4-2016

Can Parasitized Lambs Self-Medicate Through Preferred Consumption of Sericea Lespedeza Pellets?

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by

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

April, 2016

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Abstract:

Zoopharmacognosy is the study of secondary plant components or other non-nutritive substances used by animals to suppress disease or to enhance animal health. The researcher in this study investigated whether parasitized lambs could self-medicate through preferred consumption of sericea lespedeza (SL) pellets.

Twelve Gulf Coast Native x Suffolk cross lambs were randomly assigned to either the infected group or control group. Those chosen for the infected group received an infective larvae count of 5000 (L3) via oral drench and were given a 5 week period for infection to establish. The control group received an albendazole and a levamisol drench 1 week before the study began to clear any resistant infection. During the study, lambs were housed in separate metabolism pens. Twice daily (morning/evening), the lambs were fed 594.9 grams of corn and 528.7 grams of SL pellets. The idea was for the lambs to consume the feed that they preferred and to leave some of the other feed once they were done eating. After the allotted 1 hour feeding time, the refused feed was collected and weighed to calculate the amount of feed consumed. The lambs were then given ad libitum hay to eat until the next feeding time. At the end of phase 1, the groups were swapped to where the infected lambs were dewormed and the controls were given worms. The sheep returned to pasture for the 5 week interval period and returned to the pens for the beginning of phase 2.

All data were analyzed using SAS with a One-way ANOVA followed by Fishers Least Significant Difference. A $p \leq 0.05$ is significant. There was no statistical significance between which feed the infected lambs preferred. The figures in the study showed a trend that infected lambs ate more sericea than the non-infected group and consequently exhibited a decrease in fecal egg counts. Although the infected lambs preferred corn over SL, it is important to note that they reaped the therapeutic benefits of zoopharmocognosy.

Introduction

Parasites contribute to large economic and production losses in the small ruminant industry. *Haemonchus controtus,* (also known as the barberpole worm, is the major parasite in sheep and goats and causes anemia. Due to misuse of chemical dewormers, *H. contortus* is highly resistant to the once effective anthelmintics, such as benzimidazoles and macrocyclic lactones. Producers are now incorporating alternative methods of parasite control such as feeding animals condensed tannin (CT) containing forage. Sericea lespedeza (SL, *Lespedeza cuneate*) is a high CT containing legume forage that inhibits adult worms from reproducing thus lowering fecal egg counts. Condensed tannin forages have low palatability; however, researchers have observed infected animals consuming these perhaps as a means of zoopharmacognosy, or self-medication. While CT do not kill many parasites, symptoms caused by the present burden may be alleviated. The purpose of this study was to determine whether parasitized lambs could self-medicate by choosing the less palatable, but therapeutic SL pellets over their standard cracked corn grain ration.

Literature Review

Haemonchus contortus

Haemonchus contortus, a nematode commonly known as the barber pole worm, is the number one contributing parasite to production losses in the small ruminant industry. It is a sexually dimorphic and dioecious species belonging to the superfamily Trichostrongyloidea. *H. contortus* is referred to as the barber pole worm because of the female's appearance as it feeds on blood - her white ovaries are wrapped around the blood filled intestines. Males do not have the barberpole appearance and have a well-developed copulatory bursa for sexual identification. This worm is 10-30 mm (0.39-1.18 inch) in length, making it visible to the naked eye with the females typically larger than the males (Sendow, 2003).

H. contortus can be found in temperate and tropical climates on six continents. Through animal migration, it has also adapted to live in colder, drier conditions. *H. contortus* has a two phase direct lifecycle: the free-living phase and the parasitic phase with a 3-5 week life cycle completion period. Eggs are passed in feces in which they can remain viable for various periods of time (depending on temperature and moisture) outside of the host. First stage larvae emerge from the eggs and develop to the third stage (L3) entering the free-living phase. The larvae reside within the warm, moist environment of the pasture forage until they are consumed by the animal, commencing the parasitic phase.

Once inside of the host, high carbon dioxide levels and high temperature stimulate the L3 larvae to exsheath and they into the lining of the abomasum by using an oral lancet to form a boring hole. The L4 larvae feed on blood and reemerge as an adult worm in 3-5 days. Once they reach maturity, the adult worms continue to feed on blood and mate. It takes about two weeks before the adult female begins to start laying eggs. The life cycle gives a perspective on how much damage *H. contortus* can cause in an animal: Each female can lay anywhere from 5,000-10,000 eggs per day. Once these eggs hatch and the L3 are consumed, they add to the growing population in the abomasum. Each adult consumes 200 microliters of blood per day. A worm count of 10,000 is enough to kill a sheep or goat: if 10,000 worms ingest 200 microliters, this would result in 2 liters of blood lost per animal per day (Burke, 2005).

Anthelmintics resistance on the rise

Phenothiazine and piperazine were among the first generation of chemical dewormers formulated in the 1950s. Just a few years later, parasites became increasingly resistant to these drugs, and researchers had to develop another effective treatment. In the 1960-70's, the second generation of chemical dewormers, benzimidazoles and imidazothiazoles, became the newest effective chemical defense against internal parasites. However, a similar outcome occurred just as with the first generation—resistance. The most recent third generation, macrocyclic lactones, emerged in the 1980's and resistance was once again an issue. Since then, no other products have been approved for retail in the United States.

There are three phases in which a parasite develops resistance to a drug. In the initial phase, resistance to the new drug is low; therefore most of the worms are susceptible and die with just a few resistant individuals remaining. The second intermediate phase is characterized by a heterozygous resistant population growth with continued exposure to the same drug group. With continuous exposure to the same drug, only the homozygous resistant worms are found in the final peak stage of drug resistance. Since benzimidazoles, imidazothiazoles, and macrocyclic lactones all have similar modes of action within their class, resistance to one particular compound may be accompanied by resistance to other members of the same drug class. This describes side resistance. An anthelmintic is considered effective at controlling parasites only if it reduces the fecal egg count (FEC) by 95% or greater. Some farms have reported that drugs such as moxidectin, fenbendazole, and doramectin all fall below 95% FEC reduction.

Why is anthelmintic resistance such a prevalent problem in small ruminants? Producers have overused and improperly used chemical anthelmintics. Treating all of the animals several times per year kills all of the susceptible worms and only strengthens the resistant gene pool. Under dosing occurs often since animals have the tendency to spit the drench out; this favors the heterozygous population. When producers use a drug past its expiration date, L3 are exposed to a weaker, less effective drug and can mature to adults.

Determining Which Animals Should Be Treated

McMasters' tests, packed cell volume (PCV) and FAMACHA (Faffa Malan Chart) scoring are three tools used for diagnosing a parasite burden in small ruminants. McMasters' is a method of determining FECs by mixing 2 grams of feces with 30 mL of a salt solution. Once blended, a representative sample is pipetted into the two chambered slide. Fecal egg count is determined by counting the number of eggs in both grids and multiplying by 50 to calculate eggs per gram. Packed cell volume involves centrifuging a hematocrit tube to determine the % red blood cell composition of the blood sample. PCV values are lower in infected animals due to blood feeding *H. contortus* and bleeding of abomasal mucosa as a consequence of blood feeding. It has also been show than lymphocyte counts increase and eosinophil counts increase as an immune response to the infection. The FAMACHA test compares the color of the mucous membranes of the inside lower eyelid to a standard color card. Since the color of a healthy animal's conjunctiva is a bright red, it is easy to diagnose anemia by looking at how pale the membrane is. The scale ranges from 1 (bright red, healthy tissue) to 5 (pale white, deadly). Producers should only deworm those animals that fall within the 4-5 range and may consider the 3's depending on the animal's health.

Smart Drenching

If producers simply follow the idea of Smart Drenching by correctly deworming animals without adding to the resistant gene pool, anthelmintic resistance would not be such a prevalent problem in the small ruminant industry. Before deworming the animal, expiration date of the drug must be checked since drug efficacy decreases after its expiration date. Fasting an animal for 24 hours pre-deworming increases the amount of the drug absorbed due to a longer passage time through the digestive tract. The correct dosage must be measured for each animal before treatment to prevent underdosing. When administering the drug, it is important to place the drench gun over the tongue so that the drug can go directly into the rumen and not fall into the oesophageal groove.

