Sericea lespedeza hay as a natural deworming agent against gastrointestinal nematode infection in goats

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Abstract

Infection with gastrointestinal nematodes (GIN), particularly *Haemonchus contortus*, is the biggest constraint to profitable goat production in the United States (US). Due to widespread prevalence of anthelmintic resistance in goat GIN, alternative, non-chemical control methodologies are needed to increase profitability of small ruminant industries. A study was designed to test the efficacy of a high condensed tannin (CT) legume, sericea lespedeza [SL, *Lespedeza cuneata* (Dum.-Cours. G. Don)] against GIN of goats fed in confinement. The goats were given a trickle infection of 500 *H. contortus* larvae/animal three times per week during the trial to simulate natural infection. Twenty Boer bucks (6–8 months old) were fed bermudagrass [BG, *Cynodon dactylon* (L.) Pers.] hay plus concentrate for 5 weeks in confinement and then 10 animals were switched to SL hay for an additional 7 weeks. Throughout the trial, feces and blood were collected weekly from individual animals to determine fecal egg count (FEC) and blood packed cell volume (PCV). Fecal cultures were made weekly from pooled samples to determine treatment effects on GIN larval development. All goats were slaughtered at the end of the trial, with adult worms in the abomasum and small intestine of each goat recovered, counted, and identified to species. Feeding SL hay to goats significantly ($P < 0.01$) reduced FEC and increased PCV compared with BG hay. In addition, a lower percentage of ova in feces from SL-fed goats developed into infective (L3) larvae. There was a direct effect of SL hay on adult worms, with significantly ($P < 0.01$) lower numbers of both abomasal (*H. contortus*, *Teladorsagia circumcincta*) and small intestinal (*Trichostrongylus colubriformis*) nematodes compared with goats fed BG hay. Feeding SL hay to goats is an effective means of controlling parasitic nematodes and may be a potential supplement/replacement for chemical anthelmintics.
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1. Introduction

Goat production is rapidly increasing in the United States (US), principally due to high ethnic demand for goat meat, and to a lesser degree, goat milk (Maxey, 1993; Pinkerton et al., 1994). Goat farming has potential to produce good economic returns due to high reproductive rates, low cost of breeding stock and ability of goats to thrive on native pastures (Haenlein, 1992). The primary constraint to economic production of goats is losses due to infection by gastrointestinal nematodes (GIN), particularly the blood worm, *Haemonchus contortus* (Miller, 1996). Warm, humid climatic conditions, which occur during the summer months in the northern US, and during spring, summer, and fall in the southern states, are ideal for growth and development of the free-living (eggs, larvae) stages of this parasite on pasture. Haemonchosis can quickly overwhelm a herd under these conditions, leading to severe losses in production and death of infected animals (Miller, 1996).

The primary method of controlling GIN infection in the US is frequent treatment with anthelmintic drugs, but this strategy has led to greatly increased prevalence of anthelmintic resistance in goats (Mortensen et al., 2003), and resistance has been reported to drugs within all three major classes of anthelmintics (Terrill et al., 2001). Novel alternatives to chemical control of small ruminant GIN have been under investigation in recent years, including use of nematode-trapping fungi to destroy parasitic larvae (Larsen, 2000; Terrill et al., 2004), vaccines against *H. contortus* (Knox, 2000; Knox and Smith, 2001), and feeding of copper oxide wire particles to expel adult worms (Chartier et al., 2000; Burke et al., 2004). Another non-chemical GIN control method is grazing or feeding of plants containing condensed tannins (CT).

Condensed tannins are long-chain polyphenolic secondary compounds produced by plants that can bind with protein and other macromolecules in aqueous solutions (Haslem, 1989). Primarily because of their influence on protein metabolism in animals, there have been a number of reports on the potential beneficial (low dietary CT levels) and/or detrimental (high CT concentrations) nutritional effects of feeding or grazing CT-containing forages (Terrill et al., 1989; Aerts et al., 1999; Barry et al., 2001). Another reported benefit of dietary CT has been reduced parasitic nematode infection in livestock (Molan et al., 1999).

