Effect of Ground and Pelleted Sericea Lespedeza Whole Plant and Leaf Only on Gastrointestinal Nematode and Coccidial Infection in Goats

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Abstract: Two 42-day feeding trials in pens were completed with young goats (Spanish, intact male, six months old, $n = 29$ Trial 1; $n = 20$ Trial 2) to determine the anti-parasitic bioactivity of whole plant and leaf only sericea lespedeza (SL; *Lespedeza cuneata*) fed as a ground meal or in pelleted form. In Trial 1, goats were fed SL leaf only pellets, SL whole plant pellets, or a commercial goat pellet as 50% of a complete ration, while in Trial 2, kids were fed either ground SL leaf meal or ground whole plant SL meal as 25% of a complete ration. Fecal samples were collected weekly for determination of gastrointestinal nematode (GIN) fecal egg counts (FEC) and coccidia fecal oocyst counts (FOC). In Trial 1, both of the pelleted SL rations reduced FEC ($p < 0.06$) relative to the kids fed the control ration, and for FOC, there were lower values on Days 7 to 42 relative to Day 0 for goats on either pelleted SL diet, while FOC for control animals did not change over time (interaction, $p < 0.01$). In Trial 2, both ground whole plant and leaf only SL diets reduced ($p < 0.05$) FEC of the goats over time, but the effect was faster in the kids on the SL leaf meal ration. At 50% of the diet, SL leaf and whole plant meal pellets were equally effective against GIN egg and coccidial oocyst production in young kids, but SL leaf meal was more effective in reducing GIN egg production than whole plant SL meal when fed at 25% of the diet.

Key words: Coccidia, gastrointestinal nematodes, goats, pellets, sericea lespedeza.

1. Introduction

Infection with gastrointestinal nematodes (GIN), coccidia (*Eimeria* spp.), and other internal parasites are a major factor causing a decrease in the productivity of livestock worldwide, especially in grazing small ruminants, such as goats and sheep [1, 2]. Poor growth rate, reduced reproductive capacity and increased mortality of heavily infected animals increases costs and reduces sustainability of small ruminant production systems world-wide [3, 4]. In tropical and subtropical regions, as well as much of the United States during the warmer months, there is a high prevalence of infective pastures due to a favorable environment for the free-living life stages (eggs and larvae) of parasites to survive and grow [5]. *Haemonchus contortus*, the infamous "barberpole worm", a dangerous blood-feeder, is the most prevalent and pathogenic GIN in sheep and goats, causing severe anemia and even death in untreated animals [3]. Use of broad-spectrum anthelminitcs has been the primary defense against GIN infections in livestock over the past 60 years, but the overuse and misuse of these drugs has led to a greatly increased prevalence of anthelmintic resistance among the major nematode species [6, 7]. In addition, poor availability and affordability of synthetic anthelmintics for resource-poor farmers have exacerbated the challenge of parasite management in many parts of the world [8].

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In addition to GIN, infection with *Eimeria* spp. (coccidia) can have devastating consequences for young animals (kids and lambs), particularly during times of stress, such as at weaning [9]. Resistance to commercial coccidiostats is also a growing problem, particularly in the poultry industry [10, 11].

The rapidly increasing prevalence of drug resistance in livestock parasites is now reaching epidemic proportions [12] and has greatly increased pressure to develop and validate novel methods of parasite management that are less reliant on chemotherapeutics. Examples of these include feeding copper oxide wire particles, use of nematode trapping fungi, and grazing or feeding of anti-parasitic plants [13].

