Evaluation of Anthelmintic Attributes of Moringa and Bamboo Leaves in Gastrointestinal Nematode-Infested West African Dwarf Goats

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Abstract
The anthelmintic attributes of moringa and bamboo leaves were evaluated using 18 gastrointestinal nematode-infested West African Dwarf goats (nine males and nine females; mean weight = 9.5 ± 0.5 kg) in a 12-week growth trial with groundnut hay as the reference diet in a complete randomized design. Condensed tannins of moringa and bamboo leaves were quantified. Feed intake, weight changes, feed conversion ratios, faecal egg counts and packed cell volumes of the goats were monitored. The animals were thereafter slaughtered for gastrointestinal worm counts, and carcass characterization.

Condensed tannins were absent in bamboo leaves while they constituted 0.1% of moringa leaves. There were no (P>0.05) dietary effects on dry matter intakes, but significant (P<0.05) dietary effects on crude protein intakes, average daily weight gains, warm carcass weights and dressing percentages were observed. Moringa-substitution of groundnut hay produced a significant (P<0.05) reduction in feed conversion ratio (18.0 vs. 27.4 g feed/g live-weight gain) while bamboo-substitution led to a significant (P<0.05) increase (45.7 vs. 27.4 g feed/g live-weight gain). The final mean faecal egg counts were between 334 - 384 eggs/g of faeces/animal, representing a drop of at least 65%, but were not (P>0.05) affected by dietary treatments. The mean worm burden pattern after slaughter indicated mixed infestations with significant (P<0.05) diet, gastrointestinal region and interactive effects.

Bamboo and moringa leaves contained no condensed tannins of anthelmintic or nutritional significance. However, complementing groundnut hay, the feed resource of choice in The Gambia, with moringa foliage (50:50 ratio), could play prominent roles in small ruminant control programmes, as it appears promising in improving resilience of West African Dwarf goats to the negative effects of gastrointestinal nematode infections and maintaining productivity under the parasitic challenge, through improved supply of crude protein to the infested animals.

Keywords: Anthelimintic, *Moringa oleifera*, Bamboo leaves, Groundnut hay, gastrointestinal nematodes, West African Dwarf goats.

1. Introduction

There are many important diseases of sheep and goats, but none presents as direct a threat to the health of goats as gastrointestinal nematodes (GINs). Adverse effects of infestation include poor growth rate and reduced carcass quality, and the usual mode of control is based on the repeated use of anthelmintics (Hoste *et al.*, 2005). However, anthelmintic resistance in worm populations is now a worldwide phenomenon, particularly prevalent in goats, and it has stimulated a global search for alternative and more sustainable solutions (Kaplan, 2004). Alternative parasite management strategies using forages containing condensed tannins have been suggested (Athanasiadou *et al.*, 2003). Based on indigenous knowledge in The Gambia and Guinea, moringa (*Moringa oleifera*) and bamboo (*Oxytenanthera abyssinica*) foliages were suspected to possess anthelmintic properties attributable to the probable presence of condensed tannins at levels considered beneficial to goats (Akinbamijo, 2006).

This study therefore evaluated the anthelmintic effects of feeding the foliages of moringa (MOR) and bamboo (BAM) separately, but in equal ratios with groundnut (*Arachis hypogea*) hay (GNH), to 18 West African Dwarf (WAD) goats that were naturally-infested with GINs. Performance indices were feed intake, weight changes, feed conversion ratios, faecal egg counts, packed cell volumes, gastrointestinal worm counts after slaughter and carcass characterization.

2.0 Materials and Methods

The study was conducted at the International Trypanotolerance Centre (ITC), The Gambia, from the end of the rainy season (November) in 2007 through the early part (February) of the dry season in 2008. MOR and BAM foliages were harvested daily from plots and stands within ITC. GNH was purchased from a local livestock feed market. Diet 1 (50MOR:50GNH) comprised of 50% of moringa foliage while Diet 3 (50BAM:50GNH) comprised of 50% of bamboo foliage, with the remaining 50% in each diet consisting of 50% groundnut hay. Diet 2 (100GNH), the reference diet, was 100% groundnut hay.

