Effects of Pine Straw as a Dietary Supplement for Internal Parasite Control in Pasture Raised Meat Goats

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Effects of Pine Straw as a Dietary Supplement for Internal Parasite Control in Pasture Raised Meat Goats

By

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Undergraduate honors thesis under the direction of

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Submitted to the LSU Roger Hadfield Ogden Honors College in partial fulfillment of the Upper Division Honors Program.

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Louisiana State University
& Agricultural and Mechanical College
Baton Rouge, Louisiana
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Abstract

The issue of gastrointestinal nematodes in small ruminants, especially *Haemonchus contortus*, has become an increasingly larger problem due to anthelmintic resistance. This anthelmintic resistance has brought about a need to find alternative methods of treating gastrointestinal nematodes. One substance that has shown positive results in treating internal parasites is condensed tannins (CT). A field study involving 21 goats at the LSU Doyle Chambers Central Research Station Small Ruminant Unit was used to study the effects of pine straw, which contains CT, on gastrointestinal nematode infections. The goats were separated into two treatments: control (n = 10) and experimental (n = 11). For 28 days, the control group received a regular diet supplemented with pasture grazing and hay fed ad libitum and the experimental group received a regular diet supplemented with pasture grazing and pine straw fed ad libitum. Every week, PCV, FAMACHA scores, body weight, and EPG were recorded. Fecal samples were also used to culture and identify the parasites infecting the goats. No significant differences were observed in PCV, FAMACHA, body weight, or EPG between goats offered pine straw compared to controls. Results of this experiment indicate that pine straw offered ad libitum did not decrease gastrointestinal nematode infection in these goats. However, future research is warranted to determine if pine straw could be an alternative to anthelmintics in internal parasite control in small ruminants.
CHAPTER 1
INTRODUCTION

In small ruminants, gastrointestinal (GI) nematodes present a large problem that is difficult and at times expensive to remedy. Of GI nematodes, those that belong to the Trichostrongyloidea superfamily are the most important. These worms rarely cause issues in small ruminants when burdens are low, but as more worms accumulate in the host, clinical issues begin to appear (Zajac, 2006). Clinical signs of heavy GI nematode infections include weight loss, anemia, bottle jaw, and diarrhea (Zajac, 2006). This affects the health and production value of these infected small ruminants. One particular parasite, *Haemonchus contortus*, is very common in pasture raised goats in warm, subtropical and tropical regions. *H. contortus* has become highly resistant to most conventional anthelmintics, such as the benzimidazoles and macrocyclic lactones. This resistance has caused the need for alternative options that are affordable, easily accessible, and practical to be discovered (Min et al., 2015). Condensed tannins (CT) have shown to have promising results in treating GI nematodes (Naumann et al., 2017). The issue with CT is finding a practical way in which to feed these compounds to small ruminants in sufficient concentration for them to be effective. Pine trees and pine straw contain CT (Min et al., 2015). This research aimed to determine if feeding pasture raised meat goats pine straw *ad libitum* in addition to their usual diet would minimize the fecal egg count of GI parasites, specifically *H. contortus* and other parasites that produce strongyle-type eggs, in comparison to pasture raised meat goats fed non-pine straw hay *ad libitum* in addition to their usual diet. The objective was to find a cheap, easy, and sustainable alternative to anthelmintics to fight the growing resistance seen in GI nematodes of small ruminants.
CHAPTER 2
LITERATURE REVIEW

2.1 Haemonchus contortus

*Haemonchus contortus* is a parasite that lives in the abomasum and feeds on the blood of its host. *Haemonchus contortus* belongs to the superfamily Trichostrongyloidea. This parasite gets its common name, barber pole worm, because the female worms have a striped appearance that resembles a barber pole. *Haemonchus contortus* mostly live in warm, moist environments, which makes Louisiana the perfect habitat for them (Besier et al., 2016). This parasite is considered the most pathogenic nematode in small ruminants because of its blood-feeding and ability to have rapid population growth (Besier et al., 2016). The main clinical sign of *H. contortus* infection is anemia, which can result in death. High infection loads can also result in bottle jaw, weight loss, and general unthriftiness (Besier et al., 2016).

