Archivos Latinoamericanos de Producción Animal (Arch. Latinoam. Prod. Anim.)
www.alpa.org.ve/ojs.index/php

Alternatives to traditional anthelmintics to control gastrointestinal nematodes in grazing meat goats

J. M. Luginbuhl[1], S. Pietrosemoli, J. M. Howell, K. L. Anderson

North Carolina State University, Raleigh NC, USA
Recibido Marzo 29, 2010. Aceptado Abril 11, 2011.

ABSTRACT. Studies were conducted to determine the efficacy of a commercial herbal dewormer (HDC, Studies 1 and 2) and a tanniferous perennial legume (Study 3) to reduce fecal egg counts (FEC) in grazing goats (*Capra hircus*). Goats grazed *Festuca arundinacea* (Study 1), *Lolium multiflorum L.* (Study 2), and *Lespedeza cuneata* or *Tripsacum dactyloides* (Study 3). In study 1, the eggs per gram (EPG) of feces from goats orally-drenched weekly with HDC decreased from 1,006 to 758 by Day 33, then stabilized at a mean of 740 EPG until the end of the trial (Day 103). Conversely, FEC of goats drenched with ivomectin (IVO) decreased from 935 EPG to 163 EPG by Day 26, then steadily increased to 646 by Day 103. The EPG differed between IVO and HDC on Day 12, 19, 26, 33, 40 (P <0.0001), 47 (P <0.007), 54 (P <0.07), 61 (P<0.002), 68 (P <0.04) and 89 (P<0.09). In Study 2, neither oral fenbendazole nor one or two weekly doses of HDC had an effect on FEC, an indication of resistance to fenbendazole by gastrointestinal nematodes. In Study 3, FEC of goats grazing L. cuneata and *T. dactyloides* for 5 wk had decreased from 860 to 500 EPG for the former and increased from 1630 to 2310 EPG for the latter (P <0.06). Thereafter, FEC of goats switched from *T. dactyloides* to *L. cuneata* decreased to 1595, 1120 and 410 during the following 3 wk, whereas FEC of goats switched from *L. cuneata* to *T. dactyloides* still decreased to 220, 195, and 70 EPG (P <0.007, P <0.02, and P <.09, respectively). Within the confines of studies 1 and 2, HDC showed some or no effectiveness in reducing FEC in goats grazing infected pastures, whereas there was a significant reduction in FEC of goats grazing *L. cuneata.*

Key words: Gastrointestinal nematodes, Goat, Herbal dewormer, *Lespedeza cuneata*

Uso de alternativas a los anthelmínticos tradicionales para el control de nemátodos gastrointestinales en caprinos de carne

RESUMEN. En tres experimentos se determinó la eficacia de un antihelmíntico botánico comercial (DBC, Estudios 1 y 2) y de una leguminosa contentiva de taninos condensados (Estudio 3) para disminuir los huevos por gramo de heces (HPG) en caprinos. Los caprinos pastorearon *Festuca arundinacea* Shreb (Estudio 1), *Lolium multiflorum* L. (Estudio 2) o *Lespedeza cuneata* y *Tripsacum dactyloides* (Estudio 3). En el Estudio 1, el HPG de los caprinos dosificados oralmente con DBC disminuyó y se estabilizó en 740 HPG hasta el fin del ensayo (Día 103). Por el contrario, el HPG de las cabras dosificadas oralmente con ivomectin (IVO) disminuyó de 935 a 163 (Día 26), y luego se incrementó constantemente hasta 646 (Día 103). Los HPG de IVO y DBC fueron estadísticamente diferentes en los Días 12, 19, 26, 33 y 40 (P<0.0001), 47 (P <0.007), 54 (P <0.07), 61 (P <0.002), 68 (P <0.04) y 89 (P <0.09). En el Estudio 2, las dosis orales de febendazol y una o dos dosis semanales de DBC no tuvieron efecto en HPG, circunstancia que indica resistencia de los parásitos gastrointestinales al febendazol. En el Estudio 3, el HPG de caprinos pastoreando *L. cuneata* y *T. dactyloides* durante 5 sem. disminuyó de 860 a 500 con la primera especie y se incrementó de 1630 a 2310 con la segunda (P <0.06). Luego, los conteos de HPG de caprinos cambiados de *T. dactyloides* a *L. cuneata* disminuyeron hasta 1595, 1120 y 410 durante las tres siguientes semanas, mientras que el HPG de los caprinos cambiados de *L. cuneata* a *T. dactyloides* continuo disminuyendo a 220, 195, y 70 (P <0.007, P <0.02, y P <.09, respectivamente). Considerando los alcances de los estudios 1 y 2, HDC mostró poca o ninguna efectividad en la reducción de HPG en caprinos pastoreando pastizales infectados con nematodos gastrointestinales, mientras que el pastoreo de *L. cuneata* propició una respuesta favorable.