18 WAD growing goats (9 males and 9 females; 9.5 ± 0.5 kg) were purchased, quarantined for 3 weeks, and subsequently kept for 6 weeks on *P. maximum* paddocks previously contaminated with L_3 larvae of small ruminant GINs to facilitate their uniform exposure to the nematodes. They were thereafter grouped into 3 of 6 goats each, with balance maintained for weight, sex, and GINs infestation levels; and allotted to the 3 test diets in a 12-week growth trial, preceded by a 14-day adaptation period to the test diets, in a complete randomized design. Each goat was housed in an individual pen that was equipped with feeding and watering facilities. The goats were offered the experimental diets at 4% of their body weight (DM basis). Clean, fresh water was provided for the animals daily. Growth rate and daily feed intake were monitored. Rectal fecal samples were collected for FEC every fortnight using the McMaster technique (Georgi, 1980). PCV was similarly monitored using the capillary microhematocrit centrifugation (Hansen and Perry, 1994).

At the end of the trial, the goats were weighed, decapitated and flayed. The volume of blood from each decapitation was measured. The head, feet, and the internal organs alongside their fat depots were removed. The warm carcass (WCW) and some non-carcass components were thereafter weighed. Dressing percentage (DP) was defined as the WCW as a percentage of slaughter body weight. The gastrointestinal tracts (GIT) of the sacrificed goats were collected for worm counting. Worm counting procedures for the abomasum and the small intestine were as described by Eysker and Kooyman (1993), while the procedure of Moyo (2006) was used for that of the large intestines.

Feed samples were analyzed for crude protein (AOAC, 1997). ADF and NDF were determined (ANKOM Technology methods 2000a; b). P, Ca, Na and K concentrations were measured with the aid of an AAS. Condensed tannins (CTs) were assayed according to Porter *et al.* (1986).

A 3*3 factorial analysis was used to investigate the parasite recovery data using the General Linear Model of the SAS (1998) package. Data collected on other animal performance indices were subjected to Analysis of Variance (ANOVA) also with the aid of the same package. Significant means were separated using the Duncan's Multiple Range Test of the same package.

3.0 Results

Among the experimental feedstuffs, the CP ranged from 135.2 to 221.6 g/kg DM for GNH and MOR respectively, while the resultant CP concentrations of Diets 1, 2 and 3 were 179.60, 135.20 and 139.40 g/kg DM respectively. The NDF and ADF were least for MOR (278.6; 289 g/kg DM), while both were highest for BAM (687.6; 422.5 g/kg DM). MOR contained more K and Ca than the other two experimental feed components. Na was found at a greater concentration in BAM while P was found at a greater concentration in GNH (Table 1). CTs were minimal (0.1%DM; Table 1) in MOR, but completely absent in BAM.

No significant differences were observed in DMI; ranging from 300 to 320 g/animal/d for 100GNH and 50MOR:50GNH respectively (Table 2). Significant differences were however observed in CP intakes which ranged from the least value of 40.56 to the highest value of 57.47 g/animal/day for animals on 100%GNH and 50MOR:50GNH respectively; based on the CP contents of the experimental feedstuffs (Table 1) and the DMI values reported in Table 2. Significant diet effects were also observed with weight gains in favour of MOR substitution of GNH. FCR ranged from 18.80 to 45.70 g/animal/day for 50MOR:50GNH and 50BAM:50GNH diets respectively, indicating that animals on 50MOR:50GNH diet consumed significantly less feed than those fed the other two diets per unit weight gain. The minimum mean PCV of 21% was observed for animals on the 50BAM:50GNH diet. Mean FEC declined by at least 65% at the end of the study but diet effects were not significant (Table 2). Parasite recovery data (Tables 3a, b and c) reflected significant diet, GIT region and diet*GIT region interactive effects on total number of nematodes. Worms were present in the abomasum and large intestines of the sacrificed animals but no worms were seen in the small intestines. Significantly higher numbers of worms were however found in the large intestines irrespective of the diet (Table 3a). Both MOR and BAM substitution of GNH resulted in significantly reduced total numbers of gastrointestinal nematodes, with MOR substitution resulting in a greater reduction (Table 3b). The two substitution regimes did not however produce similar effects on nematode numbers in the same region within the GIT (Table 3c). It was nonetheless observed (Table 3c) that 50MOR:50GNH and 100%GNH had comparative effects on nematode numbers in the abomasums and the large intestines respectively. While the effect of 50MOR:50GNH on nematode number in the abomasum was statistically similar to that of 100% GNH on nematode number in the large intestine, the effect of 50MOR:50GNH on nematode number in the large intestine was comparable to the effect of 100%GNH on nematode number in the abomasums. MOR substitution of GNH significantly increased two economically important carcass characteristics; WCW and DP, while BAM substitution significantly decreased DP (Table 4).