*Haemonchus contortus* has major cost in ruminant production, including cost of anthelmintics, decreased production from ruminants, and death of ruminants (Naumann et al., 2017), but in recent years this parasite has become a larger issue due to the classic form of controlling *Haemonchus* infections, veterinary anthelmintics, losing their effectiveness. The decline in effectiveness of anthelmintics is due to the parasite forming a resistance to the anthelmintic drugs (Kearney et al., 2016). *Haemonchus contortus*’ resistance to anthelmintics has made testing other methods to rid the body of gastrointestinal nematodes essential.
2.2 Condensed Tannin Effect on Protein Absorption

Some research has produced positive results in limiting the occurrence of GI parasites when feeding goats forages and legumes that contain tannins. Tannins are a secondary plant metabolite (Sieniawska & Baj, 2017). Tannins can be grouped into two different categories: hydrolysable and condensed tannins (CT) (Naumann et al., 2017). Condensed tannins are known to have the ability to bind to dietary proteins (Naumann et al., 2017). The protein binding ability of CT is especially important in the nutrition of ruminants. This allows these proteins to withstand degradation in the rumen and pass further down the digestive tract to be absorbed (Naumann et al., 2017). By decreased protein degradation in the rumen, CT increases the amount of dietary protein that can be absorbed and utilized by ruminants, but it is important to note that feeding too much CT can actually create bonds with protein that make it undigestible and unable to be absorbed and utilized by the body (Sykes & Coop, 2001).

2.3 Protein’s Effect on Parasite Loads

Improved protein nutrition may be essential in fighting off gastrointestinal nematode infections for a variety of reasons. It is known that parasitism increases protein demands of GI tissue due to the damage being caused in those tissues and the body’s need to repair the damage (Sykes & Coop, 2001). Increased protein absorption may also increase the ability of the immune system to mount a cell-mediated response against GI nematodes, as cytokine and cellular responses are protein demanding (Sykes & Coop, 2001). Research has shown that when sheep are abomasally infused with protein while infected with Trichostrongylus colubriformis, a GI nematode, there were decreased worm burdens and egg outputs in feces in comparison to sheep
not infused with protein (Brown et al., 1991). This indicates that protein has some effect on the animal’s ability to fight GI nematode infections.

2.4 Condensed Tannin’s Anthelmintic Properties

There have also been studies that indicate that condensed tannin has anthelmintic abilities, in addition to its nutritional abilities. Studies have shown that supplementing products that contain condensed tannin can lead to decreased parasite loads and fecal egg counts and increased packed cell volumes. One particular study found that feeding goats *Lespedeza cuneata* (a CT containing forage) at 75% of the dry matter decreased *H. contortus* egg counts by 91.9% (Terrill et al., 2009). Despite this, it is speculated that the anthelmintic properties of CT is not equal across all forages that contain CT; this is most likely due to the varying structure of CT (Naumann et al., 2017). The exact mode of action in which CT act on GI nematodes is still unknown, but some studies have attempted to find the mode of action through *in vitro* studies. Studies have indicated that possible modes of action could be through inhibiting or delaying exsheathing of certain parasites once ingested. Exsheathing is the process by which the parasite leaves its protective sheath that it lives in within the environment. Delaying or inhibiting this process affects the ability for the parasite to succeed (Hoste et al., 2012). Other modes of action have been speculated, though more research is needed to positively say the exact mode of action of CT regarding its anthelmintic properties.

2.5 Pine Trees

Small goat producers have claimed that feeding their goats pine straw results in a reduced parasite load (Sarao, n.d.). This is likely because pine trees are known to contain condensed tannins. Research in which goats were artificially inoculated with *H. contortus* and then fed
either a control diet or a diet containing ground pine bark resulted in fewer parasites in the group receiving the pine bark (Min et al., 2015). Despite the results of pine bark studies and small goat producer’s claims, little research has been done to see if pine needles contain enough condensed tannin to have a positive effect on GI nematode infections in small ruminants.
CHAPTER 3
MATERIALS AND METHODS

