An evaluation of *Panicum maximum* cv. Gatton: 3. The partial digestion by sheep of organic matter, nitrogen and neutral detergent fibre of herbage at three stages of maturity during summer, autumn or winter

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Abstract

The aim of this study was to quantify the partial digestion of organic matter (OM), nitrogen (N) and neutral detergent fibre (NDF) in sheep grazing *Panicum maximum* cv. Gatton pastures at three stages of pasture maturity during summer, autumn or winter. As pasture progressed from the young to the mature stage, OM digestibility decreased for all seasons, but OM disappearance in the rumen was unaffected. OM disappearance from the small intestine decreased with increasing pasture maturity during summer, and OM disappearance from the large intestine decreased with increasing pasture maturity during winter. N disappearance from the small intestine decreased with increasing pasture maturity during all seasons and N disappearance from the large intestine decreased with increasing pasture maturity in summer. Non ammonia nitrogen disappearance from the small intestine was decreased with increasing pasture maturity only for mature autumn pasture. Total tract N disappearance decreased with increasing pasture maturity during summer and autumn. NDF disappearance from the rumen decreased with increasing pasture maturity during autumn and winter, while NDF disappearance from the large intestine was unaffected. NDF disappearance from the total tract decreased with increasing pasture maturity during all seasons. It was concluded that *P. maximum* cv. Gatton pasture would best be utilized at the younger stages of development and that nutritional value would be higher in summer followed by younger autumn and winter pastures.

Keywords: *Panicum maximum*, partial digestion, nutrition, sheep.
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Introduction

This experiment was part of a series of trials conducted to evaluate the nutritional value of *Panicum maximum* cv. Gatton grown under dry-land conditions (Relling *et al*., 2001a, b). The aim of this study was to quantify the partial digestion of organic matter (OM), nitrogen (N) and neutral detergent fibre (NDF) in sheep grazing *Panicum maximum* cv. Gatton pastures at three stages of pasture maturity during summer, autumn or winter.

Material and methods

Details of the experimental site and fertilization of the *Panicum maximum* cv. Gatton pastures are given in Relling *et al*. (2001a and b). Twelve Döhne-Merino wethers equipped with rumen, abomasal and terminal ileal fistulas were randomly allocated to three treatment groups. An additional 15 wethers were randomly allocated to the three treatment groups and fitted with faecal collection bags to determine voluntary intake of pasture. Three oesophageal fistulated sheep were randomly allocated to each treatment and were used to determine the quality of the material selected at each stage of maturity. The animals were fistulated according to Chapman & Grovum (1984). All the animals were treated against internal parasites, inoculated against pulpy kidney disease and injected with vitamin A two weeks prior to the start of the experimental period. The treatment against internal parasites was repeated every six weeks. The animals had *ad lib.* access to a 50:50 dicalciumphosphate/salt lick, and fresh water was available at all times.

Three camps of 0.24 ha each were used. These were subdivided into three smaller camps that were manipulated to produce young, early reproductive or mature stage pastures by mowing the three subsections in each camp at different intervals. The periods of pasture re-growth were 84, 42 and 21 d for the mature, medium and young growth stages, respectively. Three pasture camps of 0.24 ha each were used. These were subdivided into three smaller camps. The stocking rate was 125 sheep/ha.

The double marker technique, with continuous infusion and sampling at pre-determined times, as described by Faichney (1975) was used to determine digesta flow. Markers were infused using a battery-driven peristaltic pump fitted to the backs of the sheep (Corbett *et al.*, 1976). Cr-EDTA (liquid phase marker) and Yb-acetate (solid phase marker) were infused continuously into the rumen for 24 h per day over a period of eight days. Sheep were adapted for a period of five days before the infusion started. A priming dose (double dose) of markers was infused on the first day of infusion (Hunter & Siebert, 1986). Markers were then infused for four days to establish steady-state conditions and sampling was done over the following four days. Cr-EDTA was prepared according to Morgan *et al.* (1976). Yb-acetate was dried at 100 ºC overnight and dissolved in de-ionised water to a final concentration of 100 mg Yb/10 ml as described by Faichney (1975). The peristaltic pump was calibrated to infuse one litre of marker fluid or 220 mg Cr and 90 mg Yb per day over a 24 h period. The markers were pumped from different containers, with separate polyethylene infusion tubes leading directly into the rumen. The actual amounts of Yb and Cr in the solutions were measured by atomic absorption spectrophotometry. The sampling times for the partial digestion trial are presented in Table 1.