Anti-parasitic effects have been reported for a number of CT-containing forages, including sulla (*Hedysarum coronarium* L.; Niezen et al., 1995, 2002), birdsfoot trefoil (*Lotus corniculatus* L.; Min et al., 1999), big trefoil (*Lotus pedunculatus* Cav; Molan et al., 2000) and sainfoin (*Onobrychis viciafolia* Scop; Paolini et al., 2003), all of which are perennial cool season legumes that are poorly adapted to the climate of the southern US. Sericea lespedeza [SL, *Lespedeza cuneata* (Dum.-Cours. G. Don)], is a high-CT warm season perennial legume which is well adapted to infertile, acidic soils and the warm climatic conditions of the southern US (Hoveland et al., 1990). Min and Hart (2003) and Min et al. (2004) reported lower fecal egg count (FEC) in goats grazing sericea lespedeza compared with non-CT grass pasture in two trials completed in Oklahoma. In a confinement feeding trial, Shaik et al. (2004) reported reduced FEC in goats fed dried, ground SL hay compared with ground bermudagrass [BG, *Cynodon dactylon* (L.) Pers.] hay. Other authors have reported anthelmintic effects of dried forages fed to goats, including sainfoin (Paolini et al., 2003) and leaves of the *Acacia karoo* tree (Kahiya et al., 2003). The advantages of hay over fresh CT forage are increased flexibility in storage and transport, as well as timing/season of feeding. The objective of the current investigation was to determine the effects of feeding SL hay on the egg, larval, and adult stages of GIN in goats fed in confinement.

2. Materials and methods

2.1. Experimental design and protocol

A confinement feeding trial was conducted using 20 weaned intact Boer male goats (6–8 months old; 23 ± 2.83 kg) at the Fort Valley State University (FVSU) Agricultural Research Station, Fort Valley, GA. Goats were housed in four pens (five animals/pen) on concrete in a covered barn with open sides. Area of each pen was 9.3 m^2, with similar temperature and sunlight conditions. Prior to confinement, the animals were grazed for 4 weeks on perennial warm-season grass (predominantly BG) pasture to allow develop-

ment of a low-level GIN infection. In addition, starting 2 weeks before moving to the pens, and then for 8 weeks during the trial, the GIN infection level of individual animals was boosted with 500 *H. contortus* larvae three times a week to simulate natural infection. The trickle infection was stopped 3 weeks before the end of the trial to allow the infection to mature prior to slaughter.

2.2. Experimental diets

The hays used in this study were first cutting BG and SL in square bales. The BG hay, which was grown in Central Georgia, was bought at a feed mill near the University, whereas the SL hay was provided by a producer near Auburn, Alabama. The SL was cut at approximately 61 cm height from a nearly pure stand (<5% weeds).

After being moved to the pens, the goats' body weights were recorded, and they were given access to BG hay at 75% of daily intake, a 16% crude protein feed supplement (ground corn, soybean meal, poultry fat, trace mineral salt and vitamin premix; Table 1) at 25% of daily intake, and ad libitum water. After a 2-week adjustment period, the goats were stratified by FEC and randomly assigned to two treatment groups ($n = 10$) in four pens (five goats per pen, two treatment and two control pens). All goats were continued on the BG (control) ration for 3 additional weeks to allow infection levels to increase. After 5 weeks in the pens, the control animals were continued on the BG hay diet, whereas the treatment group was switched to the SL hay diet for a 6-week experimental period. Based on the composition of BG (13.3% CP) and SL (12.6% CP), separate supplements were formulated to balance for CP. Hay for both treatments was fed at 3.5% BW

Table 1
Constituents of 16% crude protein supplemental feed offered to parasitized goats at 20% of daily intake

Feed constituent	%
Corn	63.58
Soybean meal	28.45
Poultry fat	3.98
Trace mineral salt[a]	1.99
Vitamin premix[b]	1.99

[a] Contains 95–98% NaCl and at least 0.05% Mg, 0.032% Cu, 0.005% Zn, 0.24% Fe, 0.011% Co, 0.007% I and 0.24% Mn.
[b] Contains at least 2200 IU vitamin A, 1200 IU vitamin D_3 and 2.2 IU vitamin E per gram.

throughout the trial, allowing approximately 25% feed refusals. Both diets consisted of approximately 75% hay and 25% supplement (729 g BG and 250 g supplement/animal; 700 g SL and 280 g supplement/animal daily).

