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Effects of a digestive modifier, browse plus on ruminal and intestinal breakdown of forages containing high tannin levels

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The potential for enhancement of forage utilization of two high tannin containing tropical browse trees and three legumes through the use of a digestive modifier called Browse Plus was investigated in this study. The study was carried out in 1995. The main objective of the study was to evaluate the potential for improving digestibilities of dry matter (DM) and crude protein (CP) of two browse tree species, namely; *Acacia albida* and *Colophospermum mopane* and three herbaceous legumes, namely; *Chamaecrista rotundifolia*, *Stylosanthes scabra*, and *Stylosanthes guineensis* by use of Browse Plus. The legumes were sampled at three phases of growth in 1994, making a total of nine samples. Forages were obtained from Sanyati, a semi-arid area of Zimbabwe. Total tannin levels in the forage samples were determined using the radial diffusion technique and *in vivo* DM and CP digestibilities were determined using the mobile nylon bag technique following infusion of 0-3 g of Browse Plus into rumens of each of the three cannulated Holstein steers that were used. Ruminal infusion of Browse Plus enhanced ($P < 0.05$) DM and CP digestibilities of 9 and 10 of the 11 forages tested, respectively. Improvement in DM and CP digestibilities tended to be higher between Browse Plus inclusion levels 0-2 g, thereafter, improvement was minimal. These were, however, not significant. There was no relationship ($P > 0.05$) between total tannin level, DM and/or CP digestibilities. The results from this study indicated that Browse Plus can improve DM and CP digestibilities of forages containing high tannin levels. This is likely to increase nutrient availability at the level of the small intestines, thereby enhancing utilization of such forages by ruminants. From the results, we recommend that Browse Plus be utilized at an inclusion rate of 2 g per animal per day in order to realize benefits from improved utilization of forages high in tannins.

Keywords: Digestibility, tannin, browse, digestive modifier, ruminants.

Introduction

Zimbabwe, and most of sub-Saharan Africa, is prone to droughts, which negatively affects livestock production (Chimonyo, 1998). Due to limited and scarce grazing during the droughts, ruminant livestock resort to browsing from various browsable trees and shrubs for survival (Dube *et al.*, 1993). Inevitably, this situation results in increased intake of tanniferous material (Smith *et al.*, 1995). Consumption of tannins, one of the many antinutritional factors in livestock feeds lowers nutrient utilization, feed conversion efficiency and animal productivity (Makkar, 1993). This might in part, be responsible for loss of body condition experienced, particularly by cattle during the dry season and (or) droughts. In view of these recognized detrimental effects of tannins on nutrient availability post-ruminally, particularly proteins (Barry and Manley, 1984; Makkar, 1993), it is imperative to improve browse utilization and nutrient availability to browsing livestock.

Various interventions have been tried to limit the detrimental effects of tannins, in browse on animal performance. Use of polyethylene glycol (PEG) which binds preferentially with tannins thereby rendering them ineffective has been widely documented (Barry and Manley, 1984; Pritchard *et al.*, 1988; Dube *et al.*, 1993). Such treatment resulted in increased nutrient availability and improved animal performance (Duncan, 1994). Similarly, Browse Plus, a product developed by Agricura Zimbabwe, a commercial company in Zimbabwe, has potential as a digestive modifier which can improve browse utilization by ruminants.

Browse Plus (BP) is a commercial product which contains PEG, polyvinylpyrrolidone, calcium hydroxide and powdered molasses (Smith *et al.*, 1995). Results of various trials in which BP has been tested as a digestive modifier in Zimbabwe are inconsistent (Dube *et al.*, 1993; Ncube and Mubaiwa, 1994; Chatora, 1995; Smith *et al.*, 1995). However, there appears to be great potential for use of BP to improve nutrient availability to ruminant animals feeding on browse. The current study examined the effects of the infusion of different levels of BP into the rumens of Holstein steers on the digestibility of various browse species obtained from a semi-arid area of Zimbabwe, where browse is abundant. The main goal was to evaluate the potential of using BP, a digestive modifier, to improve nutrient availability at the level of the intestines in ruminant animals from forages containing high levels of tannins. Specific objectives of the study were to determine levels of tannins in some local browse shrubs and legumes and to determine DM and CP digestibilities following the infusion of different levels of BP into rumens of cannulated Holstein steers. Also, the study aimed to determine the optimum inclusion rate of BP for efficient nutrient supply at the level of the small intestines for absorption.