Refugia and Grazing Strategies

Producers should also consider preserving refugia, a population that consists of susceptible worms, only by deworming the heavily burdened animals in order for the resistant gene pool to remain diluted. Taking into consideration that only 30% of the herd contributes to the pasture parasite contamination, the other 70% with light parasite loads should house refugia.

The concept of refugia is important when establishing grazing strategies. It is detrimental to move animals onto a clean pasture immediately after they've been dewormed since the residual resistant population will contaminate the new pasture. The old pasture must be allowed to rest during the spring/rainy season in order for the L3 larvae to die.

Mixed-grazing is an increasingly common practice of placing different animals on the same pasture simultaneously. As the animals co-graze, they clean up after one another. For instance, horses, which are not affected by small ruminant parasites, reduce the number of those parasites on the pastures and vice versa (FAO).

Biological Methods of Control

When determining breeding stock, it is wise to select those animals that are more resistant to parasites. For example, Gulf-Coast Native sheep thrive in tropical climates in which *H. contortus* is more prevalent due to ideal conditions of the free-living phase. The lambs at the LSU Ben Hur Research Farm are the cross progeny of a Sulfolk ram and Gulf-Coast Native ewes. Researchers found that the offspring are more resistant to parasites and have acceptable carcass and finishing weights (Miller et al. 2001). Other parasite resistant breeds include the Red Masai and Katahdin, which are both raised in humid climates. Instead of breeding sheep that have a consistently high parasite load, those individuals should be culled as they are a hindrance to the flock.

More research is being performed in other aspects of biological control of parasites. *Duddingtonia flagrans*, a nematode trapping fungus, is fed to animals to kill developing larvae in the feces. Treating copper deficiencies with copper oxide wire particles has a secondary effect on reducing fecal egg count. While the mechanism is not fully understood, studies have shown that particles lodge in the abomasum and interact with stomach acid to release copper which in turn results in a reduction in the prolificacy of adult worms (Stanton, 2014). Copper also boosts the immune system in ruminants, which aids in battling *H. contortus.* Vaccines are only 30-60% efficient in controlling worm populations. Developing a *H. contortus* vaccine depends on extracting antigens from worms by slaughtering the animal to obtain worms from the abomasum. Once the vaccine is administered to the animal, antibodies respond to the foreign antigen and begin to destroy worms present in the abomasum. The vaccine loses efficacy within a few months and animals must be treated 3-4x per year. Until vaccines can be mass produced in labs, this remains an inefficient method for worm control (Besier, 2015).

Adverse effects of Condensed Tannins on Worm Population

Condensed tannins (CT) are long chain polyphenolic secondary compounds produced by plants that can bind with proteins and other macromolecules in aqueous solutions (Haslem, 1989). Studies suggest that CT have anthelmintic properties by suppressing worm prolificacy and ultimately lowering FEC. SL is a high tannin containing legume forage (46-152 g/kg of dry matter: 4-15%). Although the direct mode of action is not entirely understood, researchers presume that CT bind to the worm's protective cuticle, which hinders them from laying eggs. CT work indirectly within feces by binding to developing larvae and through reducing the bacterial population in feces on which developing larvae feed (Min et. al, 2005). The bypass protein content of SL improves nutrition, which, in turn, boosts the immune system against the parasitic infection.

Research has been conducted on the effects of SL on parasite burdened small ruminants. One study found that SL fed goats had a reduced number of adults in the abomasum and had higher PCV values than those that had not consumed any. In addition, the treated group also had lower FECs (Min et. al 2004). In other studies, SL fed animals inhibited worm prolificacy thereby reducing reinfection rates.

Using CT containing plants to control worms is becoming more accepted in small ruminant production. It is more eco-friendly and can be used in organically raised livestock as compared to chemical anthelmintics. Rural or lower income producers who cannot purchase chemicals can grow CT containing plants to use instead of costly chemicals.

Evidence of Self-Medication in Small Ruminants

Zoopharmacognosy is the study of secondary plant components or other non-nutritive substances used by animals for self-medication (Rodriguez & Wrangham, 1993). It can also be defined as a behavior of using non-plant substances to suppress a disease or, to enhance animal health

(Huffman 1997). Self-medication in small ruminants was first documented in the early 1990s. Ugandan shepherds observed goats consuming *Albizia anthelnutica*, a plant with anthelmintic secondary compounds instead of the palatable grasses on the field. After the goats ate the plant, they defecated visible larvae in their feces, which was followed by an improvement in their symptoms. Laboratory analysis showed a reduction in FECs in the goats that ate the plant (Grade' et. al 2009).

Self-medication is a learned behavior as it seems unusual that an animal would want to consume plants that produce bitter, burning, and sour gustations and contain smells that irritate the nose. Anorexia is a symptom that coincides with parasitism, which in turn produces an anorexic behavioral adaptation in the animal. Anorexic animals are more selective of beneficial compounds due to their aversion to familiar foods. Since they are out of homeostasis, the anorexic animals are more neophilic and try new foods as a remedy to their infection. Social environments can stimulate self-medication in young animals. It can be taught through observation of the mothers or through flockmates. If young parasitized lambs see a flock mate grazing a CT forage to alleviate symptoms, thus the others may imitate and begin to self-medicate as well (Villalba et al., 2012).

Several studies have shown that parasitized sheep will choose a CT feed over a standard, more palatable feed. The sheep tend to eat until the symptoms associated with the parasitic burden disappeared. When FEC and reinfection levels decreased, their CT forage consumption also decreased. Lambs that were not parasitized showed no preference towards the medicated feeds (Villalba et al., 2010).

Materials and Methods

This study was performed at the Ben Hur Research Station metabolism pens. Twelve Gulf Coast Native x Suffolk cross lambs were randomly assigned to either the infected group or control group. Those chosen for the infected group received a 5000 L3 via oral drench and were given a 5 week period for infection to establish. The control group received an albendazole and a levamisol drench 1 week before the study began. The lambs were given a one week adjustment period in their new surroundings and were fed 594.9 grams of cracked corn twice daily along with ad libitum hay and fresh water. Each pen had two buckets for each type of feed.

Phase 1 of the study started on November 28, 2015 and ended on December 22, 2015. The lambs were about 8 months old at the time. Twice a day (morning/evening), the lambs were offered 594.9 grams of corn and 528.7 grams of SL pellets. The idea was for the lambs to consume the feed that they preferred and to leave some of the other feed once they were done eating. After the allotted 1 hour feeding time, the refused feed was collected and was weighed to calculate the amount of feed consumed. The lambs were then given a new basket of hay to eat until the next feeding time.

On 11/23 (Day 1), 11/30 (Day 7), 12/7 (Day 14), 12/14 (Day 21), and 12/21 (Day 28), fecal and blood samples were collected from each lamb and were analyzed at the LSU Vet School Parasitology Lab. A McMasters fecal flotation was used to estimate eggs per gram. Fecal egg count (FEC) was monitored to determine whether the lambs that ate more SL had a decreased FEC to those that preferred corn. A centrifuged hematocrit tube analysis determined the percentage of red blood cells in the sample or PCV. This test was performed to detect anemia due to *H. contortus* blood-feeding habits. The data was recorded onto a general FEC/PCV sheet and entered into an Excel spreadsheet.

At the end of phase 1, the groups were swapped: the infected lambs were dewormed and the controls were given worms (5000 L3). The sheep were then returned to pasture for the 5 week interval period and returned to the pens on January 11, 2016 to begin the 1 week adjustment period. The control lambs were dewormed again to kill any worms picked up while on pasture. Phase 2 officially began January 18th and ended February 2nd. The same procedure was followed as phase 1.

Results

During the time of the study, the data was recorded in an Excel spreadsheet. All data were analyzed post study using SAS with a One-way ANOVA followed by Fishers Least Significant Difference. A $p \leq 0.05$ is significant.

The graphs above were created using Excel. The amount of feed consumed was recorded as a percentage since a can of cracked corn weighs more than a can of SL.