Condensed tannins (CT) in some plant species have been recognized as having anthelmintic properties, but until fairly recently, little research had been done to validate these plants (vegetative legumes, shrub species, legume trees) as livestock feed. There have been a number of reports documenting reduction in GIN infection in sheep and goats fed CT-containing forages, including sulla (*Hedysarum coronarium* L.) [14, 15], birdsfoot trefoil (*Lotus corniculatus* L.) [15], big trefoil (*L. pedunculatus* Cav.) [16], and sainfoin (*Onobrychis viciifolia* Scop.) [17]. As each of these is cool-season vegetative legumes, they are generally poorly adapted to warmer regions of the Southeastern United States. Research on anti-parasitic plants in this region has focused mainly on sericea lespedeza (SL; *Lespedeza cuneata* (Dum.-Cours. G. Don)), a high CT, low-input, warm-season perennial legume well adapted to acidic, infertile soils in the South [18].

In addition to its use as pasture, hay, and a conservation plant in the Southeast [19], there is recent documentation of bioactive properties of SL. Examples of SL bioactivity include reduction of ruminal methane in livestock [20, 21], increased rumen protein bypass [22], and suppression of house flies, *Musca domestica*, in feces [23]. Of particular interest is SL control of *Eimeria* spp. [24, 25] and *H. contortus* as well as other GIN in both sheep and goats

[26-28]. The parasitic inhibition bioactivity of SL has been attributed to the unique type of CT in this forage (up to 98% prodelphinidin-type tannins) [25, 29]. These anthelmintic properties have been documented in both fresh (grazed) [29, 30] and dried (hay, leaf meal, pellets) [13, 28] forms of SL. The dried forms of SL have been included in feeding trials with both sheep and goats using unground (long) and ground SL hay [13, 26], leaf meal [31, 32], and whole plant and leaf only pellets fed as the primary diet [25, 28] or leaf only pellets fed as a supplement on grass pasture [33].

One area of SL bioactivity with little documented research is possible differences in nutritional and anti-parasitic properties of SL leaves only compared to whole plant SL. Older SL literature showed that CT levels are much higher in leaves than stems [34], and recent work has shown that the CT in SL leaves and stems also differs in their molecular structure, with leaf CT being much larger in size than stem CT (polymers of larger mean degrees of polymerization; 42 vs. 18, respectively) and slightly higher concentration of prodelphinidin tannins (98% vs. 94%, respectively) [29]. With higher levels of crude protein (CP) as well as CT in SL leaves [34], the ratio of SL leaf to stem material in feed rations may influence the nutritional value and bioactivity of this forage. The specific objective of the current investigation was to evaluate possible differences in anti-parasitic bioactivity of dried SL whole plant (SLWP) (leaves + stems) compared to leaves only, both in ground (meal) and pelleted forms when fed to young goats.

2. Materials and Methods

All procedures completed in this investigation were approved by the Institutional Animal Care and Use Committee (IACUC) at Fort Valley State University (FVSU). The study consisted of two confinement feeding trials conducted at the FVSU Agricultural Research Station in Fort Valley, GA. At the end of both trials, goats were harvested through the FVSU abattoir under federal inspection, with adult worms

recovered from the abomasum from each animal for counting and identification to species as described by Shaik *et al.* [26].

2.1 Trial 1

Twenty-seven naturally parasite infected 6-month-old intact male Spanish kids (34.1 ± 7.0 kg) were fed in individual pens with packed dirt floors and mulch bedding. Diets consisted of SL pellets made from ground whole plant (SLWP) or leaf meal (SLM), or a commercial pellet (control; CON) at 50% of a complete ration (Table 1), with the remaining 50% made up of ground corn (83.3%), soybean meal (12.7%), trace mineralized salt (2.0%), and vitamin premix (2.0%). The rations were fed for 42 d at 3.5% of body weight with daily adjustments to allow for approximately 10% orts. Animals were provided *ad libitum* access to fresh water daily in buckets. Body weights were collected at the start and end of the trial, and blood and fecal samples were collected from individual animals every 7 d throughout the study, beginning on Day 0 (first day of treatment).