Table 1 Time schedule used for rumen fluid sampling during estimation of the partial digestion of *P. maximum* cv. Gatton.

	Day 1	Day 2	Day 3	Day 4
Time	09:00	12:00	15:00	18:00
	21:00	24:00	03:00	06:00

Rumen, abomasal and ileal fluid was collected at each sampling. Faeces were collected twice daily at 08:00 and 18:00. Total faecal excretion was measured and a 10% sub-sample was pooled and frozen until analysis. Rumen fluid samples were thawed at room temperature and centrifuged as described by Morgan *et al.* (1976). The supernatant was used for determination of rumen ammonia and volatile fatty acid (VFA) concentrations. Abomasal and ileal fluid samples were thawed and a portion of the samples was centrifuged to determine concentrations of ammonia nitrogen (NH_3-N), Yb and Cr (Morgan *et al.*, 1976). A sub-sample was taken to determine dry matter content (DM), and rest of the sample was dried at 60^0C for 24 h and then ground. DM determination was done according to AOAC (1995). Ash determinations were done on faeces and oesophageal, abomasal and ileal samples (AOAC, 1995). NDF concentrations in oesophageal, abomasal, ileal and faecal samples were determined according to Robertson & Van Soest (1981). Nitrogen content of all samples was determined by the macro Kjeldahl method (AOAC, 1995).

An analysis of variance for balanced data (Statistical Analysis Systems, 1994) was used to analyze data with the ANOVA model for different combinations of maturity and season effects. Significance of differences between means was determined by multiple comparisons using the Tukey t-test (Samuels, 1989).

Results and Discussion

A decrease ($P < 0.05$) in digestible organic matter intake (DOMI) was observed as pastures matured from medium to mature re-growth in summer and autumn (Table 2). Abomasal flow at the mature stage in summer was lower ($P < 0.05$) than at the younger stages, while no difference was observed in other seasons. No differences in ileal digesta flow were observed in summer and autumn, but in winter the highest flow was observed at the medium stage and the lowest at the young stage. The reason for this is unclear. When OM disappearance from the rumen was expressed as a percentage of organic matter intake (OMI) (Table 2), there were no significant differences between stages of maturity for any season. The values obtained for summer were in the same range as those reported by Du Preez & Meissner (1992) for *Lolium multiflorum*, but were lower than the range reported by Hogan *et al.* (1989) for tropical pastures (*Digitaria decumbens* & *Setaria sphacelata*). Although no difference was detected between stages of maturity for digestion in the rumen, a number of publications have indicated that stage of maturity, as well as level of intake, could have an effect on digestion in the rumen. Funk *et al.* (1987) and Hart & Leibholtz (1990) reported an increase in OM digested in the rumen as pastures increased in maturity. Merchen *et al.* (1986) confirmed these findings indirectly, as they reported a decrease in OM digestion in the rumen as intakes increased (increased intakes is normally associated with younger pastures). The decrease in OM digestion in the rumen might be the result of an increase in digesta flow with younger pastures, as digestibility is usually higher. In support of these findings, the digesta flow in the abomasum in the current study tended to be higher for the more mature pastures. In contrast, Du Preez & Meissner (1992) found no effect of feeding level on OM disappearance from the rumen when roughage diets were fed.

Table 2 Mean (± s.d.) for organic matter digestion (% of OMI), DOMI (g/kg $W^{0.75}$/d) and digesta flow (l/d) in sheep grazing *P. maximum* cv. Gatton pastures at different levels of maturity in summer, autumn or winter