Phase 1 Results:

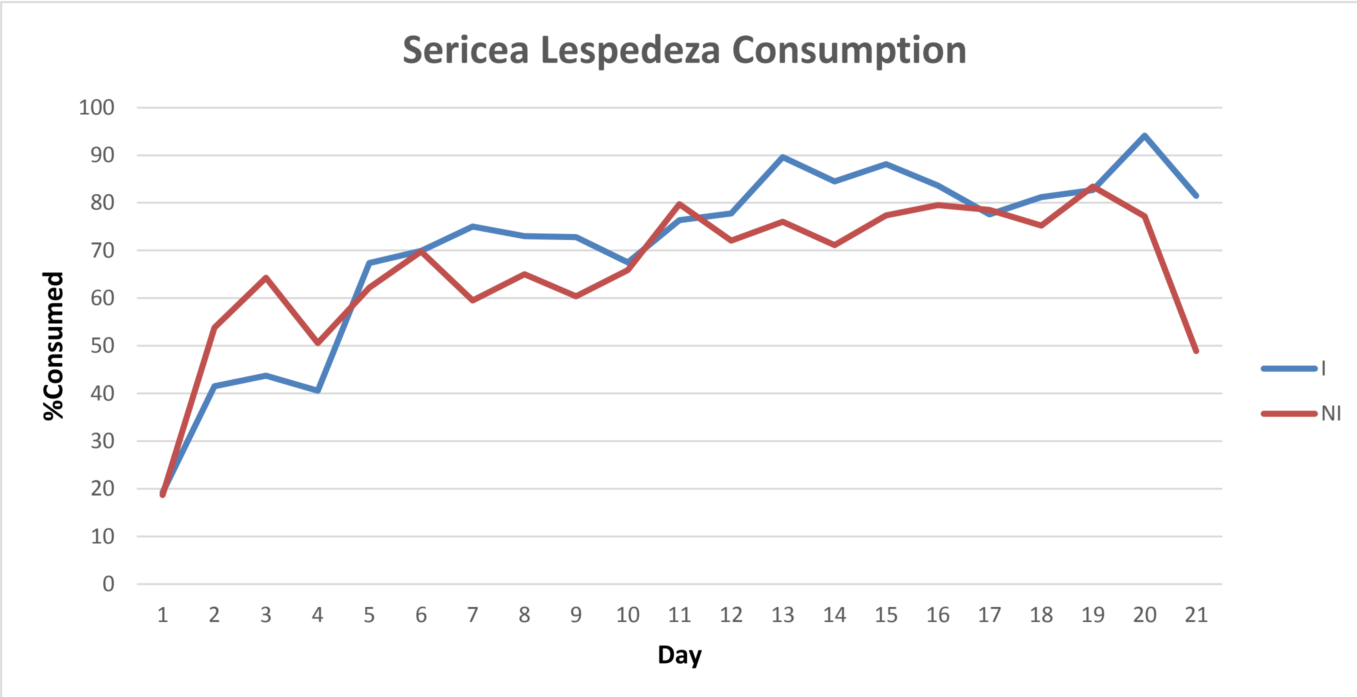

Figure 1: Percent sericea lespedeza consumed by both groups over 21 days
I=Infected NI= Non-Infected (Control)

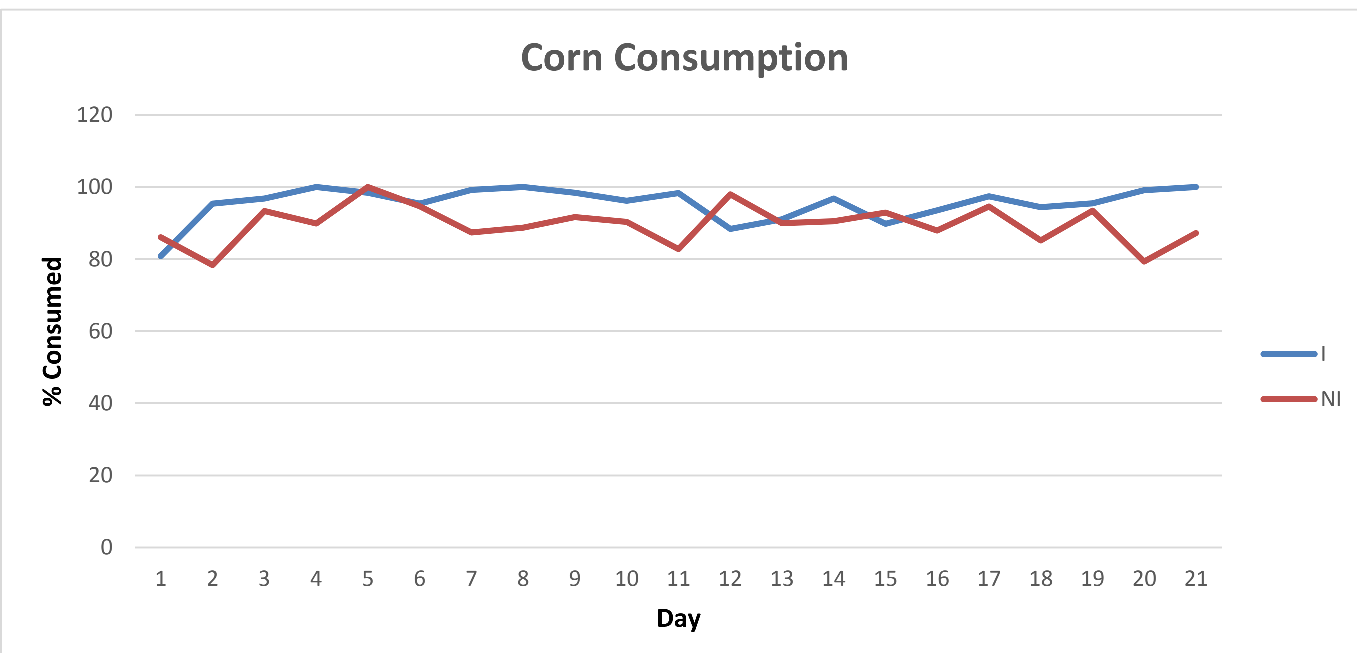

Figure 2: Percent corn consumed by both groups over 21 days
I=Infected NI= Non-Infected (Control)