2.3. Analysis of hay samples

Samples of SL and BG hay were ground in a Wiley Mill to pass a 1 mm screen and then analyzed for N and CT content. Nitrogen analysis was completed using a Truspec C/N analyzer (Leco Corporation, St. Joseph, MI), while extractable, protein-bound, and fiber-bound CT content was determined by the Terrill et al. (1992) butanol–HCl method using purified quebracho CT as the standard (Kahiya et al., 2003).

2.4. Sampling procedures and analysis

Throughout the 11-week confinement trial (5-week pre-trial, 6-week trial periods), fecal and blood samples were collected weekly from individual animals for FEC and packed cell volume (PCV) analysis, respectively. Feces were collected rectally, with ova counted using a modified McMaster procedure (Hansen and Perry, 1994). Data were expressed as eggs per gram (EPG) of feces. Blood samples were taken by jugular venipuncture into EDTA-vacutainer tubes, with PCV determined using a micro-haematocrit centrifuge and reader. Fecal cultures were prepared weekly on 10 replicates of pooled samples from control and treatment goats as described by Terrill et al. (2004) to allow counting and identification of nematode larvae to species. Percentage GIN larval development was calculated by the following formula:

$$\text{percentage larval development} = \frac{\text{number of larvae/g feces}}{\text{eggs/g feces}} \times 100.$$

2.5. Recovery and counting of adult nematodes

At the end of the trial, the goats were slaughtered at the USDA-approved abattoir at the FVSU Agricultural Research Station, and adult worms recovered from the abomasum and small intestine (Hansen and Perry, 1994). Body weights were recorded pre-slaughter, and

fecal and blood samples taken from individual animals for FEC and PCV determination, respectively. After slaughter, the abomasum and small intestine of each goat were ligated, opened, and the contents washed into plastic buckets. For each sample type, the contents were brought up to 3 L with tap water, thoroughly mixed, and then two 5% aliquots (150 mL) taken into 250-mL storage containers. Approximately 100 mL of formalin (5%) was added to each aliquot as a preservative. For both abomasal and small intestinal samples, the worms in one aliquot were washed on a mesh screen (no. 270) with tap water, the formalin discarded, and the nematodes recovered into a 50 mL centrifuge tube. All the nematodes in the tube were then counted and identified to species and sex using a phase contrast microscope.

2.6. Statistical analysis

The egg count and PCV data were analyzed as a randomized block design using repeated measured analysis with pen, treatment, and time in the model and pre-trial and trial periods analyzed separately (SAS, 1992). Percentage larval recovery and % *H. contortus* data from pooled fecal cultures were analyzed using repeated measures analysis with treatment and time in the model and pre-trial and trial periods analyzed separately. Adult worm data were analyzed using the General Linear Models procedure in SAS (1992) with treatment and pen as independent variables.

3. Results

3.1. CT levels in SL hay

The extractable, protein-bound, and fiber-bound CT concentrations in the SL hay were 3.6, 13.4, and 5.4%, respectively, with a total CT concentration (extractable + protein-bound + fiber-bound) of 22.4%. All CT analyses are expressed on a % DM basis.