	Young	Medium	Mature
Summer			
DOMI	60.0[a] (5.1)	57.0[a] (4.7)	48.1[b] (1.8)
Abomasal digesta flow	32[a] (8)	33[a] (3)	19[b] (4)
Ileal digesta flow	6[a] (2)	7[a] (1)	6[a] (3)
OM disappearance - rumen	54[a] (3.0)	48[a] (4.4)	50[a] (2.5)
OM disappearance - small intestine	24[a] (1.3)	25[a] (5.3)	13[b] (4.7)
OM disappearance - large intestine	2[a] (2.0)	1[a] (0.6)	3[a] (1.9)
OM disappearance - total tract	80[a] (0.5)	74[b] (1.6)	66[c] (1.6)
Autumn			
DOMI	48.8[a] (5.5)	44.1[a] (2.2)	26.7[b] (3.5)
Abomasal digesta flow	29[a] (6)	37[a] (9)	28[a] (11)
Ileal digesta flow	11[a] (2)	13[a] (3)	12[a] (4)
OM disappearance - rumen	45[a] (10)	37[a] (9)	28[a] (11)
OM disappearance - small intestine	21[a] (5)	23[a] (5)	25[a] (7)
OM disappearance - large intestine	3[a] (1)	4[a] (1)	5[a] (3)
OM disappearance - total tract	69[a] (5)	65[a] (4)	47[a] (20)
Winter			
DOMI	26.8[a] (3.0)	25.6[a] (3.5)	23.3[a] (1.7)
Abomasal digesta flow	23[a] (4)	30[a] (2)	24[a] (8)
Ileal digesta flow	8[b] (1)	11[a] (1)	10[ab] (2)
OM disappearance - rumen	47[a] (1)	45[a] (4)	47[a] (2)
OM disappearance - small intestine	9[a] (0)	8[a] (3)	7[a] (3)
OM disappearance - large intestine	4[a] (1)	5[a] (3)	1[b] (1)
OM disappearance - total tract	60[a] (1)	59[a] (3)	54[b] (1)

[a,b,c] Row means with common superscripts do not differ ($P > 0.05$)

The site of proportional OM digestion for high quality forages moved towards the lower digestive tract in the study of Faichney & White (1977). In the current study a similar pattern was observed for summer pastures (Table 2) where the proportion of OM disappearance in the small intestine was lower for the mature pasture stage compared to the medium mature stage. No differences between stages of maturity were found in autumn and winter

Digestion in the large intestine did not differ between stages of maturity in summer and autumn. During winter the OM disappearance at the mature stage was lower than at the younger stages (Table 2). This finding differs from that of Kawas *et al.* (1990), who stated that OM digestion shifted to the large intestine as pasture maturity progressed. Hogan *et al.* (1969) also reported that the proportion of mature pasture disappearing in the large intestine was higher compared to younger material. In winter OM disappearance from the rumen and the small intestine did not differ between levels of maturity, while total tract digestibility decreased at the mature stage. The decrease in total digestibility was caused by the lower digestibility in the large intestine. In this study there was no shift of digestibility to the large intestine from the rumen as noted by Kawas *et al.* (1990), but a decrease in digestibility in the large intestine without any effect in the rumen and small intestine.

The total tract OM disappearance decreased with stage of maturity in summer, which was consistent with results reported by Haggar & Ahmed (1971) and Akin *et al.* (1977). In autumn no differences were observed for disappearance from the total tract (Table 2), although it follows the same pattern predicted by Haggar & Ahmed (1971) and Akin *et al.* (1977). A large standard deviation for mean values for the mature stage in autumn resulted in a non-significant difference.

N intake decreased with level of pasture maturity, and the medium and mature stages differed in summer and autumn (Table 3). No differences were observed in winter.

Table 3 Means (± s.d.) for N intake (g/d), abomasal N flow (g/d) and N digestion (% of total N intake) in sheep grazing *P. maximum* cv. Gatton pastures at different levels of maturity in summer, autumn or winter

	Young	Medium	Mature
Summer			
N intake	47^{a} (4)	45^{a} (3)	28^{b} (1)
Abomasal N flow	50^{a} (4)	46^{a} (2)	28^{b} (2)
N disappearance - small intestine	79^{a} (2)	73^{b} (3)	70^{b} (3)
*NAN disappearance - small intestine	75^{a} (6)	71^{a} (4)	70^{a} (2)
N disappearance - large intestine	8^{a} (1)	2^{c} (1)	4^{b} (1)
N disappearance - total tract	86^{a} (2)	75^{b} (3)	74^{b} (3)
Autumn			
N intake	27^{a} (3)	27^{a} (2)	17^{b} (3)
Abomasal N flow	29^{a} (4)	28^{a} (2)	17^{b} (2)
N disappearance - small intestine	77^{a} (2)	71^{a} (3)	66^{b} (4)
NAN disappearance - small intestine	74^{a} (9)	71^{a} (5)	54^{b} (9)
N disappearance - large intestine	7^{a} (1)	6^{a} (1)	8^{a} (2)
% N disappearance - total tract	84^{a} (2)	78^{ab} (3)	74^{b} (5)
Winter			
N intake	14^{a} (2)	14^{a} (1)	13^{a} (0)
Abomasal N flow	15^{a} (2)	15^{a} (2)	14^{a} (1)
N disappearance - small intestine	60^{a} (3)	56^{ab} (3)	54^{b} (3)
NAN disappearance - small intestine	50^{a} (6)	46^{a} (4)	45^{a} (4)
N disappearance - large intestine	9^{a} (3)	8^{a} (1)	7^{a} (2)
N disappearance - total tract	70^{a} (4)	62^{a} (3)	63^{a} (4)