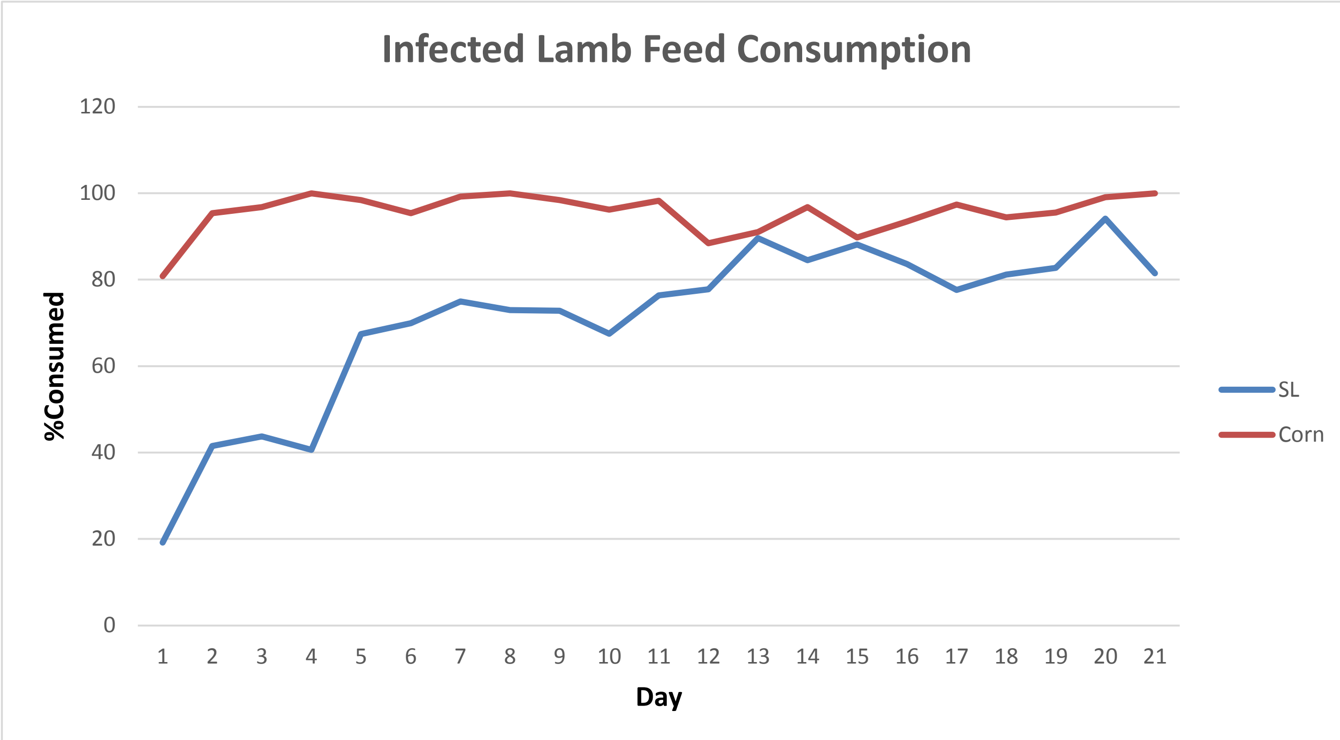

Figure 3: Infected lamb feed consumption of both feeds over 21 days
Corn=Corn SL= Sericea lespedeza

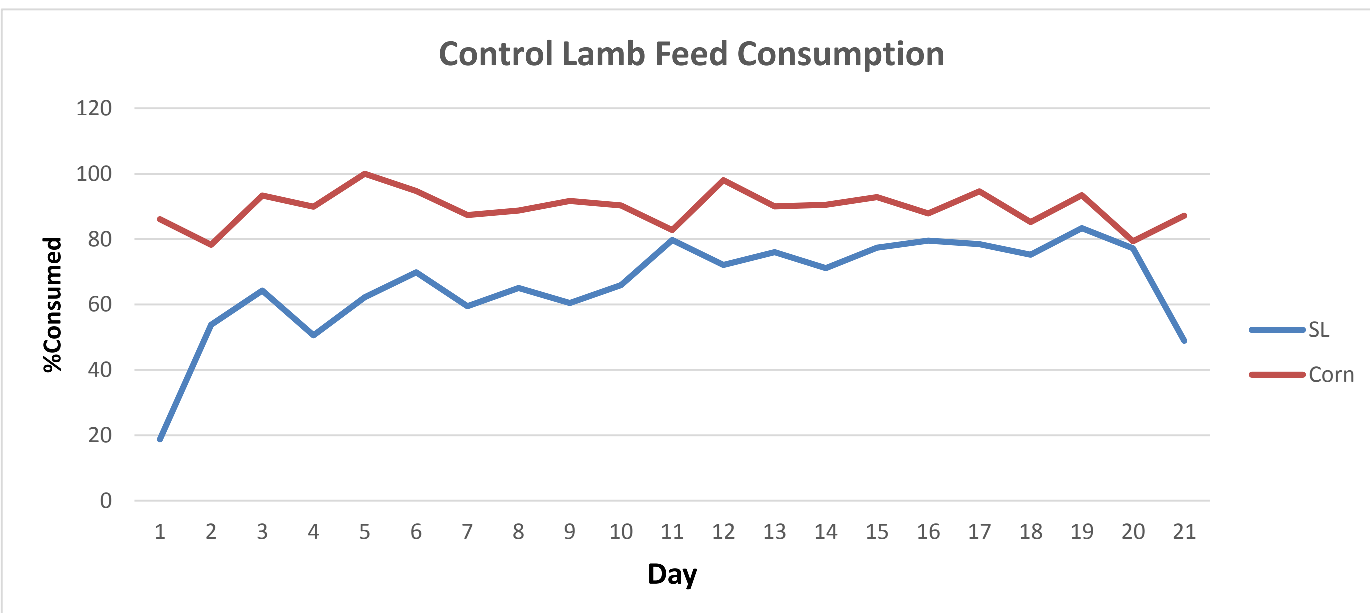

Figure 4: Control lamb feed consumption of both feeds over 21 days
Corn=Corn SL= Sericea lespedeza

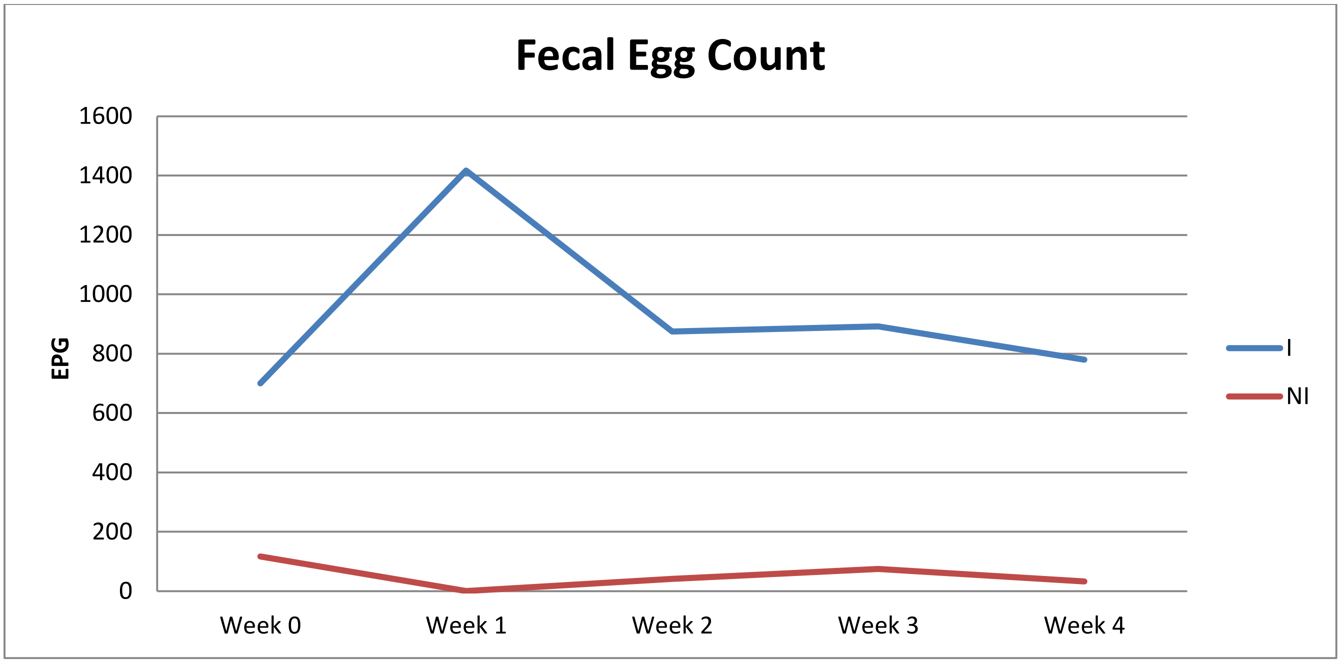

Figure 5: Fecal Egg Count in eggs per gram (EPG) between two groups tested at weekly intervals