Materials and Methods

Site description

Sanyati District is a tropical semi-arid area that lies approximately 250 kilometres west of Harare in Mashonaland West Province. The site is 900 to 1 200 metres above

sea level. Sanyati lies in Natural Region IV of Zimbabwe, an agro-ecological zone where farming operations are semi-extensive (Chimonyo, 1998). Mean diurnal temperatures experienced in Sanyati are 32°C in the hot dry season and 24°C during the cold dry months. It receives low to moderate annual rainfall (450 to 600 mm) during the rainy season that normally extends from November to March. Periodic dry spells of up to 3 weeks are common during the rainy season.

The savannah vegetation characteristic of this semi-arid area consists of abundant tropical browse trees and shrubs, particular *Acacia* sp. and *Colophospermum mopane*. Some of these browse trees provide browse for animals during the times of pasture scarcity, particularly during the dry season or droughts when pastures are generally poor. In addition, the grazing lands are hilly and the cattle graze along the Munyati river, particularly during the dry season.

Forage description

In this study, two types of forages, browsable shrubs and planted herbaceous legumes were used. Prior to the inception of the study, feeding behavior of cattle was monitored during the dry season of 1991/1992. It was observed that the animals preferred and commonly browsed on certain browse species, mainly *Colophospermum mopane* and *Acacia albida* for sustenance. Following these observations, leaves and twigs of *C. mopane* and *A. albida* were harvested and conserved during that period. Earlier, three herbaceous pasture legumes namely *Stylosanthes scabra*, *Stylosanthes guianensis* and *Chamaecrista rotundifolia* had been planted in large protected plots within grazing lands. These legumes were then harvested at three different stages of growth, i.e., early, middle and late growth phases. For each forage tested, materials were bulked and sun dried after which, materials were further dried in an oven for 72 hours at 60°C and then milled through a 1 mm screen.

Forage evaluation

The total amount of tannins in each of the forages was estimated using the radial diffusion method described by Hagerman (1987), while DM and CP digestibilities were determined using the mobile bag technique (Hvelplund *et al.*, 1992). Briefly, forage samples (1 g) were weighed into a mobile bag with an effective size of 6 x 6 cm and a pore size of 9 x 9 µm. Bags were heat sealed and placed inside large nylon bags of 20 x 15 cm and a pore size of 1 x 0.5 mm. Next, the large bags were divided into six compartments of 10 x 7 cm effective size to avoid clumping of bags. The bags were then incubated in the rumen for 24 hours following which they were machine washed and incubated in hydrochloric acid solution, pH 2.4 for 1 hour at ambient temperature. Thereafter, samples were incubated in pepsin-HCl solution (100 mg pepsin per liter of 0.004 M HCl, pH 2.4) for 2 hours at 40°C. The bags were then introduced into the small intestines through a duodenal cannula and recovered in faeces 8 to 36 hours later. Again, bags were machine washed in cold tap water and the residue oven dried at 105°C for 24 hours. Dry matter and crude protein digestibilities were then estimated following AOAC procedures (AOAC, 1990).

Effects of inclusion rate of Browse Plus on digestibility

Using a crossover experimental design with three Holstein steers cannulated at both the rumen and small intestines, six levels of BP inclusion levels were tested for all the different forages. Browse Plus was infused daily into the rumen of each of three steers using a 50 ml syringe linked to rubber tubing. Six inclusion levels of BP, i.e., 0.5; 1.0; 1.5; 2.0; 2.5 and 3.0 g per day were tested. Each test period lasted 6 days. Day 1 permitted clearance of BP from the rumen with the next two days being ruminal adaptation to the presence of BP. On days 4 and 5, forage samples were introduced into the rumen and further processed as described before. Day 6 was given to allow for further clearance of BP from the rumen before the next treatment. As mentioned earlier, DM and CP were then estimated following AOAC procedures (AOAC, 1990).