4 .Discussion

The presence of worms in the abomasums of all the sacrificed animals suggests the probable prevalence of *Haemonchus contortus*, in the study area. Reyes (2006) in a study conducted in Nicaragua with sheep found only *Haemonchus contortus* in the abomasum. The other common nematode in the abomasums is *Telodorsagia circumcincta* (Brown stomach worm), while the common nematode in the large intestine is Oesophagostumum *spp.* (Nodular worm) (Miller and Horohov, 2006). No CTs were detected in BAM while the concentration in MOR has been described as being of no nutritional significance (Hoffmann E., personal communication, 2008). Significant reductions in total numbers of nematodes however resulted from the substitution of GNH with either of the MOR or BAM, even though there were no significant changes in the final FEC values and percentage drops in FECs. These seemingly contradictory observations could be taken as an indication that there were no effects, direct or otherwise, of condensed tannins on the GIT nematodes. CTs are reportedly (Barry and Manley, 1984) beneficial to ruminants at levels between 2.0 and 4.0 %DM. Within this range, possible direct effects could be mediated through CT-nematode interactions, which reduce nematode viability (Min and Hart, 2003). Such interactions have been reported (Niezen *et al*., 1995) to account for reduced FECs and nematode burdens in lambs that grazed *Hedysarum coronarium* as compared to *M. sativa* in New Zealand. Indirect effects on resistance and resilience could be mediated by changes in the supply of digested protein (Min and Hart, 2003). Moderate levels of condensed tannins (20 to 40g of CT/kg of DM) bind to protein by hydrogen bonding at near neutral pH (pH 6.0 to 7.0) in the rumen to form condensed tannin-protein complexes. These complexes are unstable at the acid pH (less than 3.5) of the abomasum and the proteins become available for digestion (Jones and Mangan, 1977; Barry and Manley, 1984). Thus, condensed tannin-containing plants can protect dietary protein against degradation in the rumen and increase amino acid supply to the abomasum and small intestine, resulting in an improved nutritional status of the animal (Min and Hart, 2003). The final FEC of 334, 369 and 384 eggs/g of faeces/animal have been described as low to medium by Kouch *et al*. (2005).

The DMI values not significant and were comparable to the values reported by Asaolu *et al*. (2010) in an earlier trial also with WAD goats. Significant differences were however observed in CP intakes across dietary treatments. The observed differences in CP intakes implied that the animals on 50MOR:50GNH consumed approximately 42% more CP than did goats fed 100%GNH, whereas those fed 50BAM:50GNH consumed only 7% more CP than those fed 100%GNH. The observed trend in CP intakes could have most probably accounted for the significant reductions in the total numbers of nematodes in the GIT as a result of MOR and BAM substitutions of GNH, as well as the significant differences in the effects of the two substitution regimes. The nutritional level of an animal can influence its ability to maintain productivity and limit the establishment of a parasitic infection (Albers *et al*, 1987). Studies have shown that by increasing the protein content of the diet, disease-related changes associated with Haemochonsis in genetically-resistant and susceptible animals can be influenced (Abbott *et al*, 1985; Wallace *et al*, 1995; 1996; 1999). Increasing dietary protein results in the animal being much better able to tolerate these infections and improves the nitrogen retention (Coop and Holmes, 1996), with the main effect of increased nitrogen supply being to increase the rate of acquisition of immunity (Barry and McNabb, 1999). The quality of the CP of MOR could have been an additional factor. The CP of MOR has been reported by Becker (1995) to be of better quality for ruminants compared to the CP of most other leaves because of its high content of by-pass protein; about 47% as compared to 30 and 41 % for *Gliricidia sepium* and *Leucaena leucocephala* (two commonly used browse plants in ruminant nutrition) respectively. A plausible reason for the observed diet by gastrointestinal tract region interaction effects could have been the mixed nature of the gastrointestinal nematode infestations, suggesting that MOR and GNH could have had similar and/or synergistic effects on some worms within the abomasums and large intestines. The situation with the abomasum becomes more interesting as the most important parasites of ruminants are the trichostrongylids, nematodes from the abomasums and small intestine (Eysker, 2001). *Haemonchus contortus*, the nematode of particular concern worldwide, especially in tropical and subtropical climatic regions, is found in the abomasum (Hansen and Perry, 1994; Chafton, 2006). The practical significance of this finding lies in the fact MOR and GNH could play prominent roles in small ruminant nematode control programmes.