[1]Autor para la correspondencia, e-mail: jean-marie_luginbuhl@ncsu.edu

Palabras clave: Antihelmíntico botánico, Caprinos, *Lespedeza cuneata,* Nemátodos gastrointestinales

Introduction

Infection by trichostrongyle gastrointestinal nematodes (GIN), particularly *Haemonchus contortus*, is considered the primary constraint to economical goat (*Capra hircus*) production in warm and humid climatic conditions (Miller, 1996). Over the past half century, the intensive use of anthelmintic drugs has been the method of choice to control GIN. However, this approach has led to the emergence and transmission of nematode populations resistant to one or all three major classes of currently available broad-spectrum anthelmintics (Mortensen *et al.,* 2003; Terrill *et al*., 2001), a worldwide phenomenon particularly severe in small ruminant industries (Jackson and Coop, 2000). Other problems associated with the use of traditional anthelmintic drugs include the withdrawal time necessary to prevent the risk of pharmaceutical residue in food products (Waller and Thamsborg, 2004), and safety in pregnant or lactating animals (Conder and Campbell, 1995). Furthermore, chemical anthelmintics may either be too costly to use by producers in developing countries, or unavailable. These factors together with the persistent demands of the public for organically raised, chemical-free animal products, have given a strong impetus to producers and researchers to devise safe, novel, effective, and economical methods of GIN control. One alternative involves the use of plants or their extracts based on ancient herbal remedies with demonstrated levels of activity against nematodes and other parasites of humans and animals (Duval, 1996; Guarrera, 1999; Waller *et al.,* 2001), whereas another approach focuses on forages containing condensed tannins [CT] (Hoste *et al.,* 2006; Min *et al.,* 2003).

The objective of these trials was to determine the efficacy of two non-pharmaceutical alternatives against naturally-acquired GIN infection in goats, a commercial herbal dewormer (HDC) and a perennial leguminous forage containing CT, to decrease fecal egg counts (FEC) in grazing goats.

Materials and Methods

Three studies were conducted at the North Carolina State University, Small Ruminant Research and Educational Unit (NCSU-SREU) in Raleigh, NC, located at approximately 35.75° N latitude and 78.75° W longitude. The climate is temperate with 1,191 mm long-term mean annual rainfall and average annual maximum and minimum temperatures of 21.1 and 10.5ºC, respectively. Soils of the study area were Cecil Series (Clayey, Kaolinitic, Thermic, Typic Hapludult), on slopes ranging from 6 to 10% (USDA, 1970).

Study 1

Twenty-four naturally infected F1 Boer X Landrace castrated goats with an average initial live weight (LW) and age of 21.8 ± 3.8 kg and 7 mo, were stratified by their initial number of trichostrongyle-type eggs per gram of feces (EPG) and placed in subgroups of six animals each. Goats were then randomly assigned within subgroup to one of two experimental treatments to balance EPG across treatments. At the start of the trial (18 December), 12 goats received an oral drench of ivermectin (IVO; Merial, Division of Merck and Co., Rahway, NJ) at 0.2 mg/kg LW, the dose recommended for sheep (Ovis aries). The other 12 goats received 2 tsp of HDC twice a day for three consecutive days, and once a day weekly thereafter for 15 wk according to recommendations received from the company marketing this product (Farmstead Health Supply, Hillsborough, NC). The HDC is an herbal powder containing a mixture of *Allium sativum L.*; *Artemisia absinthium* (LINN.), commonly called wormwood, *Centaurium erythraea L., Foeniculum vulgare P. Mill., Gentiana lutea L., Plantago psyllium L., Achillea millefolium L., Chondrus crispus L., Coriandrum sativa L., Foeniculum vulgare P. Mill., Hyssopus officinalis* (LINN.), *Juniperus communis L., Laminaria digitata (Hudson) Lamouroux, Rheum rhabarbarum L., Sambucus racemosa L., and Tussilago farfara L.* The HDC was mixed with water in a 20 cc syringe and given as an oral drench solution. According to the marketers of HDC, every batch comes from the same lot of herbs and from the same company, which would reduce variation in composition.