2.2 Trial 2

For the second trial, 20 naturally GIN-infected six months old intact male goats were fed ground SL hay (whole plant or leaf only) as 25% of a complete ration in pens with 5 goats/pen and 2 pens/treatment for 42 d. The treatment rations were balanced for protein and energy using ground corn, soybean meal and dry molasses. Animals were provided with *ad libitum* access to the assigned feed ration and water. Goat GIN infection was boosted by giving each animal 500 *H. contortus* larvae three times per week throughout the trial. Fecal and blood samples were collected from individual animals every 7 d beginning at Day 0 (first day of treatment).

2.3 Analyses

2.3.1 Blood Samples

For each trial, blood samples were collected from individual animals by jugular venipuncture into 3 mL purple top BD Vacutainer® tubes containing K_2EDTA, placed on ice for transfer to the laboratory, and placed on a tube rocker until processed. For each sample, micro-hematocrit capillary tubes were filled with whole blood, sealed, and then centrifuged for 10 min at $10,000 \times g$ in a hematocrit centrifuge (IEC Model Mb, Needham Heights, MA). After centrifugation, the tubes were removed and percentage packed cell volume (PCV) values read using a hematocrit reader.

2.3.2 Fecal Samples

Using a gloved finger technique, fecal samples were collected directly from rectum of all animals during each trial for determination of fecal egg count (FEC), and for Trial 1, fecal oocyst count (FOC), using the modified McMaster technique [35]. Results were expressed as eggs per gram (epg) or oocysts per gram (opg) of feces.

2.3.3 Recovery and Counting of Adult Nematodes

During harvest of the animals at the FVSU abattoir, as described by Shaik *et al.* [26], the abomasum of each animal was ligated and removed, with the contents washed into plastic buckets and brought up to

Table 1 Chemical composition of sericea lespedeza (SL) ground meal and pellets (all values expressed on dry matter basis).

Forage type	Constituent		
	CP %	NDF %	ADF %
SLWP	12.7	41.9	40.0
SLM	17.6	36.6	25.3
SLWP pellet	14.6	41.9	42.7
SLM pellet	14.7	49.3	37.1
Commercial pellet	16.0	NA	NA

SLWP = sericea lespedeza whole plant; SLM = sericea lespedeza leaf meal; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; NA = data not available.

3 L with tap water. Aliquots (5%, 150 mL) were collected and placed into 250 mL storage containers, with 100 mL of formalin (10%) added to each aliquot as a preservative. The adult nematodes in the samples were processed and then counted and identified to species and sex using a stereoscope microscope (Leica Zoom 2000, Leica Microsystems Inc., Chicago, IL) with total adult nematodes in the abomasum calculated as number of worms counted in each 5% aliquot $\times$ 20.

2.4 Statistical Analyses

FEC, FOC and blood PCV data were analyzed using a linear mixed model for repeated measures in a completely randomized design using SAS 9.4, TS1M3 MIXED [36]. Adult GIN were analyzed as a completely randomized design using the general linear model (GLM) procedure of SAS [36]. The FEC, FOC, and PCV data were log-transformed prior to statistical analysis (log(FEC + 25), log(FOC + 25); log(PCV + 1)) and reported as least squares means, with statistical inferences based upon log-transformed data analysis. For significance levels, *p*-values of < 0.05 were considered significant and a tendency was noted at $p < 0.10$.

3. Results

3.1 Trial 1—SL Leaf and Whole Plant Pellets at 50% of the Diet

3.1.1 FEC

FECs were impacted by treatment ($p < 0.01$) in which SLM and SLWP fed goats had lower ($p < 0.01$ for SLM, $p = 0.0564$ for SLWP pellets) FEC than those goats fed the CON diet (Fig. 1). The FECs were also impacted by day ($p < 0.001$) and were highly variable, with Day 0 differing from Days 7, 28 and 35 ($p < 0.02$), Day 7 also differing from Days 14 and 21 ($p < 0.02$), and Days 14 and 21 also differing from Days 28, 35 and 42 ($p < 0.04$). Average FECs were 2,131 $\pm$ 319, 1,087 $\pm$ 319, 2,379 $\pm$ 323, 2,018 $\pm$ 323, 1,224 $\pm$ 336,

1,440 $\pm$ 329 and 2,094 $\pm$ 319 epg for Days 0, 7, 14, 21, 28, 35 and 42, respectively.