The observed trends in CP intakes as well as the superior quality of the protein in MOR could also have been accountable for the observed trends in weight gains, FCR, WCW and DP. The nutrient and mineral compositions of the test feed components/diet compositions have already been extensively discussed by Asaolu *et al*. (2010). The observed FCR values supported the earlier observed improvement of the overall nutrient utilization of GNH by MO substitution by WAD goats (Asaolu *et al*., 2010). The DP values fell within the reported (Dhanda *et al*., 1999; Getahun, 2001) range in goats, which vary between 38 and 56%, depending on breed and nutritional levels amongst other factors. The mean PCV of all the experimental animals fell within the range of 21 – 35 % reported (Dhollander *et al*., 2005; Ikhimoya and Imasuen, 2007) for WAD goats, suggesting an absence of disease conditions irrespective of the experimental diets.

5. Conclusion

There were no CTs of anthelmintic significance in both moringa and BAM foliages. However, complementing GNH, the traditional feed resource of choice in The Gambia, with MOR (50:50), could play a prominent role in small ruminant nematode control programmes. The feeding regime seems to be a viable option at improving the nutritional status of GIN-infested goats, with the resultant increased resilience to nematode infestation and improved productivity indices as well as important carcass components. This feeding strategy assisted them to withstand the negative effects of nematode infestations and obtain some relative positive effects on productivity.

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Table 1: Nutrient, mineral (gkg^{-1}DM) and condensed tannins (%) of experimental feed components/diet compositions fed to WAD goats naturally infested with gastrointestinal nematodes

Nutrients/CTs	Feed components/Experimental diets					
	MOR	GNH	BAM	50MOR:50GNH Diet 1*	100%GNH Diet 2	50BAM:50GNH Diet 3*
DM (g/kg)	250.00	870.00	450.00	560.00	870.00	660.00
g/kg DM						
CP	221.60	135.20	145.20	179.60	135.20	139.40
NDF	279.60	452.10	687.60	363.40	452.70	551.30
ADF	289.00	403.00	422.50	344.40	403.00	411.20
K	12.60	10.90	11.20	11.80	10.90	11.10
Na	2.80	1.10	3.40	1.90	1.10	2.00
Ca	19.70	12.60	7.00	16.30	12.60	10.30
P	1.30	3.50	1.40	2.40	3.50	2.60
CTs (%)	0.1	ND	0.0	ND	ND	ND

MOR= Moringa foliages, GNH = Groundnut hay, BAM= Bamboo foliages; DM=Dry matter; CP=Crude protein; NDF=Neutral detergent fibre; ADF=Acid detergent fibre; K=Potassium; Na=Sodium; Ca=Calcium; P=Phosphorus; CTs=Condensed tannins
**Nutrient compositions were computed for mixed experimental diets*

Table 2: Performance indices of WAD goats naturally-infested with gastrointestinal nematodes fed a sole diet of groundnut hay and its combinations with moringa and bamboo foliages.

Item	Experimental diets			SEM
	50MOR:50GNH (Diet 1)	100GNH (Diet 2)	50BAM:50GNH (Diet 3)	
Mean initial weight (Kg)	9.50	10.00	9.00	0.40
Mean final weight (Kg)	10.90^{a}	10.90^{a}	9.60^{b}	0.30
ADG (g/animal/day)	17.00^{a}	11.00^{b}	6.80^{c}	2.10
Mean DMI (g/animal/d)	320.00	300.00	310.00	7.50
Mean CPI* (g/animal/d)	57.47^{a}	40.56^{b}	43.21^{b}	2.65
FCR (g feed/g weight gain)	18.80^{c}	27.40^{b}	45.70^{a}	2.80
Mean PCV	26.00	27.00	21.00	2.60
Initial mean FEC (eggs/g/animal)	1190.00	1100.00	1060.00	28.50
Final mean FEC (eggs/g/animal)	334.00	384.00	370.00	25.00
% Drop in FEC	71.90	65.10	65.10	5.80