NI=Infected (Control) I= Infected

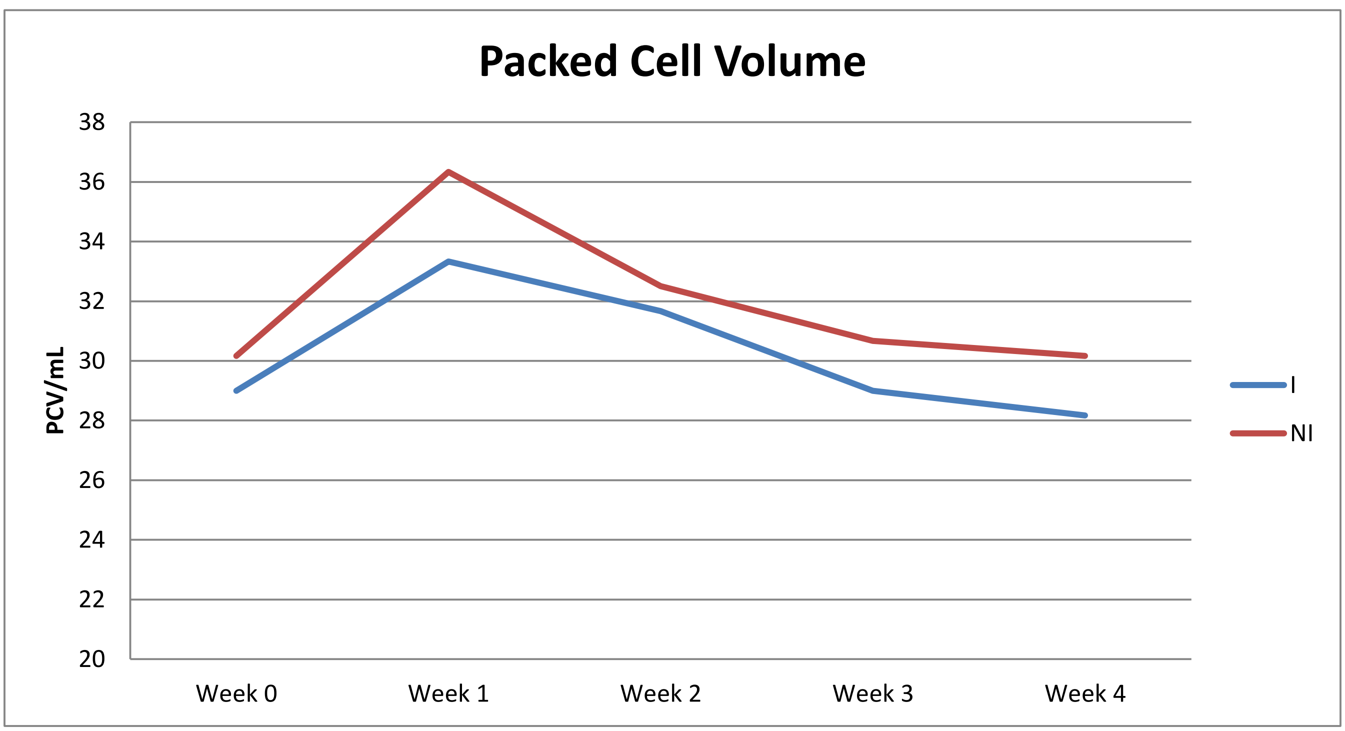

Figure 6: Packed cell volume between two groups tested at weekly intervals

NI=Infected (Control) I= Infected

Phase 2 Results:

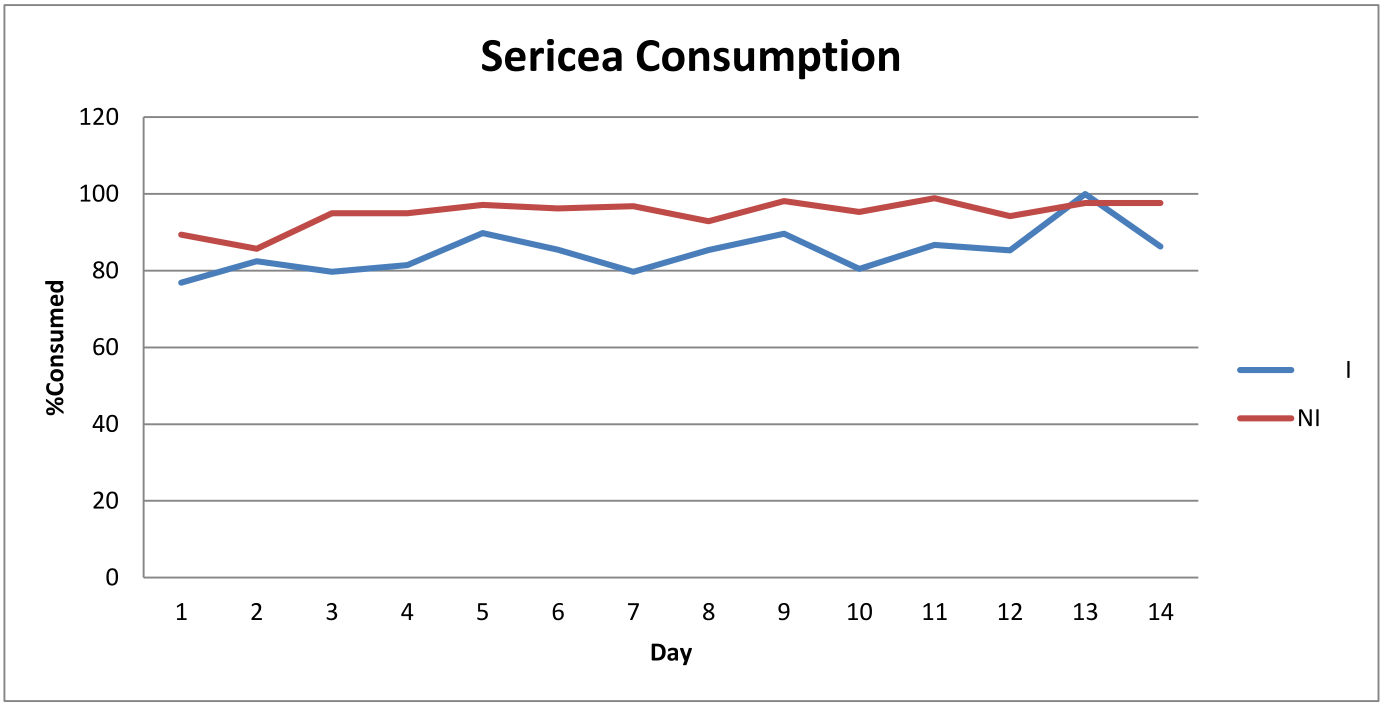

Figure 7: Percent sericea lespedeza consumed by both groups over 14 days
NI=Non-Infected (Control) I=Infected