3.1.2 FOC

There was a treatment $\times$ day interaction ($p < 0.02$) for FOC (Fig. 2). Compared to Day 0, FOCs were lower at all other time points measured for goats fed SLM pellets or SLWP pellets ($p < 0.01$), but were not different over time for CON fed kids. When treatments were compared within days, there were no differences on Day 0, but FOCs of the kids were lower ($p < 0.03$) relative to control for the SLWP fed goats and tended to be lower ($p < 0.07$) in the animals on the SLM diet on Day 7. The FOC values were lower ($p < 0.05$) in goats fed the SLM compared to the CON diet on Days 14, 21, 28, 35 and 42, while the SLWP fed goats were more variable, with lower FOC than CON on Days 14 ($p < 0.009$) and 35 ($p < 0.001$) only.

3.1.3 PCV

Percentage PCV was not impacted by treatment, but was influenced by day ($p < 0.001$), with Day 21 values being higher ($p < 0.01$) than those on Days 7, 14 and 42, and Day 28 values being higher ($p < 0.01$) than those from Days 14 and 42. Values averaged 21.4%, 20.6%, 20.2%, 23.5%, 23.0% and 19.7% (SEM = 1.0%) for Days 0, 7, 14, 21, 28 and 42, respectively. Data were not available for Day 35.

3.1.4 Adult Worm Number and Body Weights

There were no treatment differences for number of adult abomasal GIN, which consisted of predominantly *H. contortus* (87.3%), with the remainder identified as *Trichostrongylus axei* (Table 2). Body weights on Days 0 and 42 as well as average daily gain were not impacted by treatment, averaging 34.2 $\pm$ 1.3 kg, 34.5 $\pm$ 1.2 kg and 7.6 $\pm$ 14.2 g/d, respectively.