3.1 Experimental Procedure

The methods used in this experiment were approved by the LSU AgCenter Institutional Animal Care and Use Committee. This study was performed at the Doyle Chambers Central Research Station Small Ruminant Unit over a 4-week period (starting Week 0: 11/2/2021 and ending Week 4: 11/30/2021). Twenty-one Savanna doeling and wether goats (mean body weight = 23.87 kg) were divided into 2 treatments (control n = 10, pine straw n = 11) based on their fecal egg counts conducted before the initial day of the experiment. However, as noted in section 3.7, if any goat has to be salvage treated, its data was removed from the analysis in totality. This resulted in there being 9 goats in the pine-straw-fed group and 7 goats in the control group. All goats received one pound of feed daily, fed collectively to all goats in each treatment in two equal amounts twice a day. The feed given to all goats was the basal diet formulated for the goat herd at the LSU Central Station Research Farm, along with being allowed to graze in a mixed grass pasture. One treatment group acted as the control group and received hay ad libitum in addition to feed and pasture grazing for 28 days. The other treatment group acted as the experimental group and received pine straw ad libitum in addition to feed and pasture grazing for 28 days.

The goats, after being separated into groups, were housed in two separate pastures and shed pens of equal size. Each shed pen had its own permanent wooden trough that was used as a feeder. Goats were fed the grain ration and fresh hay (control group) free choice, or pine straw
(experimental group) free choice every evening. Fresh, clean water was provided continuously throughout the trial.

On day 0 of the trial, fecal samples, body weights, blood samples, and FAMACHA scores were collected. This was repeated once every week during the trial and again 9 days after the trial ended. The fecal egg counts were measured using the McMaster technique (Whitlock, 1948). Infection levels were also monitored using the FAMACHA© system, which is a visual evaluation of the color of the mucous membrane of the lower eyelid as an indication of anemia in infected animals (Kaplan et al., 2004). Blood sample collections were analyzed for packed cell volume using the microhematocrit centrifuge technique.

3.2 Weight Collection

Individual weights of every goat were recorded on day 0, 7, 14, 21, and 28 of the experiment, and again 9 days after the experiment ended. The scale was tared after every weight collection before the next goat was put in the scale.

3.3 Blood Sample Collection and Analysis

Blood samples were collected on day 0, 7, 14, 21, and 28 of the experiment, and again 9 days after the experiment ended. Blood samples were collected via jugular venipuncture using 18-gauge 1-inch needles into 10ml Vacutainer© tubes containing K$_2$EDTA. These samples were taken to a lab in Louisiana State University School of Veterinary Medicine where they were analyzed using a microhematocrit centrifuge for packed cell volume (PCV). Packed cell volume represents the percent of red blood cells present in a blood sample.

3.4 Fecal Sample Collection and Analysis
Fecal samples were collected on day 0, 7, 14, 21, and 28 of the experiment, and again 9 days after the experiment ended. Fecal samples were collected directly from the rectum of each goat and placed in individual sample containers. Fecal samples were then refrigerated at 4 degrees C. The next day, fecal samples were analyzed using the McMaster technique. Two grams of fecal sample were mixed with 30 ml of salt solution (400g sodium chloride, 1 liter of water), then strained through a cheese cloth. The mixture was this pipetted into the McMaster slides and read under a microscope at 40X magnification. Strongyle type eggs were counted, and eggs per gram (EPG) was determined using the following formula.

\[
\text{# of eggs} \times 50 = \text{EPG}
\]

### 3.5 Parasite Identification

Parasite genera were identified by culturing the larvae from the feces. Fecal samples were collected and samples from the same treatment were mixed together. The fecal samples were then mixed with perlite and water and incubated in a Forma Scientific CO2 water jacketed incubator at 27 degrees Celsius for 7 days in order for the larvae to hatch from the eggs. After the 7 days, the fecal samples were then wrapped in cheese cloth and submerged in a Baermann apparatus consisting of a water filled funnel with a test tube attached to the bottom. A rubber pipe and clamp were attached to the test tube. Fecal samples were left like this for 24 hours to allow larvae to travel down the funnel into the test tube. Once collected, larvae were sent to Louisiana State University’s parasitologist for identification.

### 3.6 FAMACHA Analysis
Faffa Malan Chart (FAMACHA) scores were analyzed on day 0, 7, 14, 21, and 28 of the experiment, and again 9 days after the experiment ended. This was done by pulling down the bottom eyelid of each goat to observe the color of the mucus membranes and compare them to an official FAMACHA card, which has varying shades from dark red (1) to pale pink (5). A score of 5 indicates anemia. FAMACHA scores were observed and agreed on by a minimum of two people to ensure consistency of the scoring.