Statistical analyses

Data were analyzed using GLM procedure of SAS for the effects of animal, BP inclusion level, and period on DM and CP digestibilities within forage (SAS, 1994). LSDs were used to determine differences between means while Pearson's correlation analysis was conducted to determine the degree of association between total tannin content and digestibilities of DM and CP.

Results

Total tannin content and inherent digestibilities of forages

Table 1 summarizes the results of total tannin content and corresponding inherent post-ruminal DM and CP digestibilities of the various forages tested following

Table 1: Mean (\pm SE) total tannin content (g resorcinol/kg) and digestibilities¹ of DM and CP of browsable shrubs and herbaceous legumes obtained from a semi-arid area of Zimbabwe

Forage type	Tannin level (g resorcinol/kg)	Digestibility ¹	
		DM	CP
<i>A. albida</i>	19.33 \pm 4.41	52.31 \pm 0.10	38.51 \pm 1.80
<i>C. mopane</i>	41.06 \pm 6.63	44.91 \pm 1.43	39.28 \pm 2.40
<i>C. rotundifolia</i> (e)	11.55 \pm 1.63	52.88 \pm 1.92	49.95 \pm 2.40
<i>C. rotundifolia</i> (m)	5.08 \pm 3.36	43.35 \pm 2.93	38.27 \pm 1.73
<i>C. rotundifolia</i> (l)	7.32 \pm 0.21	44.40 \pm 2.12	36.88 \pm 1.07
<i>S. scabra</i> (e)	11.47 \pm 0.81	44.83 \pm 3.57	45.24 \pm 3.19
<i>S. scabra</i> (m)	11.39 \pm 1.31	48.12 \pm 0.61	43.08 \pm 1.56
<i>S. scabra</i> (l)	10.72 \pm 1.80	51.94 \pm 0.41	46.23 \pm 1.88
<i>S. guianensis</i> (e)	4.72 \pm 1.91	47.32 \pm 1.19	42.60 \pm 0.72
<i>S. guianensis</i> (m)	3.43 \pm 0.36	46.49 \pm 0.48	41.76 \pm 1.50
<i>S. guianensis</i> (l)	3.67 \pm 0.87	45.71 \pm 1.73	38.56 \pm 0.50

Where: e = early cut, m = mid cut and l = late cut.

¹Inherent DM and CP digestibilities of forages in the absence of Browse Plus i.e., 0g Browse Plus.

Table 2: Dry matter digestibilities (percent) of various forages following infusion of different levels of Browse Plus (g/kg feed) into the rumens of rumen and abomasal cannulated Holstein steers.