3.2 Trial 2—SL Leaf and Whole Plant Ground Meal as 25% of the Diet

3.2.1 FEC

There was a treatment $\times$ time interaction ($p < 0.007$) in FEC goats fed SLM or SLWP meal for 42 d (Fig. 3).
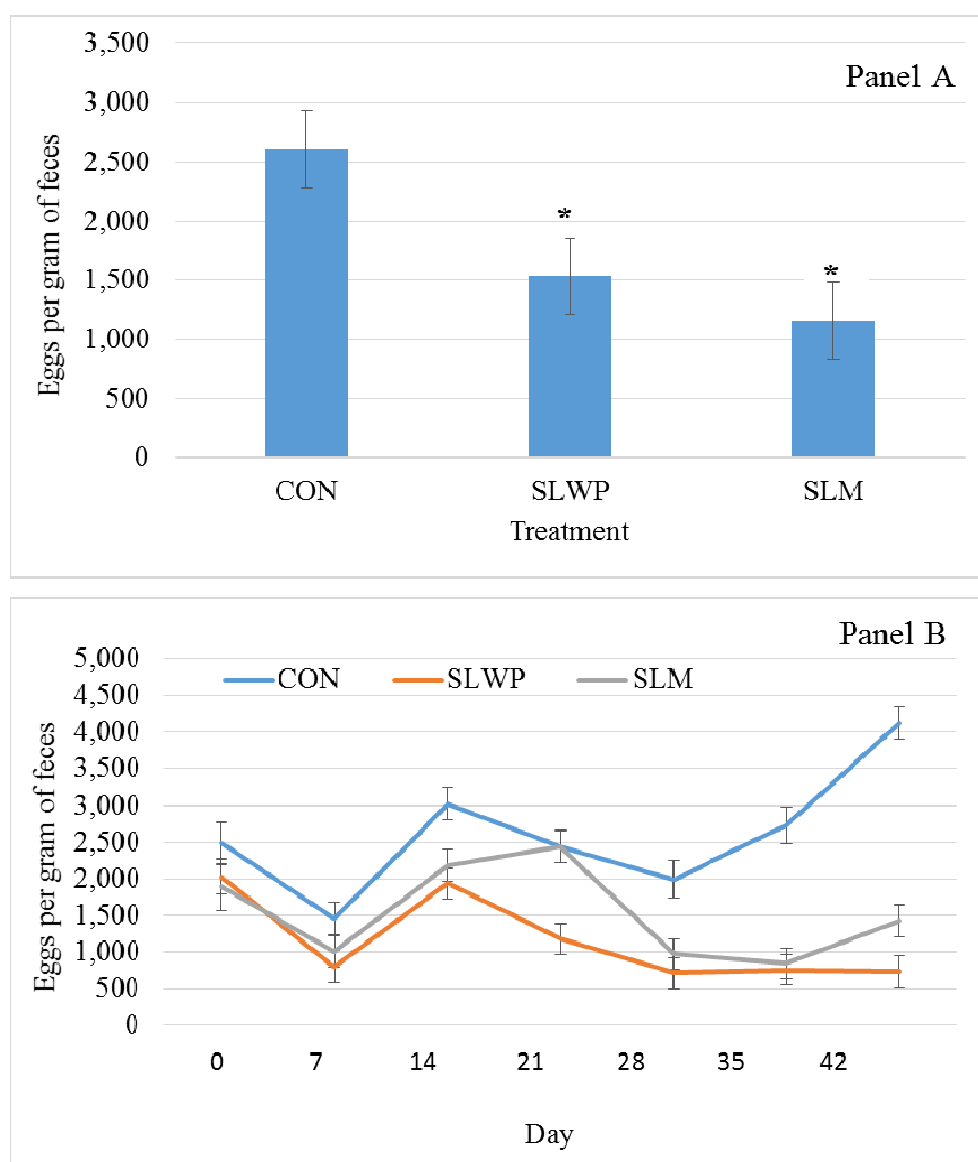
Fig. 1 Fecal egg count (FEC) (eggs per gram of feces) for goats fed sericea lespedeza leaf meal (SLM) or whole plant (SLWP) pellets compared to a commercial control (CON) pellet at 50% of a complete ration for 42 d.
Effect of treatment, $p < 0.01$, Panel A; columns with a * differ from CON, $p < 0.01$ for SLM and $p = 0.0564$ (tendency) for SLWP. Panel B for visual appraisal only.

Compared to Day 0, leaf meal feeding was effective faster, reducing FEC ($p < 0.01$) at Days 7, 21 (tendency, $p < 0.08$), 28, 35 and 42, while whole plant meal fed goat FEC was only reduced ($p < 0.05$) at Days 35 and 42. There were no differences in FEC of goats fed either SL ration on Days 0, 7, 14, 21 and 42, but the SLM treatment animals had lower ($p < 0.05$) FEC than whole plant SL meal fed goats on Days 28 and 35 (Fig. 3).

3.2.2 PCV

There was an effect of day ($p < 0.001$) on percentage PCV, with each time point varying from Day 0, $p < 0.05$ except Day 21 ($p = 0.0512$) (Fig. 4). There was no effect of treatment on PCV values.

3.2.3 Adult Worm Number

There was no treatment effect on adult worm numbers (Table 1), with *H. contortus* only making up 39% ± 8% of the total.