Throughout the trial, goats on both treatments were co-grazing an old stand of *Festuca arundinacea* L. Schreb var. Kentucky 31 pastures naturally infected with trichostrongyle eggs. Goats had free-choice access to a mineral mix (SSC-317803, Southern States Cooperative, Inc. Richmond, VA), water and shelter. Live weights, and fecal and blood samples were obtained from each goat during the weekly scheduled drenching. The average daily gain (ADG) for each goat was calculated by regressing LW over days.

Study 2

Forty-five naturally infected Boer X Landrace yearling female and castrated male goats were stratified by initial LW (39 ± 3.9 kg) and placed in subgroups of five animals with similar LW. Animals were then randomly assigned within sub-group to one of nine *Lolium multiflorum L.* var. Florlina paddocks (0.14 ha) to balance LW across paddocks. *L. multiflorum* had been sod-drilled in October at the rate of 42 kg/ha and fertilized at planting and in February of the following year with 56 kg N/ha in the form of pelleted ammonium nitrate (Green Charger Fertilizer Co., Richmond, VA). All goat groups were managed on their respective paddocks using controlled rotational grazing with electronetting (Premier1 Supplies, Washington, IA). Goats were moved to a fresh strip of grass three to four times per week depending on forage availability, and immediately back fenced. Goats had free-choice access to the mineral mix used in Study 1 and water. Following an initial grazing of all paddocks from 19 Mar. to 10 Apr. to infect goats with GIN, they all received an oral drench of fenbendazole (FBZ; Intervet, Millsboro, DE) at 15 mL/ kg LW on 15 Apr. In addition, goats received either 0 HDC (T1), 2 tbsp HDC (T2), the recommended dose (Farmstead Health Supply, Hillsborough, NC) or 4 tbsp HDC (T3) twice daily for three consecutive days starting on 15 Apr., followed by once a day on a weekly basis when collecting fecal and blood samples. Fecal and blood samples were taken on 10 Apr., and on a weekly basis for 28 d after first administration of HDC and FBZ.

Study 3

Plots of *Lespedeza cuneata* (Dum.-Cours. G. Don) var. Serela, a perennial tanniferous legume (Mosjidis *et al.*, 1990), and *Tripsacum dactyloides* [L.] L. var. Pete, a warm-season native grass, were sod-drilled in late February and early May, respectively. *T. dactyloides* was seeded at a rate of 22.4 kg/ ha of dry seeds wet pre-chilled since the first week of March, and *L. cuneata* at a rate of 33.6 kg/ha of dehulled seeds.

Twenty-four naturally infected Boer X Landrace castrated yearling goats (LW: 40.6 ± 3.7 kg) were separated into two equal groups and initially control-grazed on either *L. cuneata* or *T. dactyloides* with electronetting. Goats were control-grazed from 30 Apr. until 9 Sep. four years after the initial planting. Plots measured 0.16 ha each. Goats were moved to a fresh forage strip depending on forage availability, and immediately back fenced. Goats had free-choice access to mineral mix used in Study 1 and water. After 4 Jun., goats initially control-grazed on *L. cuneata* were switched to plots of *T. dactyloides* and goats initially control-grazed on *T. dactyloides* were switched to plots of *L. cuneata*. Fecal samples were obtained weekly from each goat. The objective was to monitor EPG while switching pastures among goat groups on a monthly basis.

Fecal and blood sampling and laboratory analyses. Fecal samples were obtained directly from the rectum of each animal and placed in individual fecal cups stored in ice for transport to the laboratory. The EPG were determined by a modified McMaster technique (Paracount-EPG™, 1984; Kaufmann, 1996) using a saturated salt solution.

Blood samples were taken by jugular vein puncture using 20-gauge, 2.54 cm needles, and aspirated into a 10 mL glass vacutainer tube containing 3.6 mg K2 EDTA solution as an anti-coagulant (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ). Blood samples were kept in ice for transport to the laboratory and processed the day of collection. A Labquake shaker (Fisher Scientific, Raleigh, NC) was used to keep the samples well mixed. Heparinized microhematocrit capillary tubes (Fisher Scientific, Raleigh, NC) were then filled slightly more than halfway with blood and sealed at one end (Hemato-Seal Tube Sealing Compound, Fisher Scientific, Raleigh, NC). The capillary tubes were then spun in a microcentrifuge (IEC Micro-HB Centrifuge, Fisher Scientific, Raleigh, NC) at 14,000 rpm for 4 min. After spinning, packed cell volume (PCV) was measured using a micro capillary reader (Fisher Scientific, Raleigh, NC). The capillary tubes were then broken and one drop of plasma was placed on a refractometer (Fisher Scientific, Raleigh, NC) to determine plasma protein (PP).