Forage	Browse Plus Inclusion Level (g)						Significance
	0.5	1.0	1.5	2.0	2.5	3.0	
<i>A. albida</i>	51.57 ± 0.80	53.96 ± 0.80	56.28 ± 0.86	63.76 ± 0.80	65.63 ± 0.80	66.63 ± 0.80	****
<i>C. mopane</i>	46.22 ± 0.86	47.34 ± 0.87	50.20 ± 0.86	52.66 ± 0.94	53.36 ± 0.87	53.56 ± 0.86	****
<i>C. rotundifolia</i> (e)	53.34 ± 1.97	56.13 ± 1.96	58.53 ± 2.14	60.16 ± 1.97	62.35 ± 1.96	62.28 ± 2.11	****
<i>C. rotundifolia</i> (m)	52.43 ± 1.09	52.73 ± 1.10	51.11 ± 1.09	51.45 ± 1.08	51.51 ± 1.10	54.52 ± 1.09	****
<i>C. rotundifolia</i> (l)	51.33 ± 0.98	54.45 ± 0.81	56.88 ± 0.97	58.41 ± 0.90	58.26 ± 0.90	57.98 ± 0.96	****
<i>S. scabra</i> (e)	52.28 ± 1.19	59.65 ± 1.19	60.40 ± 1.18	64.54 ± 1.19	63.09 ± 1.19	61.91 ± 1.20	****
<i>S. scabra</i> (m)	48.92 ± 0.82	46.58 ± 0.83	52.97 ± 0.82	52.18 ± 0.83	52.49 ± 0.84	54.24 ± 0.91	****
<i>S. scabra</i> (l)	53.14 ± 1.12	54.27 ± 1.11	52.38 ± 1.11	52.07 ± 1.12	51.55 ± 1.12	54.03 ± 1.13	ns
<i>S. guianensis</i> (e)	50.82 ± 0.82	50.58 ± 0.83	50.14 ± 0.82	50.07 ± 0.82	50.46 ± 0.83	50.25 ± 0.90	ns
<i>S. guianensis</i> (m)	46.76 ± 0.83	46.85 ± 0.92	48.91 ± 0.84	47.55 ± 0.91	48.12 ± 0.83	50.67 ± 0.84	**
<i>S. guianensis</i> (l)	45.01 ± 0.73	46.79 ± 0.74	48.77 ± 0.73	51.78 ± 0.74	52.23 ± 0.73	50.46 ± 0.79	***

ns (non significant); * P<0.05; ** P<0.01; *** P<0.001.

Table 3: Crude protein digestibilities (percent) of various forages following infusion of different levels of Browse Plus (g/kg feed) into the rumens of rumen and abomasal cannulated Holstein steers.

Forage	Browse Plus Inclusion Level (g)						Significance
	0.5	1.0	1.5	2.0	2.5	3.0	
<i>A. albida</i>	40.14 ± 0.82	40.58 ± 0.82	43.45 ± 0.88	44.32 ± 0.81	43.22 ± 0.82	42.88 ± 0.82	*
<i>C. mopane</i>	40.80 ± 3.70	45.97 ± 3.65	47.57 ± 3.67	40.93 ± 3.70	47.91 ± 4.03	51.14 ± 3.67	****
<i>C. rotundifolia</i> (e)	50.27 ± 1.22	48.00 ± 1.21	48.82 ± 1.33	47.85 ± 1.22	51.16 ± 1.21	51.91 ± 1.30	ns
<i>C. rotundifolia</i> (m)	43.40 ± 0.97	44.85 ± 0.97	46.01 ± 1.00	47.66 ± 0.98	47.34 ± 0.97	47.24 ± 0.97	****
<i>C. rotundifolia</i> (l)	42.69 ± 0.83	45.76 ± 0.84	50.09 ± 0.91	51.00 ± 0.83	52.29 ± 0.84	56.22 ± 0.89	****
<i>S. scabra</i> (e)	45.71 ± 1.78	48.81 ± 1.78	49.02 ± 1.18	53.67 ± 1.79	52.82 ± 1.78	52.63 ± 1.20	**
<i>S. scabra</i> (m)	42.95 ± 1.24	42.12 ± 1.25	46.80 ± 1.23	46.52 ± 1.24	49.28 ± 1.25	48.84 ± 1.46	**
<i>S. scabra</i> (l)	45.43 ± 0.82	46.62 ± 0.84	47.14 ± 0.82	49.37 ± 0.83	49.20 ± 0.83	49.70 ± 0.91	*
<i>S. guianensis</i> (e)	42.12 ± 0.97	43.81 ± 0.98	45.13 ± 0.96	45.63 ± 0.97	44.64 ± 0.98	48.66 ± 1.06	**
<i>S. guianensis</i> (m)	42.71 ± 0.80	43.44 ± 0.89	44.34 ± 0.82	42.31 ± 0.89	44.46 ± 0.81	46.69 ± 0.82	**
<i>S. guianensis</i> (l)	40.74 ± 0.69	40.61 ± 0.70	42.41 ± 0.69	44.51 ± 0.69	46.21 ± 0.73	46.08 ± 0.75	***

ns (non significant); * P<0.05; ** P<0.01; *** P<0.001.