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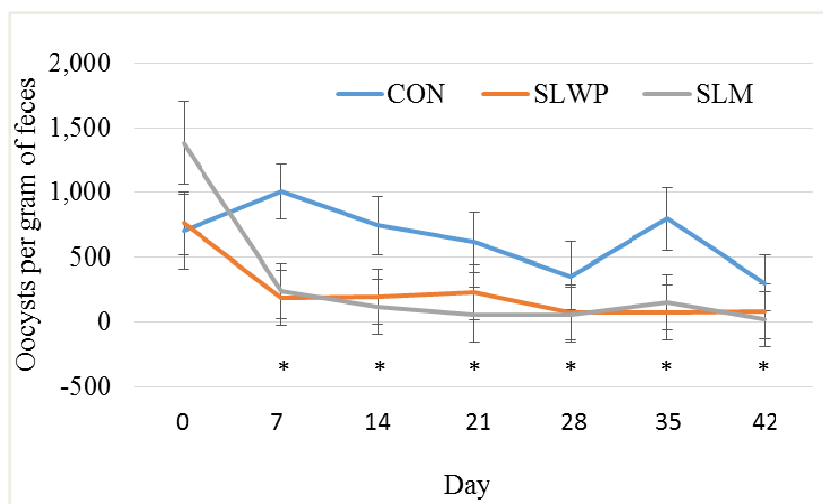

Fig. 2   Fecal oocyst count (FOC) (oocysts per gram of feces) for goats fed SLM, SLWP or a CON pellet at 50% of the diet for 42 d.

Compared to Day 0, points with * differ $p < 0.01$. Treatment by day interaction, $p < 0.02$.

Table 2   *Haemonchus contortus*, *Trichostrongylus axei* or *Teladorsagia circumcincta* along with total abomasal gastrointestinal nematode (GIN) counts for goats fed 50% SLM or SLWP pellets compared to a commercial feed pellet (control) (Trial 1) or SLM or SLWP (Trial 2) for 42 d.

Trial 1	*H. contortus* Female	*H. contortus* Male	*T. axei* Female	*T. axei* Male	Total
Control	700 ± 243	344 ± 150	88 ± 45	63 ± 29	$1,194 \pm 400$
SLM	483 ± 280	442 ± 173	33 ± 52	33 ± 33	992 ± 461
SLWP	736 ± 259	179 ± 160	143 ± 48	86 ± 31	$1,443 \pm 427$
Trial 2	*H. circumcincta* Female	*H. circumcincta* Male	*T. circumcincta* Female	*T. circumcincta* Male	Total
SLM	114 ± 40	138 ± 43	258 ± 137	186 ± 105	696 ± 274
SLWP	133 ± 51	162 ± 53	213 ± 100	198 ± 121	706 ± 292

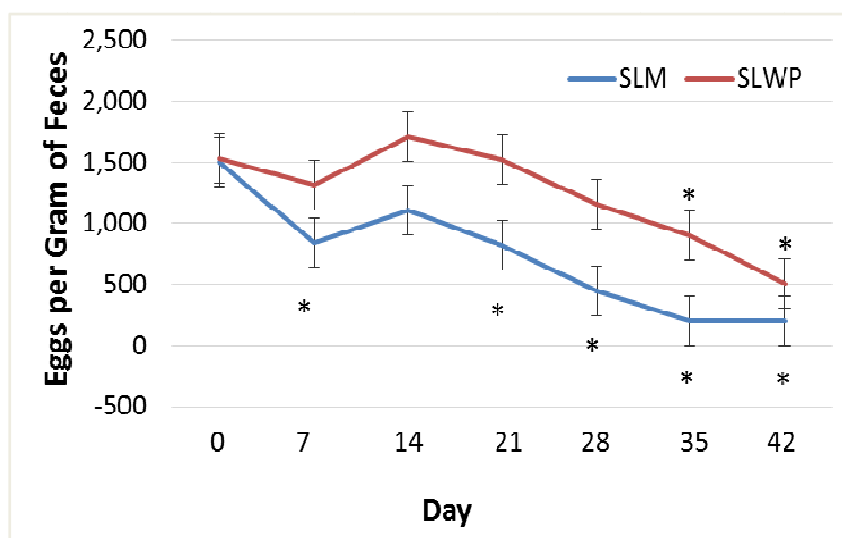No statistical differences were found among treatments.