3.2. Fecal egg counts

Egg counts were similar between the two groups during the pre-trial, with EPGs increasing from approximately 250 to 2500 in all animals during this
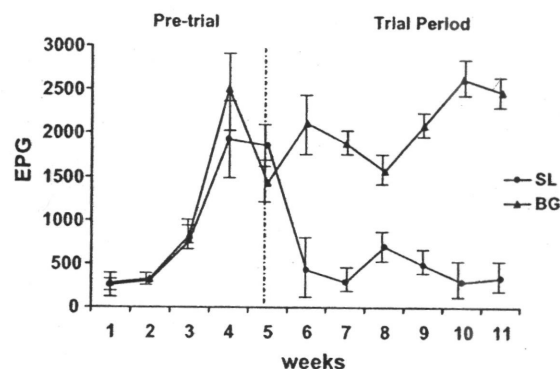

Fig. 1. The effect of feeding sericea lespedeza (SL) or bermudagrass (BG) hay on eggs per gram (EPG ± S.E.M.) of feces from parasitized goats.

period (Fig. 1). During the 6-week trial period, treatment, time, and treatment × time effects were all significant ($P < 0.01$). Egg counts dropped by 79.7% 1 week after sericea feeding was started, and the reduction increased to approximately 88% over the last 2 weeks of the trial period (Fig. 1).

3.3. Blood packed cell volume

Treatment and time main effects were significant ($P < 0.01$) for PCV data. During the pre-trial, PCV was higher ($P < 0.01$) in BG animals (27.2) than in SL goats (24.3), while PCV was higher ($P < 0.01$) in the SL group than in the BG animals during the trial period (23.1 versus 19.7, respectively) (Fig. 2). The significant time effect was due to variation in PCV
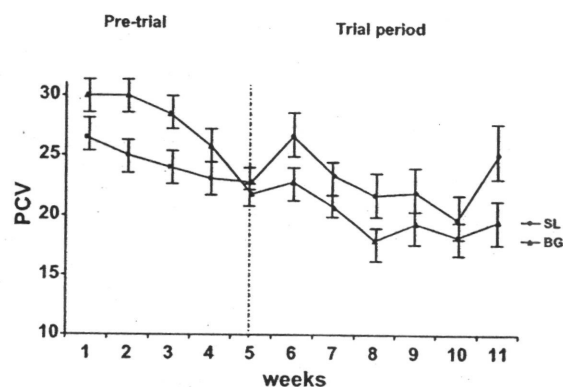

Fig. 2. The effect of feeding sericea lespedeza (SL) or bermudagrass (BG) hay on blood packed cell volume (PCV ± S.E.M.) of parasitized goats.

data from both SL and BG groups throughout the trial period. The BG group PCV dropped from 30% to below 20% from weeks 1 to 11 of the confinement period, while there was a much smaller drop in PCV for the SL goats during this period.

3.4. Percentage larvae recovered from fecal cultures

Percentage larvae recovered from fecal cultures was similar between SL and BG groups during the pre-trial period (73.1 and 71.3%, respectively), whereas treatment, time, and treatment × time effects were significant ($P < 0.01$) for larval recovery data during the trial period. The larvae recovered from fecal cultures from SL-fed goats decreased from 61.2 to 57.7% during the trial period, whereas the BG group increased from 64.3 to 70.3% during this period (Fig. 3).

3.5. Percentage H. contortus recovered from fecal cultures

Throughout the pre-trial period, treatment and control groups had similar levels of H. contortus in fecal cultures (95.9 and 95.7%, respectively). During the trial period, treatment, time, and treatment × time effects were all significant ($P < 0.01$) for % H. contortus larvae recovered in cultures. In the fecal cultures from BG-fed goats, the % H. contortus consistently remained 96–97% throughout the trial period, whereas in SL-fed goats, % H. contortus dropped to 89.5% after a week, 86% after 3 weeks, and 84.7% by the end of the trial period (Fig. 4).
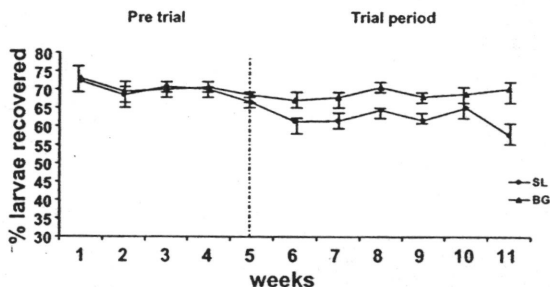