30 hours of rumen incubation. Browsable shrubs contained relatively higher levels of tannins than forage legumes. Also, early growth phases of legumes were associated with higher tannin levels than the later stages of growth. However, there were no differences ($P > 0.05$) in DM and CP digestibilities of these forages (Table 1) and there was no association ($P > 0.05$) between tannin content, DM and (or) CP digestibilities.

Effects of Browse Plus inclusion level on forage percent DM and CP digestibility

Infusion of BP improved ($P < 0.05$) *in vivo* DM digestibility of all forages tested except for late-cut *S. scabra* and early-cut *S. guianensis* (Table 2). Similarly, digestibility of CP was enhanced ($P < 0.05$) in 10 of the 11 forages tested following the infusion of BP (Table 3).

Although absolute responses in DM and CP digestibilities were variable among forages, there was a general tendency for an increase in DM and CP digestibilities responses with an increment in the amount of BP infused per day (Tables 1 and 2). The increase was generally steep from 0 to 2 g inclusion levels after which the rate of increase was marginal.

Discussion

Results from this study demonstrate that BP has positive effects on DM and CP digestibilities of most of the various forages tested. The results suggest that the utilization of browse species or forages containing high levels of tannins can be enhanced when low levels of up to 2 g of BP are included in the diet of ruminants. Economically, the use of BP would benefit farmers during times of drought when animals tend to browse (Smith *et al.*, 1995) or when highly fibrous and tanniferous feeds are used for ruminant animal feeding. Despite the potential for compensatory growth following improved pasture availability, it is more cost effective and advisable to maintain a certain minimal animal body condition to ensure that production is not compromised when conditions improve. This is most critical for animals that are used to provide draught power. In most of the cases, at the time of critical draught power requirements i.e., during ploughing time in October to November, most of the animals are in their worst conditions as they will be emerging from the dry season. Under such circumstances and in drought years, BP appears to offer an alternative to the purchase of high cost animal feed supplements. This is in view of its ability to improve DM and CP digestibilities of forages containing high tannin levels thereby increasing nutrient availability at post-ruminal sites, as shown in this study.

A number of studies have been reported in Zimbabwe on use of BP as a digestive modifier (Dube *et al.*, 1993; Duncan, 1994; Ncube and Mubaiwa, 1994; Chatora, 1995; Smith *et al.*, 1995). Similar results as observed in this study were reported by Dube and co-workers as improvement in *in vitro* DM digestibilities (IVDMD) of three classes of browse when either polyethylene glycol (PEG) or BP was incorporated into the diet (Dube *et al.*, 1993). A year later, Ncube and Mubaiwa (1994) reported the benefit of improved digestibilities of *A. nilotica* fruits fed to lambs when BP was

added up to 3 g per animal per day in their diets. Despite increased IVDMD in the presence of BP as reported in the study by Dube and co-workers, there was no response in terms of feeding behavior and live weight change when steers were given access to one gram BP either in drinking water or through dosing (Dube *et al.*, 1993).

To date, responses of both large and small ruminants to the use of either PEG or BP are inconsistent in this country, and the world over. Responses vary from increased forage digestibilities (Dube *et al.*, 1993; Ncube and Mubaiwa, 1993; current study), enhanced voluntary feed intakes and live weight gains, to failure to respond to BP treatment (Smith *et al.*, 1995). Such variations in responses emphasize the need to determine the mechanism(s) by which BP effects biological changes. Most authors postulate that where BP has enhanced digestibility, this is probably due to the fact that the PEG in BP formed stronger bonds with tannins than the tannin-protein bond, thus releasing protein for digestion (Ncube and Mubaiwa, 1994). However, the different responses reported in the literature indicate that a more intricate mechanism(s) may be at play. There is, therefore, need for caution in explaining some observed responses.