^{a,b,c} Row means with common superscripts do not differ (P > 0.05)
*NAN = non-ammonia-nitrogen

The N disappearance in the small intestine, expressed as a proportion of N intake, decreased as pastures matured in all three the seasons (Table 3). These findings are in agreement with those of Kawas *et al.* (1990), who found that the digestibility of N decreased in the small intestine with increased pasture maturity. Minson (1990) reported that the quantity of N digested in the small intestine is positively correlated with the N-content of forage. In this study N intake decreased as pasture matured. According to Van Vuuren *et al.* (1991), a large proportion of N in mature pasture is associated with cell walls. This may explain the decrease in the proportional digestion of N in the small intestine as pasture matured.

Meissner *et al*. (1993) predicted that non-ammonia-nitrogen (NAN) disappearance as a proportion of N intake in subtropical grasses should be in the order of 70%. In this study NAN values, as a percentage of N intake, were in this range in summer and in young and medium mature autumn pasture. The value for mature autumn pasture and winter pasture at all stages was much lower than values reported in the literature (Table 3). NAN, expressed as a percentage of N intake disappearing in the small intestine, decreased with level of maturity in summer although not significantly. In autumn this value was significantly lower at the mature stage, and in winter no significant decrease between stages was observed. It is generally accepted that the greatest portion of protein present in the small intestine will be of microbial origin when roughage is fed, as a very small part of plant protein would be able to flow through the rumen (θrskov, 1982). The high level of disappearance of NAN at the younger stages of maturity is an indication that more amino acids (of microbial protein origin) were available for absorption at this stage. The decrease in NAN with increasing pasture maturity (Table 3) could also be explained by the results of Mullahey *et al.* (1992) and Kabunga & Darko (1993) who found that the degradability of protein (which decreased with increasing stage of maturity) was not associated with increased N or amino acid flow to the duodenum. The lower CP content of mature plants, coupled with the lower DOMI from such plants, resulted in a decrease in microbial production (Hume & Purser, 1974; Kawas *et al.*, 1990). This is associated with a decrease in the net flow of N to the duodenum, in spite of the decrease in protein degradation in the rumen (Hume & Purser, 1974; Kawas *et al.*, 1990). A decrease in the N flow from the abomasum was observed during autumn and winter and from the medium to the mature stages (Table 3), which is consistent with these findings.

Van Niekerk (1997) noted that the N fraction in older grasses was more protected against rumen degradation, and was also more protected against post-rumen digestion. It would seem that the same effect was evident in this experiment for summer pasture, since the N digested in the large intestine was higher for the young stage than for the other stages (Table 3). This trend was not observed in autumn or winter, but it must be kept in mind that the N concentration in the large intestine is low in comparison to that in the small intestine and total tract. It is possible that the results for autumn and winter could have been masked by experimental error, as one would have expected a pattern similar to that observed in summer.

In summer, the total digestion of N as a proportion of N-intake decreased as pastures matured from the young to the medium stage. A decrease from young to mature pastures was also observed in autumn. No significant differences occurred in winter. Hume & Purser (1974) and Kawas et al. (1990) also reported a decrease in total tract N digestion as pastures matured. Van Vuuren *et al.* (1991) ascribed this to increased resistance of cell walls to microbial breakdown and an increase of N associated with cell walls. Although comparatively low during winter, the digestion of N in the total tract was still high compared to the results of Gohl (1981) who reported lower (36-62%) values for the digestion of N in *P. maximum* through three stages of maturity in the dry season.