Animal Care. All goats used during the studies described herein were born and raised at the NCSU–SREU in Raleigh, NC. Management and experimental practices were approved by the North Carolina State University Institutional Animal Care and Use Committee.

Statistical Analyses. Data from all studies were analyzed using the MIXED procedure of SAS (2009). Studies 1 and 2 were analyzed as randomized complete block designs (Steel *et al.*, 1997) with four animal replicates and three observations per cell (Study 1), and with three field replicates and five observations per cell (Study 2). Study 3 was analyzed as a completely randomized design with 12 observations per treatment. The FEC data were log transformed: ln(FEC + 10). Statistical inferences were made on transformed data and untransformed means were presented.

Results and Discussion

Study 1

Treating goats with IVO resulted in a dramatic drop in EPG (Figure 1A). The EPG remained low until 27 Jan. (Day 40), after which they increased. This response is typical of animals receiving a single dose of chemical anthelmintic and then continuously grazing contaminated pastures. Nevertheless, EPG only decreased by 80.4, 82.1 and 82.6% by 30 Dec., 6 Jan., 13 Jan. (Day 12, 19, and 26 post-IVO treatment), respectively. Goats were drenched according to the dosage recommended for sheep. As the rate of passage of digesta is faster in goats than in sheep and as goats metabolize drugs at a much faster rate (Conder and Campbell, 1995), it is possible that goats received a sub therapeutic dose of IVO. Alternatively, these results may indicate the start of anthelmintic resistance by GIN on the NCSU–SREU premises.

Goats in the HDC treatment group showed an initial decrease followed by a peak on 6 Jan. (Day 19). The EPG then leveled out after 20 Jan (Day 33). The EPG differed and were higher for HDC than for IVO on 30 Dec. and 6, 13, 20 and 27 Jan. ($P < 0.0001$), 3 Feb. ($P < 0.007$), 10 Feb. ($P < 0.07$), 17 Feb. ($P < 0.002$), 24 Feb. ($P < 0.04$) and 17 Mar., respectively Day 12 to Day 68 and 89 post initial treatment. These results also showed that HDC administered weekly kept EPG values at an average of 740 from 20 Jan. (Day 33) until the end of the trial (Day 103) while the average for the IVO goats for the same period was 472 EPG. Nonetheless, by the end of the experiment on 31 March, the EPG of IVO and HDC goats had reached 646 and 896, respectively.

Plasma protein (g/dL) tended to decline for each treatment group as the trial progressed (Figure 1B). All measured values were well within normal range, although two individual values, one in each treatment group, were slightly below those deter- mined normal for goats in North Carolina (6.4 - 8.0 g/dL) by Stevens *et al.* (1994). Packed cell volume (%) differed ($P < 0.05$) on 20 Jan., 10 Feb., and 14 Mar. (Figure 1C). Packed cell volume values showed no distinct explainable patterns. Worm burdens of *H. contortus* species may not have been high enough to show a dramatic difference between treatments for these two variables. Average daily gain for the IVO-treated group tended to be higher (mean: 77.3 g/d) than ADG of the HDC-treated group (mean: 71.5 g/d; $P < 0.09$; data not shown). This trend in ADG could be attributed to the immediate action of IVO.

The marketers of HDC claim signs of parasitism (pale eyelids and diarrhea) will be alleviated when their herbal product is given weekly following treatment with a chemical anthelmintic (Phillips and Gladden, 1996). Their brochure also claims that when an animal seems to be anemic, treatment with the HDC mixture for three days will alleviate clinical evidence of parasitism. Various active ingredients are found in the HDC such as *allicin*, a *diallyl thiosulfinate* thought to be responsible for the anthelmintic effects of *A. sativum* through its ability to expel gastrointestinal parasites (Chevallier, 1996; Koch and Lawson, 1996), although recent studies (Burke *et al.*, 2009b) failed to show any control of *H. contortus* with garlic products. According to Grieve (1971), the secoiridoids found in *C. erythraea* and *G. lutea* are thought to strengthen digestive function as well as help expel parasites from the intestines. The same author also reported that *G. lutea* contains amarogentin, the compound responsible for its bitter qualities that stimulates bitter taste receptors and ultimately improves the digestive process. *Centaurium erythraea* has also been given as a vermifuge to expel parasites and worms from the intestines (Grieve, 1971), and has also been useful in treating anemia (Lipp, 1996). *Foeniculum vulgare* is believed to have antiflammatory qualities and *P. psyllium* is thought to remedy diarrhea. *Artemisia absinthium* is noted for its extreme bitterness. The bitter quality of that plant stimulates salivary gland and digestive organ secretions. *Ar. absinthium* is also thought to have tonic, stomachic, febrifuge, and anthelmintic qualities (Chevallier, 1996). One of the constituents of *A. absinthium,* a volatile oil containing sesquiterpene lactones, is anti-inflammatory and strongly insecticidal. Most importantly, preparations of *A. absinthium* are thought to be helpful in treating anemia, and have been shown to be a moderately effective remedy for eliminating worms (Chevallier, 1996).