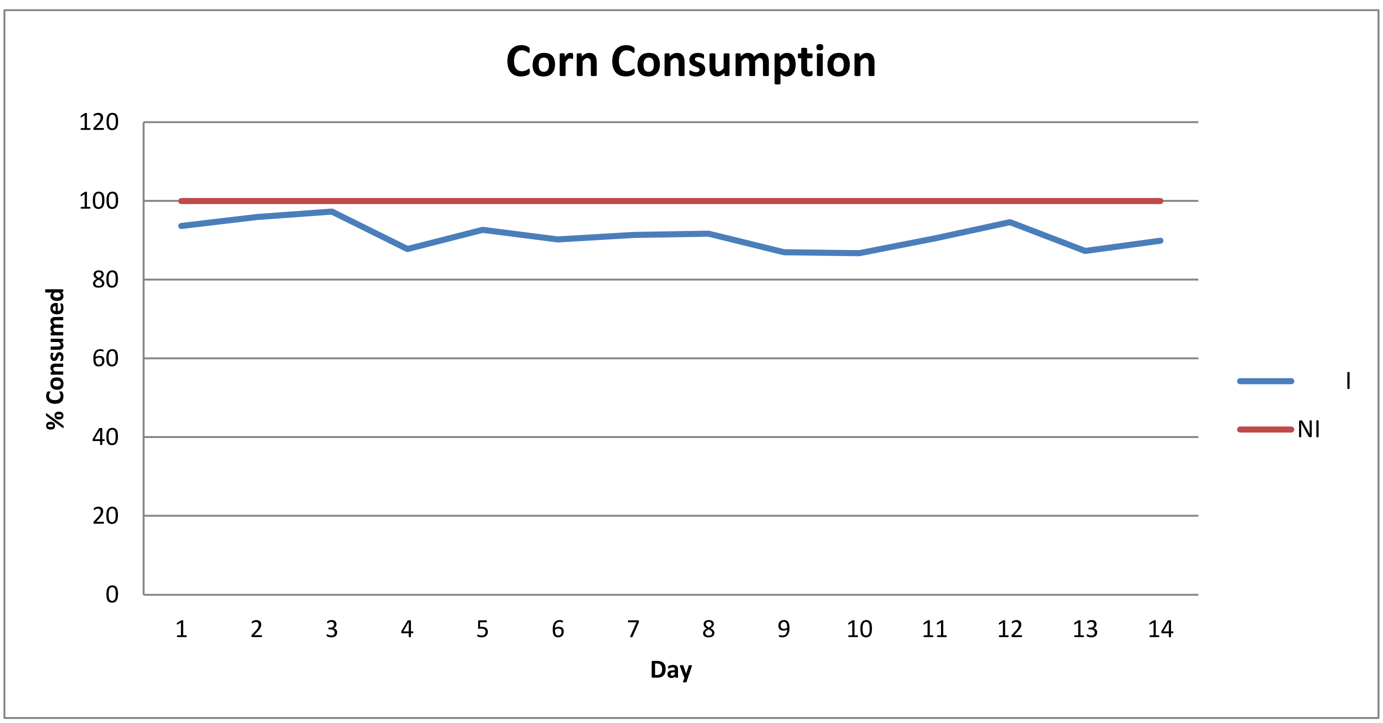

Figure 8: Percent corn consumed by both groups over 14 days
NI=Non-Infected (Control) I=Infected

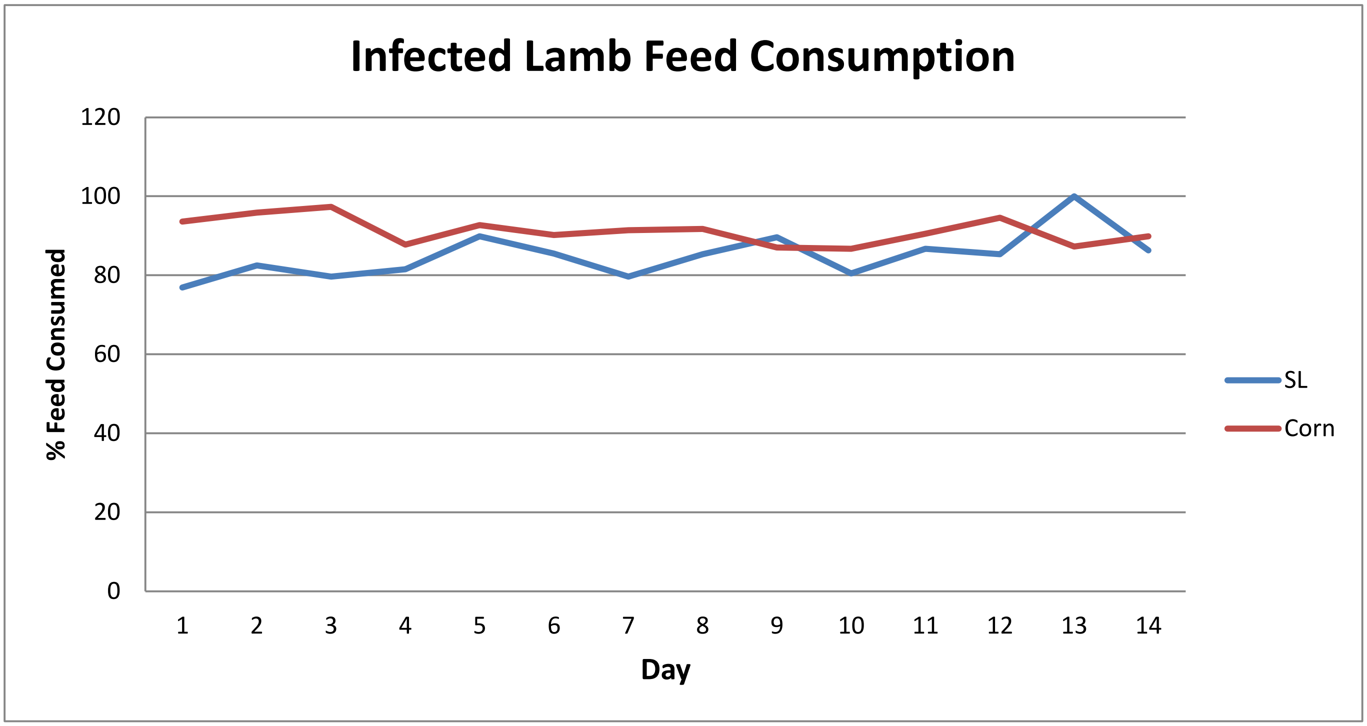

Figure 9: Infected lamb feed consumption over 14 days
Corn=Corn SL= Sericea lespedeza

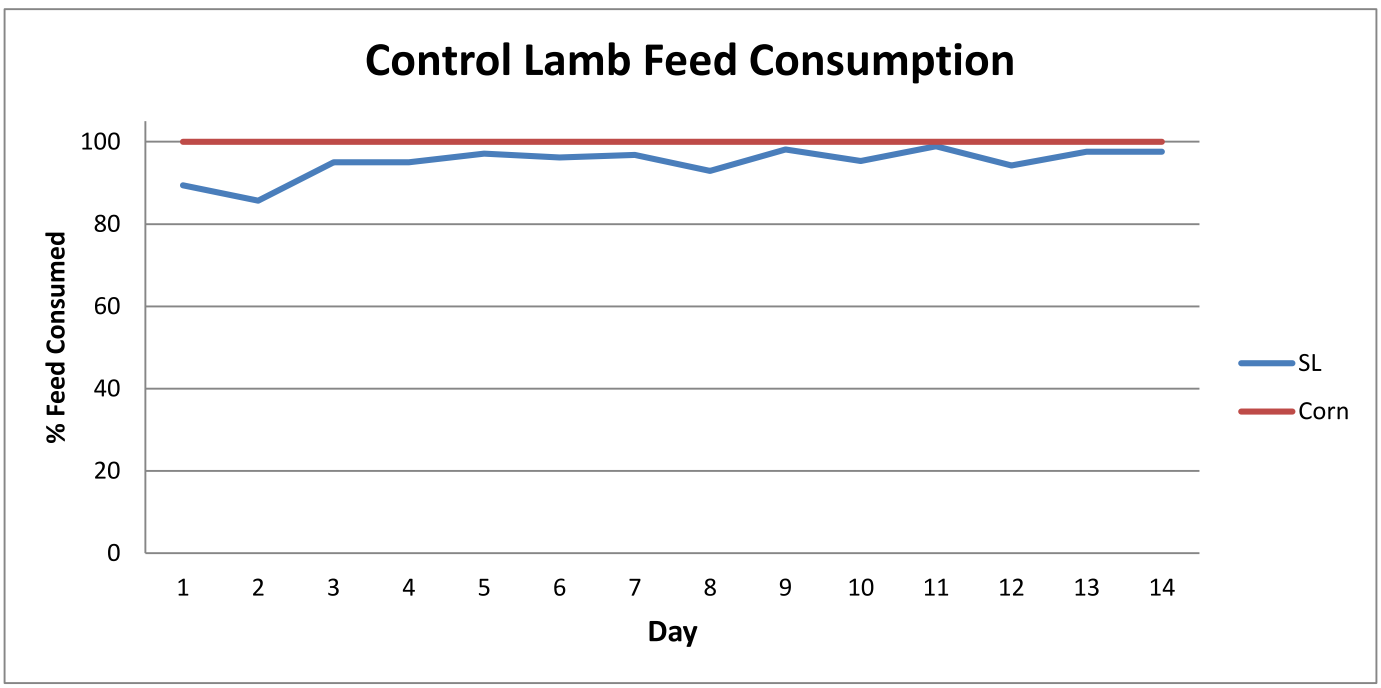

Figure 10: Control lamb feed consumption over 14 days
Corn=Corn SL= Sericea lespedeza