Table 4 Means (± s.d.) for NDF intake (g/day) and NDF disappearance (% of total NDF intake) in the rumen, large intestine and total tract of sheep grazing *P. maximum* cv. Gatton pastures at different levels of maturity in summer, autumn or winter

	Young	Medium	Mature
Summer			
NDF intake (g/d)	746[b] (58)	842[a] (47)	743[b] (32)
NDF disappearance - rumen	65[a] (1)	61[a] (1)	54[a] (5)
NDF disappearance - large intestine	13[a] (3)	12[a] (3)	8[a] (4)
NDF disappearance - total digestive tract	78[a] (3)	72[a] (4)	61[b] (2)
Autumn			
NDF intake	709[ab] (86)	787[a] (53)	556[b] (103)
NDF disappearance - rumen	65[a] (1)	61[b] (1)	54[c] (2)
NDF disappearance - large intestine	4[a] (2)	4[a] (1)	4[a] (1)
% NDF disappearance - total digestive tract	68[a] (3)	64[b] (1)	58[c] (2)
Winter			
NDF intake	416[b] (44)	519[a] (49)	571[a] (20)
NDF disappearance - rumen	58[a] (1)	53[b] (3)	44[c] (3)
NDF disappearance - large intestine	4[a] (2)	5[a] (4)	8[a] (4)
NDF disappearance - total digestive tract	62[a] (1)	57[b] (2)	51[c] (2)

[a,b,c] Row means with common superscripts do not differ (P > 0.05);

The intake of NDF was higher at the medium stage in summer, with no significant difference between the young and mature stages (Table 4). The decrease in NDF intake at the mature stage could have been influenced by the low DOMI (Table 2), although the NDF content of material selected at the mature stage was higher than that for the younger stages (Relling *et al*., 2001a, b). In autumn the intake of NDF decreased from the medium mature to the mature stage of re-growth. NDF intake increased with stage of maturity in winter. The proportion of NDF intake disappearing from the rumen decreased with increasing level of pasture maturity in autumn and winter (Table 4). Hogan *et al.* (1969) and Kawas *et al.* (1990) also noted a decrease in digestion of fibre in the rumen as stage of maturity increased. There were no differences between levels of maturity for NDF digestion in the large intestine (Table 4). The disappearance of NDF in the total tract decreased with stage of maturity. This effect was noted in all three seasons, though in summer it was only significant between the medium and mature stages. The decrease in the digestion of fibre in the total tract with level of maturity was consistent with other reports (Hogan *et al.*, 1969; Cherney *et al.*,1992; Jung & Vogel, 1992). Lignin content is negatively correlated with fibre digestion. The ADL content increased with level of maturity (Relling *et al.*, 2001a, b), and this was probably one of the reasons for the decrease in digestibility. Butler & Bailey (1973) and Jung & Allen (1995) also reported a negative relationship. The digestibility of

NDF (Table 4) was in the same range as those observed by Gohl (1981), who reported values for *P. maximum* of 71.6% and 73,5% and 63.9% for young, medium and mature material, respectively.

Conclusions

OM digestibility decreased with increasing pasture maturity in all seasons, but it was not possible to establish the reason for this difference from the partial digestion study. The disappearance of N in the small intestine decreased with increasing pasture maturity in all seasons. It is concluded that summer and young autumn pastures will support better animal production rates than older autumn and winter pastures. There was no clear effect of stage of maturity on disappearance of N from the large intestine. The digestion of N in the total tract decreased with level of pasture maturity in summer and autumn. There was no effect of pasture maturity in winter, possibly because the winter pasture was in a dormant stage.

It was expected that NDF intake would increase with level of development, but this was only observed in winter. DOMI decreased with increasing pasture maturity in summer and autumn but not in winter. The lower DOMI intake in summer and autumn could have been responsible for the absence of an effect on NDF intake. The disappearance of NDF from the total tract decreased with level of pasture maturity in all three seasons, reflecting an increase in lignin content, which is negatively correlated with the digestion of fibre. Digestion of OM and N decreased with increasing pasture maturity in all seasons and was higher in summer, followed by autumn and winter.

It is concluded that *P. maximum* cv. Gatton pasture would be best utilized at younger stages of development, and that the nutritional value would be higher in summer followed by younger autumn and winter pastures.

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