Prior to infusion of BP in the rumens of the ruminal and intestinal cannulated Holstein steers used in this study, DM and CP digestibilities were observed not to be related to the tannin content of the forages. This is an interesting observation, which suggests that probably it is not the total quantity of tannin available that determines the detrimental effects of tannins on nutrient utilization. Rather, the type(s) of tannin(s) present may play a paramount role in determining the degree of utilization of high tannin content forages. This is in view of the fact that, tannins differ in their hydrophobicity and affinity for different protein types (Mehansho *et al.*, 1987). Invariably, the variants of tannins present at any given time will determine the types of tannin-protein interactions established. The affinities of such bonds, will in turn, determine the level of availability of nutrients associated with such a bond at the level of the small intestines, when pH changes.

Although, not directly related to digestibilities, intake of *A. nilotica* and *A. tortilis* fruits were observed not to be related to the tannin content of the fruits (Ncube and Mubaiwa, 1994). Earlier, in 1993, Dube observed no differences in intake of *A. karoo* and *A. nilotica* by goats, despite the fact that the former contained four times more tannin than the later (Ncube and Mubaiwa, 1994). Such differences between studies further reinforce the point that probably it is not the total tannin content that is important. This view is given more credence from observations that some classes of tannins are toxic to rumen microflora and the host animal (Mueller-Harvey *et al.*, 1988) whereas, others, such as insoluble proanthocyanidins, are associated with enzyme resistant proteins (Tanner *et al.*, 1990). Invariably, associations of the available tannins would be expected to respond differently to the presence of digestive modifiers, like BP. Resultant responses will thus depend on species of browse, stage of plant maturity and degree of forage processing.

Infusion of BP up to 3 g per animal per day improved DM and CP digestibilities of at least 9 and 10 of the 11 forages tested, respectively. Responses in enhancement of DM digestibility among the tested forages following infusion of up to 3 g BP per animal per day varied from 5 to 32 percent whereas protein responses varied from 4 to 52 percent. As mentioned earlier, differences in responses among these forages may highlight variations in the types of tannins available, either in response to species and (or) to stage of development of the forage. However, these results highlight the potential for the use of BP as a digestive modifier to promote nutrient availability at the level of the intestines from forages containing appreciable levels of tannins. Improvements in diet utilization will be expected to realize economic benefits during the dry season, particularly during droughts, when feed becomes scarce and ruminant animals may be forced to change their feeding behavior (Smith *et al.*, 1995).

Despite the consistent general progressive improvements in DM and CP digestibilities with increments in BP inclusion among the forages, relative improvement was of a greater magnitude between 0 and 2 g BP inclusion levels. Thereafter, the relative increments diminished substantially. For example, DM digestibility of *A. albida* increased by 22 percent between 0 and 2 g BP, whereas, only a 5 percent improvement was realized between 2 g and the maximum dosage tested in this study, 3 g. On the other hand, respective CP digestibility increased by 15 percent when BP infusion was increased from 0 to 2 g, but was negative (declined) thereafter. In the event of farmers being interested in using BP in improving nutrient availability post-ruminally, from the results of this study, it would be recommended that at least a dosage of 2 g BP be used.

Conclusion

In conclusion, Browse Plus had positive effects on DM and CP digestibilities on most of the forages tested. Despite variations in responses among forages tested, it can be inferred from the results of the study that benefit from use of BP can be realized, particularly in drought years where animals depend more on fibrous diets, probably containing high levels of tannins, which is common in most browse plants. This will benefit both the smallholder farmers in reducing the need for purchasing expensive animal feed supplements and the commercial ranching enterprise, by enhanced use of browse. From this study, an inclusion level of 2 g BP appears adequate to improve utilization of forages containing appreciable levels of tannins. For economical considerations, minimal improvements in both DM and CP digestibilities occur beyond this inclusion level of 2 g. However, it is important to emphasize that there is need to evaluate the mechanism(s) by which BP modifies digestion, to allow for bridging the gap between negative and positive results. Also, such information is vital for precise and more accurate recommendations to be made.

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