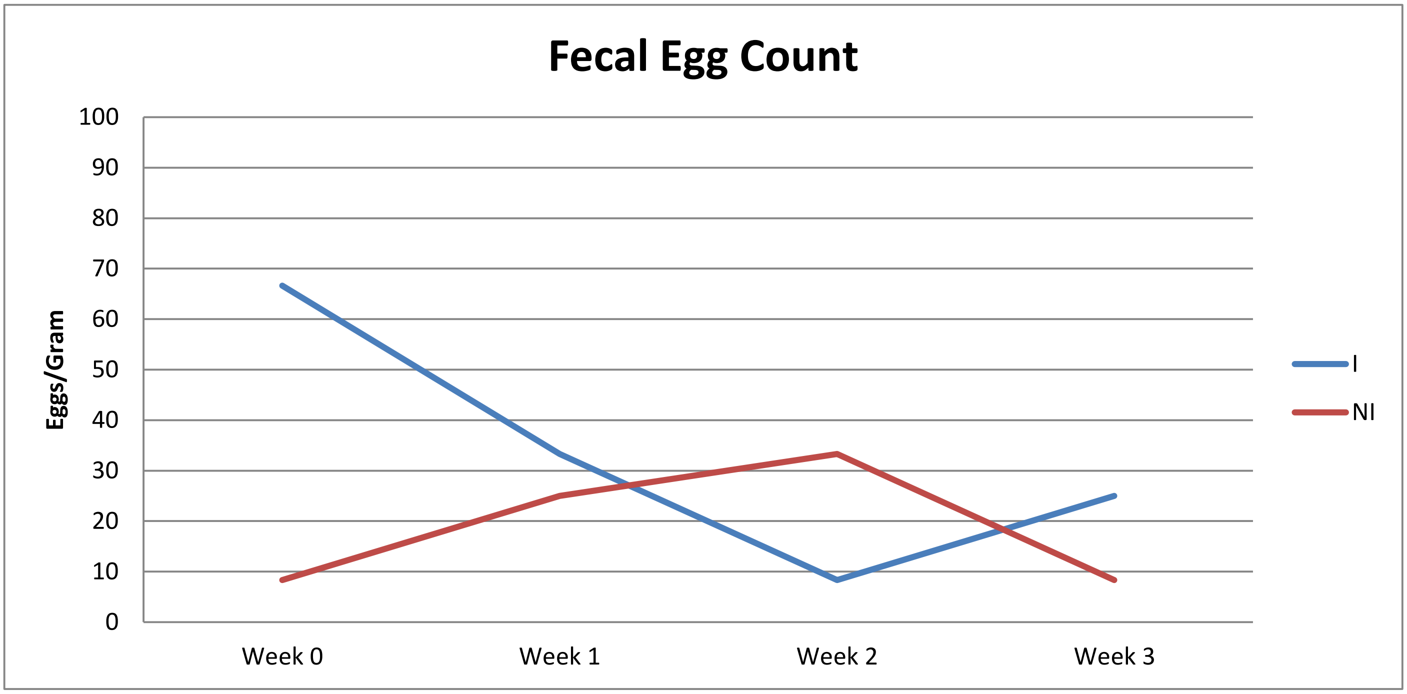

Figure 11: Fecal Egg Count in eggs per gram (EPG) between two groups tested at weekly intervals

NI=Infected (Control) I= Infected

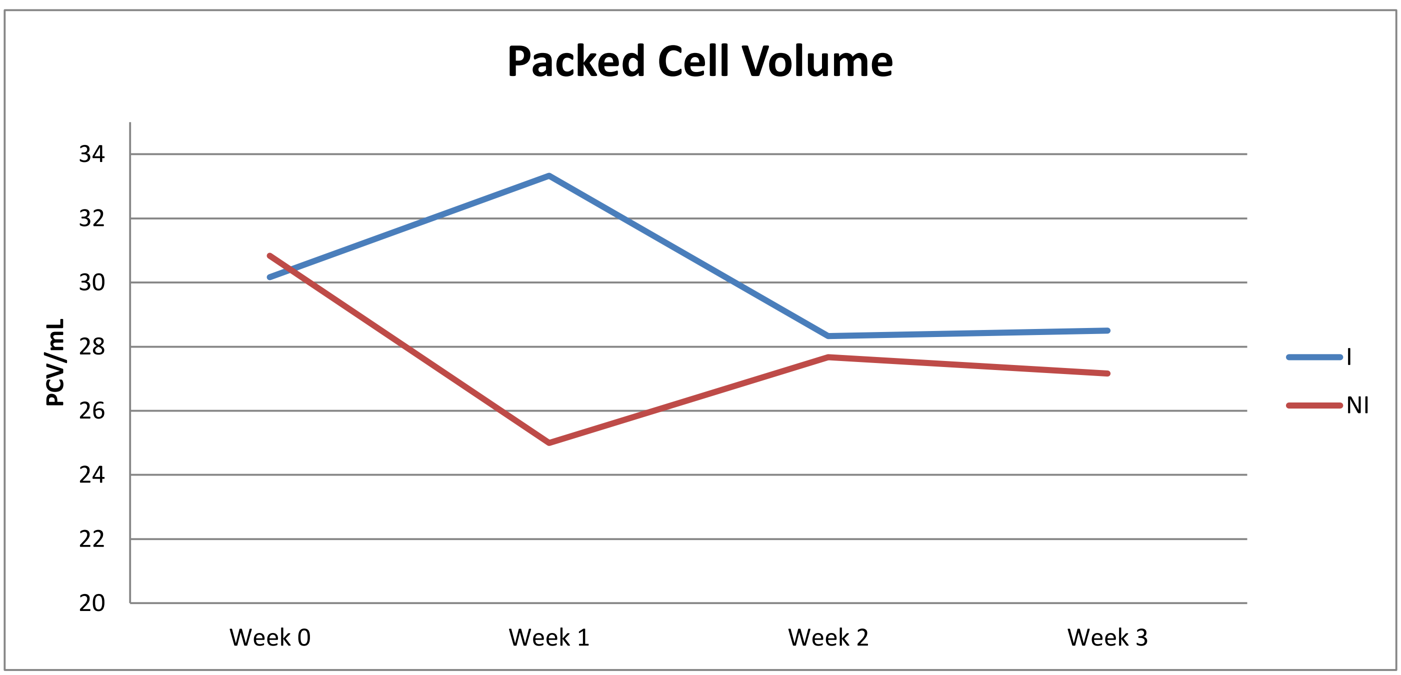

Figure 12: Packed cell volume between two groups tested at weekly intervals

NI=Infected (Control) I= Infected

Phase 1

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Group	1	10	0.16	0.6950
Day	20	786	8.88	<.0001
Group*Day	20	786	1.12	0.3260
Time	1	786	0.99	0.3196
Group*Time	1	786	0.16	0.6935
Day*Time	20	786	1.53	0.0655
Group*Day*Time	20	786	0.37	0.9945
Feed	1	786	302.59	<.0001
Group*Feed	1	786	3.30	0.0698
Day*Feed	20	786	6.78	<.0001
Group*Day*Feed	20	786	0.85	0.6535
Time*Feed	1	786	4.84	0.0281
Group*Time*Feed	1	786	0.12	0.7345
Day*Time*Feed	20	786	1.50	0.0745
Group*Day*Time*Feed	20	786	0.50	0.9685

Table 1: Output data of Phase 1 results. Any P-values below 0.05 are considered statistically significant. P-values ranging from 0.05-0.1 indicate a trend in the data. The data highlighted are specific to this project and does not show significance.

Phase 2:

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Group	1	10	2.10	0.1783
Day	13	548	0.60	0.8571
Group*Day	13	548	0.60	0.8535
Time	1	548	3.10	0.0788
Group*Time	1	548	0.37	0.5451
Day*Time	13	548	1.55	0.0942
Group*Day*Time	13	548	0.46	0.9460
Feed	1	548	27.64	<.0001
Group*Feed	1	548	0.97	0.3248
Day*Feed	13	548	1.76	0.0467
Group*Day*Feed	13	548	0.68	0.7861
Time*Feed	1	548	5.63	0.0180
Group*Time*Feed	1	548	1.48	0.2241
Day*Time*Feed	13	548	1.80	0.0400
Group*Day*Time*Feed	13	548	1.14	0.3211

Table 2: Output data of Phase 2 results. Any P-values below 0.05 are considered statistically significant. P-values ranging from 0.05-0.1 indicate a trend in the data. The data highlighted are specific to this project and does not show significance.