3.7 Treatment for Dangerous Levels of Infection

In the case of infections that could potentially become fatal, goats were treated. If infections resulted in a PCV less than 14% or an EPG of over 10,000, the LSU Central Station Research Farm veterinarian was consulted to determine if treatment was necessary. If so, the veterinarian recommended the method of treatment. Initially, goats that were considered at risk were treated with albendazole, doramectin, and levamisole using doses appropriate for their weight. After observing that these anthelmintics were not effective in decreasing EPG and increasing PCV, the treatment protocol was changed, and goats were given copper oxide wire particle boluses (1g dose). Once a goat was treated, it was removed from the project.

3.8 Statistical Methods and Calculations

SAS® (Version 9.3, SAS Inst. Inc., Cary, NC) GLM procedure was used to analyze the data using a repeated measures analysis of variance. Independent variables are weeks, the dates of which are the following: Week 0: 11/2, Week 1: 11/9, Week 2: 11/16, Week 3: 11/23, Week 4: 11/30, Week 5: 12/9. Response variables included body weight, FAMACHA score, packed cell volume, and fecal egg count. Fixed effects in the model included treatment, week, and a treatment by week interaction. The random effect was goat. A first order autoregressive
covariance structure was used. Prior to statistical analysis, all goats treated with anthelmintics, copper bolus, or dry lotted were removed from the data in totality; therefore, the graphs only represent those goats that never received treatment. Prior to statistical analysis, fecal egg counts were transformed by a $y = \ln(\text{fecal egg count})$ transformation. Significance of main effects and interactions were determined to be significant if $P < 0.05$. All data are presented as least squares means. Effects and interactions of all measured parameters were determined to be significant if $P < 0.05$. 
CHAPTER 4

RESULTS

4.1 Straw Intake

<table>
<thead>
<tr>
<th>Week</th>
<th>Average Pine Ingested Daily by Group (lbs)</th>
<th>Average Pine Ingested Daily per Goat (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.429</td>
<td>0.202</td>
</tr>
<tr>
<td>2</td>
<td>2.000</td>
<td>0.182</td>
</tr>
<tr>
<td>3</td>
<td>2.343</td>
<td>0.213</td>
</tr>
<tr>
<td>4</td>
<td>1.629</td>
<td>0.138</td>
</tr>
</tbody>
</table>

Table 1: This table shows the average amount of pine ingested daily per week in pounds by the pine-straw-fed group.
4.2 Packed Cell Volume

As seen in Figure 1, the packed cell volume of each group remained fairly constant. The differences in PCV (P = 0.0981) between the two groups were not significant.

Figure 1: Average weekly packed cell volume
4.3 FAMACHA

As seen in Figure 2, the FAMACHA scores also stayed fairly consistent throughout the 5 week period. There was no significant difference in FAMACHA scores between the two treatments ($P = 0.4038$).

![Figure 2: Average FAMACHA scores of the goats in each treatment by week.](image)
4.4 Eggs Per Gram

As seen in Figure 3, there were no large changes in EPG values throughout the study. There was no significant difference in EPG between the two groups. \( P = 0.4661 \).

![Figure 3: Average eggs per gram of the goats in each treatment by week.](image-url)
4.5 Weight

As seen in Figure 4, body weights increased throughout the first 4 weeks in both treatment groups. From week 4 to 5, body weights decreased. Though the weight gain of both groups from week to week was significant, there were no differences (P = 0.8715) between treatments.

![Figure 4: Average weekly body weights of the goats in each treatment by week.](image-url)
4.6 Parasite Identification

Results of the coprocultures are presented in Table 2. Goats in both treatments were infected by *Haemonchus contortus*, *Trichostrongylus* spp., *Oesophagostomum* spp., and *Strongyloides* spp.

*Haemonchus contortus*, which was the main parasite of concern in this study, consistently increased in the group fed pine straw over the 5 week period, while it consistently decreased over the 5 week period in the control group. The *Trichostrongylus/Teladorsagia* spp. increased over the 5 week period in the period in the control group, but decreased in the experimental. Both *Oesophagostomum* spp. and *Strongyloides* spp. remained fairly consistent throughout the study.