Fig. 3. The effect of feeding sericea lespedeza (SL) or bermudagrass (BG) hay on % nematode larvae recovered from feces of parasitized goats (±S.E.M.).
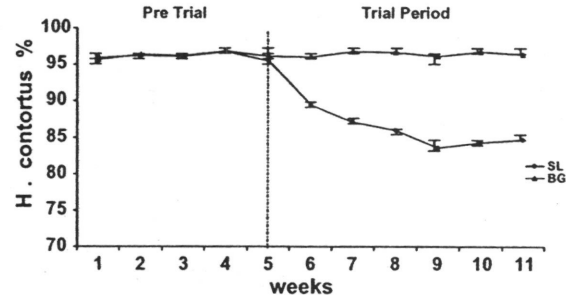

Fig. 4. The effect of feeding sericea lespedeza (SL) or bermudagrass (BG) hay on % H. contortus (±S.E.M.) in nematode larvae recovered from feces of parasitized goats.

3.6. Adult nematodes

The number of adult nematodes in both the abomasum and the small intestines was lower ($P < 0.001$) in goats fed SL compared with BG hay (Table 2). The only abomasal worms present were H. contortus and Teladorsagia circumcincta, and the small intestinal worms identified were all Trichostrongylus colubriformis. The SL diet reduced the total count ($P < 0.001$) and number of males ($P < 0.05$) and females ($P < 0.01$) of all three of these species in the goats, compared with animals fed the BG diet. Also, for all three species, there was a greater reduction in the number of female worms compared with males. The percentage reductions in number of male and female H. contortus, T. circumcincta, and T.

Table 2

Total male and female nematodes in abomasum and small intestine of parasitized goats fed sericea lespedeza (SL) or bermudagrass (BG) hay and a small amount of concentrates

Adult nematodes	Diet			
	BG	SL	S.E.M.	P
Abomasum (total)	3450 a	1359 b	70	<0.001
H. contortus	2728 a	834 b	68	<0.001
Male	1269 a	491 b	25	<0.001
Female	1459 a	343 b	49	<0.001
O. circumcincta	712 a	525 b	22	<0.001
Male	318 a	273 b	12	<0.05
Female	394 a	252 b	20	<0.01
Small intestine (total)	949 a	571 b	39	<0.001
T. colubriformis	949 a	571 b	39	<0.001
Male	417 a	305 b	25	<0.01
Female	532 a	266 b	22	<0.001

Row means with unlike letters differ significantly.

colubriformis were 61.3, 76.5, 14.2, 36.0, 26.9, and 50.0, respectively (Table 2).

4. Discussion

Feeding of SL hay appears to be an effective means of controlling *H. contortus* infection in goats. These results confirm reports on anthelmintic effects of grazed SL pastures in goats. Min et al. (2004) reported 71.7% reduction in FEC in goats grazing SL pastures compared with annual grass pasture. These authors suggested that the primary effect of SL in the diet is reduction in fecundity, or egg-laying of adult worms rather than direct killing of the worms. The results of the current study show that SL hay had a direct effect on adult worms (particulary females) in addition to any effects upon fecundity, based upon lower numbers of both abomasal and small intestinal nematodes in the goats on the SL hay diet. The relative contribution of reduced fecundity or direct effects on the worms could not be determined in this study because the animals were fed the treatment diets up to the point of worm recovery. In another study with this forage, Lange et al. (2005) reported reduced FEC and worm counts in sheep fed SL hay compared with BG hay, and they attributed the results to both direct effects on the nematodes and a reduction in fecundity.

The anthelmintic efficacy of SL hay was highest against *H. contortus*, but also significantly reduced numbers of *T. circumcincta* and *T. colubriformis*, with a greater effect on female than male nematodes of each species. There have been several reports of reduced worm counts in small ruminants fed fresh CT forages (Niezen et al., 2002) or purified CT (Athanasiadou et al., 2000, 2001), but the reported reductions were for either abomasal or small intestinal nematodes, but not both. A specific effect on female nematodes has not been reported previously.

