & Huffman (1940) recorded lignin digestibilities ranging from −5,1 to 23,7%. The site of lignin digestion is in the rumen (Gaillard & Richards, 1975). In cattle fed speargrass, a large proportion of lignin consumed was converted to a soluble lignin-carbohydrate complex in the rumen (Gaillard & Richards, 1975). Further research by Neilson & Richards (1978) showed that most of the dissolved lignin-carbohydrate complex precipitated in the abomasum and was present in the solid fraction of the faeces. These lignin-carbohydrate complexes may explain the variable lignin digestibilities.

The increase in the DOM content from 3 to 6 weeks of age (Table 2) associated with a concomitant increase in fibre with age, might be partially responsible for the positive relationship between fibre and DOM in the 200 N treatment. However, this does not apply for the 400 N treatment, because the DOM values declined with age of regrowth. The suspected negative effect of nitrogen on the digestibility of kikuyu might explain the positive correlations between fibre and DOM. Crude protein levels in the kikuyu were negatively associated with the digestibility of the ADF, CF and NFE fractions in the herbage (Table 4). Increasing CP levels are usually associated with higher digestibilities for the CF and NFE fractions (Schneider & Flatt, 1975). Because the CF and NFE fractions on average comprise 26% and 47% respectively of the kikuyu dry matter, a lower digestibility for these fractions could result in a lower overall digestibility for kikuyu. Thus as CP levels increase, fibre and NFE digestibilities will be reduced with

Table 4 The relationship between the CP content (%) of kikuyu herbage and the digestibilities of the various chemical fractions in the herbage

Digestion coefficient of chemical fractions	Regression equation		r
Y	a	b X	
CP	55,8	+0,53 (CP)	0,507
NFE	78,9	−1,18 (CP)	−0,710*
CF	78,2	−1,93 (CP)	−0,614*
ADF	74,9	−1,05 (CP)	−0,625*
OM	71,6	−0,62 (CP)	−0,546

*P < 0,05

a consequent reduction in the DOM content of the kikuyu. As fibre and nitrogen were inversely related for the present data, this may explain the positive correlations between fibre and DOM.

Jeffery (1971) found that an increase in nitrogen fertilization from 50 kg N/ha to 200 kg N/ha caused a significant (P < 0,05) decrease in the DMD of kikuyu. Drummond (1975) recorded increased CP levels in kikuyu herbage with a concomitant decrease in DMD for an increased level of nitrogen fertilization, from zero nitrogen to 134 kg N/ha. The CP content of kikuyu in the present investigation was negatively associated with the digestibility of the CF, NFE, ADF and OM fractions, but positively correlated to its own digestibility (Table 4).

Tainton, Barrow & Bransby (1982) reported that animal performance declined with increasing nitrogen fertilization levels on kikuyu pasture. Pattinson (1981) found that oesophageal fistulated steers selected for high-fibre herbage when grazing kikuyu, but on coastcross 11 they selected for low-fibre herbage. Pattinson (1981) also recorded that the intake of kikuyu in the autumn was lower than during midsummer, even though the autumn kikuyu was of better 'quality', in that it had higher CP and lower CF levels than the summer grazing. It was postulated that some factor in the nitrogen fraction might have been responsible for the lower autumn intake (Pattinson, 1981).

Hegarty (1982) and McClure & Hunter (1983) cited kikuyu as a pasture species which can accumulate high nitrate levels. Marais (1980) reported that increasing nitrate levels in kikuyu herbage adversely affected its *in vitro* digestibility. Cellulose digestion *in vitro* has been shown to be decreased by supplemental nitrate (Hall, Gaddy & Hobbs, 1960; Miyazaki, Okamoto, Tsuda, Kawashima & Vesaka, 1974). Nitrate has been suspected of causing decreased live mass gains in sheep grazing spring 'flush' pastures high in nitrates (Ulyatt, 1964). The association between NO_3-N and the digestion coefficients of the other chemical fractions for the present data is presented in Table 5.

The relationship between CP and NO_3-N contents for the kikuyu herbage is described by the equation CP = 13,4 + 5,7 (NO_3-N) with r = 0,779 (P < 0,01).

It is postulated that the negative association between NO_3-N or nitrogen levels in kikuyu and its DOM value could result from the negative correlation between CP or NO_3-N on the digestibility of the fibre and NFE fractions in the herbage.

There are indications that the relationship between nitrate and the other chemical fractions, including DOM, is better explained by a log-normal distribution of the data rather than by a normal distribution (Table 5). Further research is required to determine which relationship, log-normal or linear, is preferred.

Table 5 The relationship between nitrate levels in kikuyu and the digestibility coefficients of the chemical fractions

	Regression equation			
Y	*a*	*b*	*X*	*r*
CP	63,2	+2,6	NO_3-N	0,340
NFE	65,3	−9,9	NO_3-N	−0,805**
CF	65,5	−5,08	NO_3-N	−0,454
ADF	61,7	−6,67	NO_3-N	−0,578*
OM	64,3	−5,03	NO_3-N	−0,599*
$\log_e$ CP	$\log_e$4,16	+0,04	NO_3-N	0,351
$\log_e$ NFE	$\log_e$4,2	−0,17	NO_3-N	−0,824**
$\log_e$ CF	$\log_e$4,19	−0,079	NO_3-N	−0,439
$\log_e$ ADF	$\log_e$4,14	−0,11	NO_3-N	−0,581*
$\log_e$ OM	$\log_e$4,18	−0,08	NO_3-N	−0,605*

*$P < 0,05$; **$P < 0,01$

Conclusion

The comparative study involving two analytical methods for determining fibre levels in herbage was confounded by the suspected interference of the nitrogen fraction in the kikuyu on its fibre digestibility. Initially the uncharacteristic correlation between fibre and nitrogen on digestibility was surprising, but a critical review of the literature indicated that these results might not be as unique as at first thought. The majority of predictive equations for digestibility cited in the literature have been derived for temperate grass species. The use of these equations to predict the nutritional quality of tropical grasses from their chemical fractions might be highly misleading owing to some poor correlations between the chemical fractions in tropical grasses and digestibility (Jarrige & Minson, 1964; Sullivan, 1964; Minson, 1971). Milford (1960) and Butterworth (1967) commented that the fibre content of subtropical and tropical grasses was not related to their nutritional values.

Grazing management and fertilization practices for kikuyu pastures are facets which need careful scrutiny and attention. Not only do highly fertilized kikuyu pastures have high nitrogen and nitrate levels, possibly resulting in lower nutritive value, but Minson (1973) observed that the voluntary intake of DOM was lower on kikuyu fertilized with a high (230 kg/ha) than with a low nitrogen application (57,5 kg/ha). The present data indicate that kikuyu with CP levels of 20% or greater contains potentially toxic levels of nitrate for livestock.

A new look at the nitrogen fertilization of kikuyu pastures to optimize nutritional quality and available energy yields rather than DM yields is neccessary for maximal animal production to be achieved, especially in dairy production for which most kikuyu pastures in Natal are used.

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