Fig. 3   FEC (eggs per gram of feces) for goats fed SLM or SLWP pellets for 42 d were impacted by a treatment by day interaction ($p < 0.007$).

Points with * differ from Day 0, $p < 0.01$ for SLM except for Day 21 (tendency, $p < 0.08$) and $p < 0.05$ for SLWP.

Effect of Ground and Pelleted Sericea Lespedeza Whole Plant and Leaf Only on Gastrointestinal Nematode and Coccidial Infection in Goats
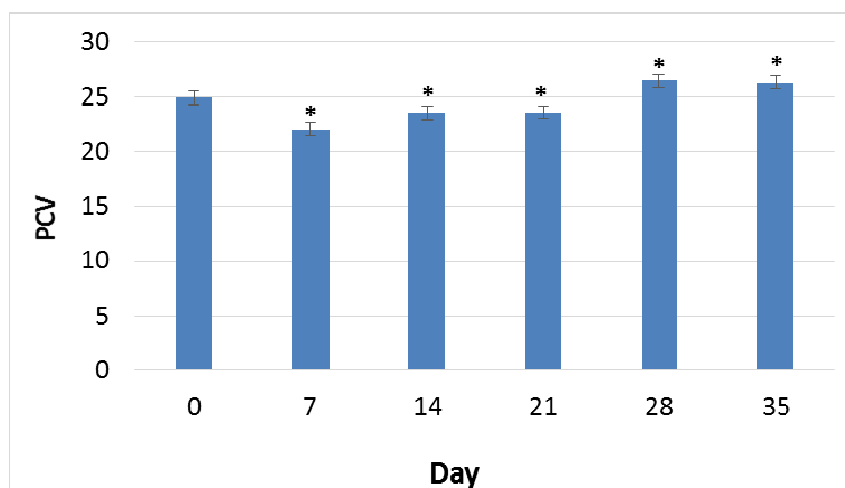
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Fig. 4 Percentage packed cell volume (PCV) for goats fed SLM or SLWP pellets for 42 d (Day 42 PCV data not available). Compared to Day 0, all points with * varied $p < 0.05$ except Day 21 ($p = 0.0512$); effect of day ($p < 0.001$).

4. Discussion

Sericea lespedeza was effective in reducing indicators of parasitic infection in goats in this investigation whether fed as the whole plant (leaves and stems) or leaf only, at different concentrations in the diet (Trial 1, 50%; Trial 2, 25%), or in different forms (Trial 1, pellets; Trial 2, meal). This confirms previous studies with this plant when included in the diet of sheep and goats in fresh (grazed) [29, 30], dried [26] and ensiled [37] forms for control of *H. contortus* [38] and *Eimeria* spp. [24, 25].

In most of the previous experiments with SL in dried forms, the treatment forages were fed at 75% of the diet or higher. Shaik *et al.* [26] reported 80% reduction in FEC in young goats fed a diet of whole (leaf + stem) "AU Grazer" SL hay compared with Bermudagrass hay (75% of the ration + 25% supplement) in a 6-week feeding trial. The goats fed the SL hay ration also had significantly higher blood PCV and lower adult worm numbers, with reductions of 70% for *H. contortus*, 26% for *T. colubriformis* and 40% for *Telodorsagia circumcincta* [26]. A similar study was completed with sheep fed unground SL hay and Bermudagrass (*Cynodon dactylon* (L.) Pers.) hay diets at approximately 80% of the diet to determine effects on establishment of GIN larvae, as well as on established infections in sheep [27]. Animals fed the

SL diet had 67%-98% lower FEC, 67% fewer adult worms, and 26% less establishment of incoming larvae than the sheep on the control diet [27]. In a study comparing pelleted whole plant SL, ground SL hay, and ground Bermudagrass hay diets (75% hay, 25% concentrate) in a 6-week feeding trial with goats, pelleting increased the percentage of total CT bound to protein in the SL material, but did not reduce its bioactivity against GIN [28]. Both the pelleted and ground SL diets reduced goat FEC compared to the control diet, with the lowest values for the kids given the SL pellets [33].