Other authors have reported anthelmintic effects of dried CT forages fed to goats, including reduced FEC in animals given sainfoin hay (Paolini et al., 2003), and reduced FEC and worm counts in goats provided dried *A. karoo* foliage (Kahiya et al., 2003). The nematocidal effects of SL hay were greater than the effects reported in these studies, which may be related to the different types of CT in these plant species. All of these plants contain relatively high levels of CT (Terrill et al., 1989; Kahiya et al., 2003), but the reactivity of the CT may differ. This is supported by reports on nutritional effects of different CT types. For example, variable effects of CT on plant protein degradation have been observed in sheep fed forage from two different *Lotus* species. At similar CT concentrations (0.25–1.75 mg of CT/mg of total soluble plant protein), *L. pedunculatus* CT was more effective at protecting plant protein from degradation by rumen microorganisms than *L. corniculatus* CT (Aerts et al., 1999). The CT in *L. pedunculatus* is higher in MW and has a higher ratio of prodelphinidin to procyanidin subunits than *L. corniculatus* CT (Foo et al., 1996, 1997). This ratio is higher in the CT from SL than from most other legumes (Burns, 1966). It appears that as with protein degradation, the chemical structure of CT, as well as its concentration, needs to be considered in studies involving GIN control.

The reactivity of the CT of SL may also explain why this forage maintains its anthelmintic properties when fed as hay. Drying a CT forage reduces the proportion of tannin that is extractable using an aqueous solvent and increases the proportion that is bound to protein (Terrill et al., 1992). The unbound, or 'free' CT is more capable of forming complexes with protein and other macromolecules than the CT that is in bound forms (Barry and Manley, 1986). This unbound CT is likely the active agent giving SL its anthelmintic properties, and although the extractable CT level is lower in SL hay than in grazed forage, the anthelmintic effects observed with goats fed the hay in confinement were comparable with reports from grazing studies (Min and Hart, 2003; Min et al., 2004). This suggests that the particular type (molecular structure) of CT in the plant is more critical for controlling GIN than the total concentration of bound and unbound forms in the diet.

Effects of drying on CT forms in forage are important from a nutritional standpoint in animals, and this needs to be considered with SL. This plant has been declared a noxious weed in parts of the Midwest because it is not considered palatable to grazing beef cattle. Too high a level of CT in the diet can reduce intake and digestibility of the forage (Terrill et al., 1989; Barry and Manley, 1986). Terrill et al. (1989) reported lower intake and digestibility of fresh-frozen high-tannin SL compared with a low-

tannin type fed to sheep. These differences were lost when then fresh forages were sun-dried and fed as hay. Reduced intake of SL does not appear to be a problem with grazing goats (Min and Hart, 2003). Also, despite differences in willingness of different animal species to graze SL, sheep, goats, cattle, and horses all readily consume SL hay (C.S. Hoveland, personal communications). Effectiveness of SL for controlling GIN infection in large grazing animals (horses, beef and dairy cattle, camelids, exotic species) needs further investigation.

Sericea lespedeza has been grown as a forage crop for hay and grazing in the southeastern US since the 1940s, and its agronomic advantages, including very good growth on infertile, acidic soils, tolerance to drought, and resistance to insect damage, are well-documented (Hoveland et al., 1990). Additional research is needed on production and use of this forage for control of parasitic nematodes in livestock under field conditions, both as a grazed forage and as hay fed as a supplement to grazing animals.

5. Conclusion

Feeding SL hay to goats can effectively reduce nematode parasite infection levels through direct anthelmintic effects on the adult worms in the gastrointestinal tract and by reducing parasite egg viability and/or larval development in feces. As SL is a crop that is well-adapted to the southern US, growing this plant for hay or grazing as a natural deworming agent may be a cost-effective, environmentally friendly alternative/addition to the exclusive use of chemical anthelmintics by small ruminant producers in this region.

Acknowledgements

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