The appropriate dosage recommended for sheep weighing approximately 19 kg (Farmstead Health Supply, Hillsborough, NC) was used in preparing the HDC treatment solution. As goats metabolize anthelmintics at a much faster rate than sheep and have a faster digesta passage rate (Conder and Campbell, 1995), it is possible that the HDC-treated goats received a sub therapeutic dose of HDC. However, higher doses of *A. absinthium* could be toxic or cause abortion in pregnant animals (Waller *et al.*, 2001). Finally, a factor to consider regarding

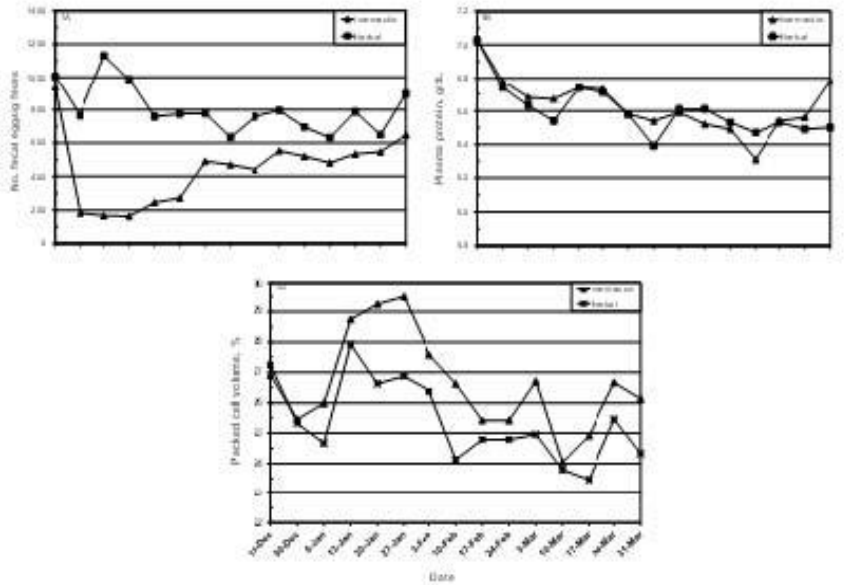

Figure 1. [A] Eggs per gram of feces, [B] plasma protein (g/dL), [C] packed cell volume (%) from castrated goats treated with a single dose of ivermectin on Day 1 or a weekly dose of herbal dewormer. The herbal dewormer was initially drenched twice a day for three consecutive days starting on 18-Dec (Study 1)

the level of effectiveness of HDC is the moderate initial EPG levels.

Study 2.

The EPG levels at the start were at least four times higher than in the previous study. Unfortunately, the oral drench of fenbendazole had no effect on EPG (Figure 2A), strongly suggesting that GIN present on the NCSU-SREU were resistant to that class of anthelmintics. Ambrosini (2000) reported similar results in sheep. Therefore, in the current scenario the claim that signs of parasitism (pale eyelids and diarrhea) are alleviated when HDC are drenched weekly following treatment with a chemical anthelmintic (Phillips and Gladden, 1996) could not be verified. The EPG may have decreased at a faster rate in the higher HDC-treated goats until 25 Apr. Nevertheless, EPG were similar between treatments on every sampling date and decreased steadily during the course of the trial from an average of 4,134 on 10 Apr. to 1,568 on 13 May. Environmental conditions during the course of the study may provide some insight to explain the above results. During the initial grazing of all paddocks to infect goats with GIN, 9.2 cm rain fell on 31 Mar. Thereafter, a total of only 4.9 cm fell between 1 Apr. and 12 May with the majority falling on 10 Apr. (1.9 cm) and 4 May (1.7 cm). As daily high temperatures averaged 24.6°C (range: 11.9 to 32.8°C) during that same period, most of this moisture was probably lost to evaporation. Rain is known it be important in releasing larvae from the manure onto the herbage, whereas larvae will be retained in the fecal pellets during dry weather (Fleming *et al.*, 2006). Therefore, the environmental conditions prevailing from 1 Apr. until 12 May have influenced the life cycle of GIN and could explain the decreasing EPG observed.