<table>
<thead>
<tr>
<th>Date</th>
<th>Parasite</th>
<th>Straw</th>
<th>No Straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/9/2021</td>
<td><em>Haemonchus contortus</em></td>
<td>67%</td>
<td>86%</td>
</tr>
<tr>
<td></td>
<td><em>Trichostrongylus/Teladorsagia</em></td>
<td>29%</td>
<td>12%</td>
</tr>
<tr>
<td></td>
<td><em>Oesophagostomum</em></td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td><em>Strongyloides</em></td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>11/23/2021</td>
<td><em>Haemonchus contortus</em></td>
<td>74%</td>
<td>76%</td>
</tr>
<tr>
<td></td>
<td><em>Trichostrongylus/Teladorsagia</em></td>
<td>24%</td>
<td>21%</td>
</tr>
<tr>
<td></td>
<td><em>Oesophagostomum</em></td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td><em>Strongyloides</em></td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>12/9/2021</td>
<td><em>Haemonchus contortus</em></td>
<td>84%</td>
<td>56%</td>
</tr>
<tr>
<td></td>
<td><em>Trichostrongylus/Teladorsagia</em></td>
<td>12%</td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td><em>Oesophagostomum</em></td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td><em>Strongyloides</em></td>
<td>1%</td>
<td>1%</td>
</tr>
</tbody>
</table>

Table 2: Results from the fecal cultures of each group.
### 4.7 Goats Removed from Study

**Experimental Group (Straw) Goats Removed from Study**

<table>
<thead>
<tr>
<th>Goat</th>
<th>Sex</th>
<th>Parasite Treatments</th>
<th>Week</th>
<th>Weight</th>
<th>FAMACHA</th>
<th>PCV</th>
<th>EPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1209</td>
<td>F</td>
<td>Week 3: Copper bolus</td>
<td>0</td>
<td>41</td>
<td>4</td>
<td>18.5</td>
<td>7750</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>41</td>
<td>4</td>
<td>13.5</td>
<td>8750</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>42</td>
<td>4</td>
<td>14.5</td>
<td>4150</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>42</td>
<td>4</td>
<td>10.5</td>
<td>5400</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>42</td>
<td>5</td>
<td>13.25</td>
<td>4300</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>39</td>
<td>4</td>
<td>17</td>
<td>550</td>
</tr>
</tbody>
</table>
| 1247  | F   | Week 1: albendazole, doramectin, levamisole  
Week 1: Dry lot  
Week 2: Copper bolus | 0    | 44     | 5       | 16.5  | 4500  |
|       |     |                                  | 1    | 41     | 5       | 11.75 | 5200  |
|       |     |                                  | 2    | 36     | 5       | 15.5  | 400   |
|       |     |                                  | 3    | N/A    | N/A     | N/A   | 0     |
|       |     |                                  | 4    | N/A    | 3       | 24    | 50    |
|       |     |                                  | 5    | 40     | 3       | 29.5  | 0     |

**Control Group (No Straw) Goats Removed from Study**

<table>
<thead>
<tr>
<th>Goat</th>
<th>Sex</th>
<th>Parasite Treatments</th>
<th>Week</th>
<th>Weight</th>
<th>FAMACHA</th>
<th>PCV</th>
<th>EPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1234</td>
<td>M</td>
<td>Week 3: Copper bolus</td>
<td>0</td>
<td>54</td>
<td>4</td>
<td>23.5</td>
<td>3000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>56</td>
<td>3</td>
<td>18.25</td>
<td>4050</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>56</td>
<td>3</td>
<td>16.5</td>
<td>4450</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>55</td>
<td>4</td>
<td>13.5</td>
<td>12050</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>54</td>
<td>4</td>
<td>14</td>
<td>3846.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>50</td>
<td>4</td>
<td>13.5</td>
<td>1250</td>
</tr>
</tbody>
</table>
| 1244  | F   | Week 1: albendazole, doramectin, levamisole  
Week 2: Copper bolus | 0    | 62     | 4       | 15.25 | 6200  |
|       |     |                                  | 1    | 61     | 4       | 11    | 8500  |
|       |     |                                  | 2    | 63     | 4       | 16.5  | 10300 |
|       |     |                                  | 3    | 63     | 4       | 21    | 50    |
|       |     |                                  | 4    | 63     | 2       | 22.5  | 150   |
|       |     |                                  | 5    | 64     | 3       | 30.5  | 50    |
| 1241  | F   | Week 1: albendazole, doramectin, levamisole  
Week 1: Dry lot  
Week 2: Copper bolus | 0    | 56     | 5       | 16    | 7300  |
|       |     |                                  | 1    | 52     | 5       | 7.25  | 12350 |
|       |     |                                  | 2    | 53     | 4       | 15.5  | 750   |
|       |     |                                  | 3    | N/A    | N/A     | 23.5  | 100   |
|       |     |                                  | 4    | N/A    | 3       | 24.5  | 50    |
|       |     |                                  | 5    | 55     | 3       | 24    | 550   |