^{abc}Means in the same row with different superscripts are significantly ($P<0.05$) different.
MOR = Moringa foliage; BAM = Bamboo foliage; GNH = Groundnut hay; ADG = Average daily gain; DMI = Dry matter intake; CPI = Crude protein intake; FCR = Feed conversion ratio; PCV = Packed cell volume; FEC = Faecal egg count SEM = Standard error of the mean.
**Values were computed from nutrient contents in experimental diets and the respective DMI values*

Table 3a: Gastrointestinal region effects on worm burdens of sacrificed WAD goats naturally infested with gastrointestinal nematodes previously fed a sole diet of groundnut hay and its combinations with moringa and bamboo foliages

	GIT region			SEM
	Abomasum	Small Intestine	Large Intestine	
Worm burdens	115.67^{b}	0.00^{c}	293.33^{a}	17.88

^{abc}Means in the same row with different superscripts are significantly (P<0.05) different.
GIT = Gastrointestinal tract; SEM = Standard error of the mean.

Table 3b: Diet effects on worm burdens in the GITs of sacrificed WAD goats naturally infested with gastrointestinal nematodes previously fed a sole diet of groundnut hay and its combinations with moringa and bamboo foliages

Diet effects on TNN				SEM
	Diet			
	50MOR:50GNH	100%GNH	50BAM:50GNH	
Worm burdens	83.67^{c}	192.00^{a}	133.33^{b}	28.11

^{abc}Means in the same row with different superscripts are significantly (P<0.05) different.
MOR = Moringa foliage; BAM = Bamboo foliage; GNH = Groundnut hay; TNN = Total number of nematodes; GIT = Gastrointestinal tract; SEM = Standard error of the mean.

Table 3c: Diet*GIT region interaction effects on TNN in the GITs of sacrificed WAD goats naturally infested with gastrointestinal nematodes previously fed a sole diet of groundnut hay and its combinations with moringa and bamboo foliages

Region of GIT				SEM
	Diet			
	50MOR:50GNH	100%GNH	50BAM:50GNH	
Abomasum	234.00^{ax}	13.00^{bz}	100.00^{by}	4.19
Small intestine	0.00^{c}	0.00^{c}	0.00^{c}	0.00
Large intestine	17.00^{bz}	563.00^{ax}	300.00^{ay}	11.14
SEM	1.03	2.55	11.75	

^{xyz} Means in the same row with different superscripts are significantly (P<0.05) different
^{abc} Means in the same column with different superscripts are significantly (P<0.05) different
MOR = Moringa foliage; BA = Bamboo foliage; GNH = Groundnut hay; SEM = Standard error of the mean.
GIT = Gastrointestinal tract

Table 4: Carcass characteristics of WAD goats naturally infested with gastrointestinal nematodes previously fed a sole diet of groundnut hay and its combinations with moringa and bamboo foliages

Carcass trait	Diet			
	50MOR:50GNH	100%GNH	50BAM:50GNH	SEM
Slaughter Body Weight (kg)	10.90[a]	10.90[a]	9.60[b]	0.30
Warm Carcass Weight (kg)	5.20[a]	4.40[b]	3.50[b]	0.20
Liver weight (g)	210.60[a]	161.00[b]	124.90[b]	12.70
Heart weight (g)	57.50[a]	52.90[a]	42.50[a]	2.80
Kidney weight (g)	70.20[a]	45.60[b]	35.60[c]	3.90
Kidney fat weight (g)	31.60[a]	13.00[b]	5.40[c]	3.10
Blood volume (ml)	372.40[a]	322.00[a]	345.00[a]	11.10
Skin + Head + Feet (kg)	1.80[a]	1.60[a]	1.50[a]	0.10
Dressing Percentage (%)	47.30[a]	40.50[b]	36.70[c]	1.20

[abc]Means in the same row with different superscripts are significantly (P<0.05) different.
MOR = Moringa foliage; BA = Bamboo foliage; GNH = Groundnut hay; SEM = Standard error of the mean.