Plasma protein and PCV values were similar between treatments (Figure 2B and C), and showed no pattern during the course of the trial. All values were within normal range. The absence of relationship between EPG and PP or PCV is not unusual when goats reaching their mature LW are grazed on high quality pastures (Glennon, 2004). In the present study, plucked samples of *L. multiflorum* averaged 4.2% nitrogen on 17 Apr.

The differing responses observed in Studies 1 and 2 may have been due in part to environmental conditions (Winter vs. Spring, low rainfall vs. high rainfall). As initial EPG also were drastically different, whether or not an EPG threshold exist for herbal dewormers to show an acceptable degree of effectiveness to keep adult worms or EPG in check is open to question. Failure of a commercial herbal dewormer to control GIN in kid and adult dairy goats was reported recently by Burke *et al.* (2009a) who drenched a medicinal plant mixture containing *A. absinthium*, *A. sativum* and *F. vulgare.*

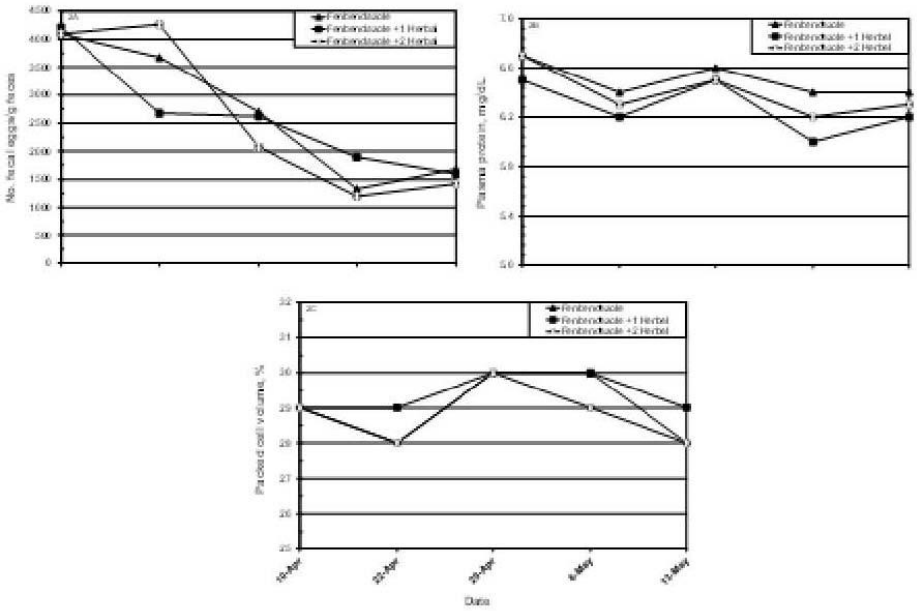

Figure 2. [A] Eggs per gram of feces, [B] plasma protein (g/dL), [C] packed cell volume (%) from goats treated with fenbendazole on 15-Apr and one or two weekly doses of herbal dewormer. The herbal dewormer was initially drenched twice a day for three consecutive days starting on 15-Apr (Study 2).

Study 3.

The EPG of goats grazing L. cuneata and T. dactyloides for three weeks had decreased from 860 to 500 EPG for the former (Figure 3) and increased from 1630 to 2310 for the latter (P <0.06). Following the pasture move on 4 Jun., the EPG of goats switched from *T. dactyloides* to *L. cuneata* decreased to 1595 (-31.0%), 1120 (-51.5%), and 410 (-82.3%) during the following 3 wk whereas the EPG of goats switched from *L. cuneata* to *T. dactyloides* still decreased to 220, 195, and 70 EPG (P<0.007, P<0.02, and P <0.09, respectively). These results are consistent with the findings of Min *et al.* (2004) showing that fecal EPG are rapidly suppressed after switching goats from a non-tanniferous forage to *L. cuneata.* The same authors also speculated the existence of a carryover effect when switching goats from *L. cuneata* to a non-tannin-containing forage.