Table 3: The sex, parasite treatments, weights, FAMACHA scores, PCV, and EPG of the goats removed from the study.
The goats throughout the first 3 weeks ate a fairly consistent amount of pine straw (0.200 ± 0.018 lbs per goat per day). In the fourth week, there was a drop in pine straw consumption (0.138 lbs per goat per day). This is likely because the pine lost its novelty and the goats no longer found it as interesting as they did in the initial weeks.

Both treatments had no significant changes in packed cell volume over the five-week period. There were no changes in FAMACHA score over during the experiment that were significant. There were also no significant differences between treatments in regard to EPG. Both groups saw significant increases in weight, which was to be expected as the goat were still growing, but there was no significant difference in growth between the two groups. The weights of the goats steadily increased for the first four weeks of the experiment, but both groups had a drop in weight in the final week. It is unknown what caused this weight loss; it could be due to stressors from changes as in the last week, the goats had a change in routine due to the feeding trial ending on the last day of the fourth week.

The variable nature of fecal cultures means changes around 30% are not considered significant. Therefore, despite the decrease in the percentage of *Trichostrongylus/Teladorsagia* spp. parasites and an increase in the percentage of *Haemonchus contortus* seen in the pine-straw-fed group and the increased in *H. contortus* percentage and decreased in *Trichostrongylus/Teladorsagia* spp. percentage in the control group, there were no significant changes in the parasites that infected the goats.
Throughout the experiments, there was one big issue: dangerous levels of infection. The Doyle Chambers Central Research Station has had a particularly hard time with parasites over the past year. This caused an issue within the research study as the parasite infections in some of the goats on the study became life-threatening to the extent that the goats had to be treated with anthelmintics and copper boluses. This resulted in a total of five goats being removed from the project. Fortunately, the resultant group sizes were still considered large enough for comparison between groups since there were greater than six animals per group.

Though feeding pine straw to goats appears to be safe, results show that when feeding it ad libitum, it does not affect parasite loads over the four week period of the study. Weight, FAMACHA, PCV, and EPG were similar for both treatments. Despite having no significant differences between treatments, this does not necessarily mean that pine straw would be a completely inefficient source of condensed tannin for preventing parasites. There are multiple possible reasons for this experiment not yielding significant differences. One possible reason for the lack of significant results could be that allowing goats to eat the pine straw ad libitum does not result in them eating enough of the pine straw to yield results. This could be due to the pine not having condensed tannin in high enough concentrations, or due to the goats simply not eating enough pine. Another possibility is that the condensed tannin in the pine straw we gave to the goats contained a CT that did not have anthelmintic properties. This is possible because one of the main challenges of using CT as an anthelmintic is that not all CTs possess anthelmintic properties due to the differing structures of different types of CT (Naumann et al., 2017).

Further research is needed to determine if pine straw does have anthelmintic properties. In future research, it would be beneficial to individually house and feed the goats to better be able to regulate amount of feed and straw ingested by each goat. Another improvement that
could be made in future research is to collect straw from one single species of pine tree to better
determine the CT contents. It would also be beneficial to have more replications and possibly
more treatments in which the pine straw is fed in varying amounts. It could also be beneficial to
grind the straw and mix it with the feed to ensure that the goats are eating the straw. Feeding the
pine straw for a longer period of time may also be beneficial.
References

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