There have been relatively few previous studies with SL fed as 50% of the diet or less. Terrill *et al.* [39] reported on a trial in which yearling bucks were offered one of four diets consisting of 75% hay and 25% concentrate, with the hay portion of each diet being a combination of ground whole plant SL (0%, 25%, 50% and 75%) and Bermudagrass (*C. dactylon* (L.) Pers.; 75%, 50%, 25% and 0%), providing total dietary SL levels of 56.3%, 37.5%, 18.8% and 0%, respectively. There were significant reductions in FEC of goats on the 56.3% and 37.5% whole plant SL rations, but no effect at the 18.8% level [39], while kids on the 56.3% SL diet had significantly reduced abomasal worm burdens. Goats on the 56.3% SL diet also tended to have higher PCV values than control animals, while PCV values and adult worm numbers

of the kids on the 37.5% and 18.8% SL rations were not different from controls [39]. In the current investigation, although both leaf only and whole plant SL were effective at reducing GIN egg counts in goat feces, the leaf only ration was more effective than the whole plant ration when fed at 25% of the diet (Fig. 3; Trial 2). In contrast, similar effects (reductions) were seen for GIN and *Eimeria* spp. oocyst counts relative to the control diet when whole plant and leaf only SL were fed at 50% of the diet (Trial 1). This is an important consideration for feed manufacturers interested in pelleting SL, as separating SL leaves from the stems and then processing them into pellets adds to the cost of production, increasing final costs to consumers (farmers).

Results of this study suggest that feeding SL at 25% of the diet may effectively express the anti-parasitic bioactivity of this plant when using only leaf material, while whole plant SL can be effectively used at 50% of the diet. The whole plant and leaf only SL pellets used in Trial 1 were only 90% SL in addition to other ingredients, such as molasses, so the actual dietary level of SL for each pellet was 45%. These results support the findings of Terrill *et al.* [39], in which ground whole plant SL effectively reduced FEC in goats when fed at 37.5% of the diet, but not at 18.8%. The question of how much dietary SL is required to reduce worm burdens in animals needs further study. None of the levels or forms of SL fed in the current investigation reduced adult GIN numbers.

Although not determined in the current investigation, including SL whole plant or leaf only meal or pellets in the diet of domestic or wild ruminant animals would also have nutritional consequences, likely due to differences in leaf and stem CP levels and CT concentration and structure. Mechineni *et al.* [29] reported much higher CT in SL leaves than stems (16.0 g vs. 3.3 g/100 g dry weight), a slightly higher percentage of prodelphinidin-type tannins (98% vs. 94%, respectively) and polymers of larger mean degrees of polymerization (42 vs. 18,

respectively). Other reports on SL also showed higher concentration of CP and CT in SL leaves than stems for both high- and low-tannin SL cultivars, but protein concentration and digestibility were negatively associated with CT level [34]. Additional research is needed to determine the optimal level of leaf and stem SL in the diet of ruminants from a nutritional standpoint while maintaining an effective level of bioactivity.

5. Conclusions

SLWP and SLM pellets were both bioactive against GIN and *Eimeria* spp. in goats when fed at 50% of the diet. When fed at 25% of the diet, SLM pellets reduced FEC more quickly and were more effective overall against GIN infection, likely due to its higher concentration of CT. This information may be of interest to both feed manufacturers and farmers interested in the production and utilization of SL as a nutraceutical feedstuff for livestock.

Acknowledgments

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