The EPG of both groups then stayed low and similar (mean: 211) until 15 Jul. Thereafter, following moderate rainfall at the end of Jun. and throughout Jul. (Figure 4) with daily high temperatures averaging 32.0°C (range 23.1 to 37.3°C), EPG of goats grazing *T. dactyloides* increased on 29 Jul. to 350(P <0.004),

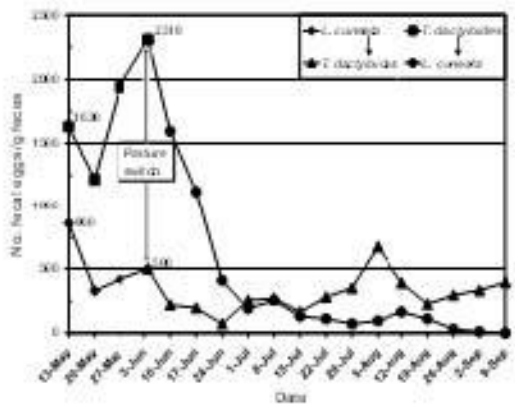

Figure 3. Egg per gram of feces from yearling goats grazing either *Tripsacum dactylloides* or *Lespedeza cuneata* pastures. Goats were switched to the other pastures on 4-Jun. (Study 3).

reaching 675 (P <0.0009) on 5 Aug. During that same period, EPG of goats grazing *L. cuneata* decreased below 100 (29 Jul.: 70; 5 Aug.: 95). As no rain fell between 30 Jul. and 14 Aug. with daily high temperatures of 32.7°C (range 27.9 to 36.4°C), EPG in goats grazed on *T. dactyloides* decreased to 390 and 225 on 12 and 19 Aug., respectively, while EPG of goats grazed on *L. cuneata* remained low (165 and 110, respectively). As 2.5 and 5.8 cm of precipitation fell on 14 to 16 and 18 to 19 Aug., respectively, followed by 11.5 cm on 24 to 31 Aug., EGP of goats grazed on *T. dactyloides* started to diverge upward while EGP on goats grazed on *L. cuneata* were negligible (26 Aug.: *T. dactyloides* 295, *L. cuneata* 30, P <0.004; 2 Sep.: *T. dactyloides* 333, *L. cuneata* 10, P <0.0001; 9 Sep.: *T. dactyloides* 394, *L. cuneata 10*, P <0.0002). Whether or not this moderate increase was the direct effect of moisture promoting egg hatching and/or releasing larvae from the manure onto the pasture, or larvae resuming development following a period of hypobiosis in the host (Zajac, 2006), or a combination of both, is speculative.

It is unfortunate that EPG were first determined two weeks after the start of the study on 30 Apr. Nevertheless, one can speculate that EPG of goats grazing *L. cuneata* had already dropped since the start of the study. According to Min *et al.* (2004), the suppression of FEC following the ingestion of forages containing CT can be observed in as few as 5 d, a period more rapid that would be expected from an immune response. Recently, *Luginbuhl et al.* (2009) have reported a decrease in EPG from 2,269 (Day 0) to 947 (Day 7) and 406 (Day 14) when switching yearling goats from a *Pennisetum americanum* to a *L. cuneata* pasture. Several authors have reported reduced worm counts in small ruminants fed fresh (Niezen *et al*., 2002) or dried (Paolini *et al*., 2003) CT-containing forages, or purified CT (*Athanasiadou et al*., 2000, 2001). *Min et al.* (2004) and Shaik *et a*l. (2006) reported a reduction in egg hatching and larval development of *H. contortus* in feces of goats either grazing or fed *L. cuneata*. Molan *et al.* (1999, 2000) reported an inhibition of egg hatching and larval development of *T. colubriformis* exposed to CT extracted from several forages. Shaik et al. (2006) showed that the number of adult male and female *H. contortus*, *Teladorsagia circumcinta* and *T. culubriformis* were all reduced in goats fed *L. cuneata* hay, with a greater reduction in the number of female nematodes compared with males. According to Athanasiadou *et al*. (2000), the fecundity of female nematodes exposed to CT was markedly reduced. More recently, Brunet *et al.* (2008) reported that the consumption of *Lysiloma latisiliquum* (Tzalam), a tannin-rich plant from the Yucatan peninsula in México, was associated with reduced *H. contortus* and *T. colubriformis* larval establishment.