Unfortunately, the data in neither phase of the study was statistically significant. However, in Phase 1, an individual day Effect Group*Feed had a P-value of 0.0698 which shows a trend that the infected lambs consumed more SL than the control group.

A graphical depiction of the data shows that as the days progressed, parasitized lambs consumed more SL than the control group. (Figure 1) Continuing into Phase 2, the previously infected (now control) lambs continued to eat more SL than those that were infected at that time (Figure 7). However, in both phases of the project, both groups preferred corn over SL.

Figures 3 & 5 are directly correlated. The FEC graph shows the infection of the infected lambs peaking around week 1 with a gradual decrease into the latter weeks (Figure 5). As the lambs ate more SL, their overall FEC decreased, thus showing the efficacy of this natural remedy.

Due to the infection not taking in Phase 2 (Figure 11), the graphs do not show any trends for interpretation and will be discussed later.

Discussion

As shown in the results, there was no significance as to which feed that the infected lambs preferred. The principle of SL therapeutic effect is shown in the decrease in the FEC as the infected lambs consumed more toward the midpoint of the study. It is interesting to note that the Phase 1 infected lambs continued to eat an increased amount of SL in the Phase 2 as controls. This could indicate that the lambs learned from Phase 1 that SL had medicinal properties, so they continued to consume the SL (as well as the corn) through Phase 2 to prevent reinfection, a kind of self-medication learned preference known as prophylaxis (Coffey et al., 2007).

Unfortunately, the infection did not take in Phase 2. This could be attributed to the increasing immunity of the growing lambs, which could have prevented the L3 from establishing. If this project were to be run again, younger, more susceptible lambs should be used to prevent immune intervention during the summer when *H. contortus* infections peak.

The amount of feed offered could have also contributed to the insignificance of preference results. Although the sheep were offered the same volume of SL as corn (1 can), they actually received more corn because of its greater density. The results would be more accurate if lambs were to receive an equal amount of each feed. During both phases of the study most lambs would eat both buckets of feed in turn yielding no preference for that day. Although the lambs grew over the three month period duration of the study, their feed rations remained unchanged. It could have been that they preferred the corn to SL, but ate both buckets for satiety. To prevent this from occurring, enough feed would have to be given so that the lambs will leave their lesser preferred feeds. Since some of the lambs would not eat when a human was present, their eating behavior was not observed; it remains uncertain whether they ate one bucket at a time or switched between each during feeding time.

This study, along with those previously published, demonstrates to producers that SL may be of benefit in integrated parasite control and management systems. Since CT does not primarily kill parasites, they can be used as a means to preserve refugia in the 70% of lambs that are not heavily burdened. Pasture contamination would be greatly reduced due to the inhibitory effect on adult worm prolificacy resulting in a lower number of eggs found in feces. The use of CT containing plants as an alternative method of parasite control is important to rural farmers of lower economic status that do not have access or cannot afford to purchase chemical anthelmintics, to which parasite resistance is increasing at an alarming rate.

More research is being performed on small ruminant zoopharmacognosy. Sheep are naturally “smart” as they are capable of selecting a less palatable, therapeutic feed contrary to their taste preferences. If CT containing forages are planted among palatable grasses such as rye and bermudagrass, this provides a way for small ruminants to self-medicate without producers having to chemically intervene to combat infection.

References

Besier, B., Department of Agriculture and Food, 2 Nov. 2015. Web. 11 Mar. 2016. https://www.agric.wa.gove.au/livestock-research-development/development-and-production-vaccine-against-barbers-pole-worm-sheep

Coffey, Hale, Terrill, Mosjidis, Miller, and Burke, "Tools for Managing Internal Parasites in Small Ruminants: Sericea Lespedeza." (2007): n. pag. Web. <http://www.ag.auburn.edu/agrn/faculty/Mosjidis/lab/documents/2007%20SL%20sericea_lespedeza%20ATTRA.pdf>.

George Et. Al. MODULE2. HELMINTHS: ANTHELMINTIC RESISTANCE: DIAGNOSIS, MANAGEMENT AND PREVENTION. Food and Agriculture Organization, n.d. Web. 10 Mar. 2016. ftp://ftp.fao.org/docrep/fao/010/ag014e/ag014306.pdf

Gradé, J. T., John R. S. Tabuti, and Patrick Van Damme. "Four Footed Pharmacists: Indications of Self-Medicating Livestock in Karamoja, Uganda." Econ Bot 63.1 (2008): 29-42.

Haslam, E., 1989. Plant Polyphenols. Cambridge University Press, Cambridge.

Huffman, M.A. "Current Evidence For Self-Medication in Primates: A Multidisciplinary Perspective." Amer J Phys Anthropol 104.S25 (1997): 171-200. *Academic Search Complete*. Web. 30 Mar. 2016.

Lange, K.C, et al. 2006. Effect of sericea lespedeza (Lespedeza cuneata) fed as hay, on natural and experimental Haemonchus contortus infections in lambs. Vet Parasitol 141. p. 273–278.

Lisonbee, L.D., J.J. Villalba, F.D. Provenza, and J.O. Hall. 2009. Tannins and self-medication: Implications for sustainable parasite control in herbivores. Behav Process 82:184-189

Li. Y., J.E. Miller, and D.E. Franke. "Epidemiological Observations And Heterosis Analysis of Gastrointestinal Nematode Parasitism in Sufflok, Gulf Coast Native, And Crossbred Lambs." Vet Parasitol 98 (2001); 273-283. *ScienceDirect.* Web. 30 Mar. 2016.

Min, B. R., W.E. Pomroy, S.P. Hart, and T. Sahlu. 2004. The effect of short-term consumption of a forage containing condensed tannins on gastro-intestinal nematode parasite infections in grazing wether goats. Small Rum Res 51. p. 279–283

Min, B.R., S.P. Hart, D. Miller, G.M. Tomita, E. Loetz, and T. Sahlu. 2005. The effect of grazing forage containing condensed tannins on gastro-intestinal nematode parasite infection and milk composition in Angora does. Vet Parasitol 151. p. 105–1

Rodriguez, E., and R. Wrangham. "Zoopharmacognosy: The Use Of Medicinal Plants By Animals." Recent Adv Phytochem (USA) (1993): 89. *AGRIS*. Web. 13 Mar. 2016.

Sendow, J. 2003. "Haemonchus contortus" (On-line), Animal Diversity Web. Accessed March 09, 2016 at http://animaldiversity.org/accounts/Haemonchus_contortus/

Stanton, Tatiana. "Using Copper Oxide Wire Particles to Help Control Barber Pole Worms on Northeast Sheep and Goat Farms." *Country Folks*. Cornell Sheep and Goat Program, 04 July 2014. Web. 10 Mar. 2016. <http://countryfolks.com/using-copper-oxide-wire-particles-to-help-control-barber-pole-worms-on-northeast-sheep-and-goat-farms/>.

Terrill, T.H., et al. "Experiences With Integrated Concepts For The Control of Haemonchus Contortus In Sheep and Goats In The United States." Vet Parasitol 186. Novel Approaches to the Control of Helminth Parasites of Livestock (2012): 28-37. ScienceDirect. Web. 30 Mar. 2016

Villalba JJ, Provenza FD, Hall JO, Lisonbee LD. 2010. Selection of tannins by sheep in response to gastrointestinal nematode infection. Journal of Animal Science, 88, 2189–2198

Villalba JJ, Landau SY. 2012. Host behaviour, environment and ability to self-medicate. Small Ruminant Research, 103, 50–59

Villalba, J. J., J. Miller, E. D. Ungar, S. Y. Landau, and J. Glendinning. "Ruminant Self-medication against Gastrointestinal Nematodes: Evidence, Mechanism, and Origins." Parasite 21 (2014): 1. EDP Sciences, 30 June 2014. Web. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4073621/pdf/parasite-21-31.pdf>.