Condensed tannins have the ability to bind to proteins and to change their properties, both physical and chemical. In addition, GIN cuticles are a proline and hydroxyproline-rich structure that covers not only the nematode body, but also the buccal cavity, the esophagus, the cloaca and the vulva (Thompson and Geary, 1995). The binding ability of CT could explain the changes observed in the cuticle of gastrointesstinal nematodes following their exposure to CT (Hoste *et al*., 2006). Recently, de Montellano *et al.* (2008) reported changes in the cuticle, the buccal capsule and the vulva, along with a thickening of both the longitudinal and transversal cuticle ridges of *H. contortus* following 24 h of *in vitro* contact to tannin-rich extracts of *Lysiloma latisiliquum* (Tzalam) and *Onobrychis viciifolia* (sainfoin). The same authors speculated that aggregate of tannin-rich extracts attached to *H. contortus* might reduce its motility, and might affect access to nutrition and egg excretion.

The lack of increase in EPG when moving goats grazing *L. cuneata* to *T. dactyloides* (Figure 3) seemed surprising. However, the months of May and June (Figure 4) were extremely dry (mean rainfall: 5.1 cm) and warm (mean daily high: 28.4°C), environmental

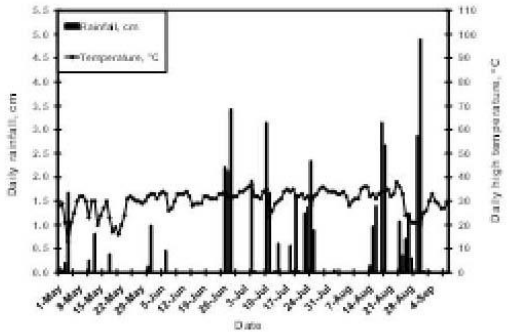

Figure 4. Daily rainfall (cm) and daily high temperature (°C) from 1-May to 4-Sep. (Study 3).

conditions not favorable to egg hatching and larvae survival and development, thus pasture larvae loads were most probably very low. Under more favorable environmental conditions, the rapid increase in EPG reported by Min *et al.* (2004) when switching goats grazing *L. cuneata* to a *Cecale cereale/ Digitaria sanguinalis* pasture seemed to show that the effect of CT was rapidly reversed. This rapid upward trend in EPG also seemed to indicate that adult worms were not eliminated by exposure to CT for 15 d, but rather that their reproduction and fecundity were impaired. Recently, Luginbuhl *et al*. (2009) have reported an increase in EPG from 242 to 981(+305.3%) by Day 7 and to 1,325 (+447.5%) by Day 14 when switching yearling goats from a *L. cuneata* to a *P. americanum* pasture. Moreover, moving growing goats grazed on a *L. cuneata* pasture for 49 d to an indoor barn with a slotted-floor, and feeding them only grass hay and a grain mixture, the same authors reported increases in EPG from 21 to 1,410 (+6,614%) by Day 21 to 5,181(+24,571%) by Day 28. Whether or not grazing *L. cuneata* pastures for longer periods would reduce adult worm burdens remains to be investigated. Nevertheless, results by Luginbuhl *et al.* (2009) seemed to demonstrate the high resilience of GIN to CT.

Conclusions

Gastrointestinal parasitism may be the most challenging health problem associated with raising goats as resistance of GIN to all classes of conventional pharmaceutical anthelmintics has been documented in many areas of the world. In addition, most of these drugs are not labeled for goats. Therefore, there is a critical need for alternatives to traditional pharmaceutical anthelmintics. In addition, growing demands of the public for organically raised, chemical-free, and wholesome animal products are forcing producers and researchers to devise new, effective, and economical methods of gastrointestinal parasite control. Under the conditions of these experiments, the herbal dewormer failed to effectively control GIN in meat goats. Conversely, the use of the tanniferous legume *L. cuneata to* control GIN seems to offer a viable alternative. Nevertheless, additional research to devise optimal approaches for integrating *L. cuneata* and other tanniferous forages into grazing and browsing systems and comprehensive GIN control programs is urgently needed.

Literature Cited

Ambrosini, F. 2000. A survey of anthelmintic resistance in Trichostrongylid parasites of sheep in Italy. J. Agric. Environ Intl. Dev. 94:175-195.

Athanasiadou, S., I. Kyriazakis, F. Jackson, and R. L. Coop.2000. Effect of short term exposure to con-densed tannins on adult *T. colubriformis*. Vet. Record 146:728-732.

Athanasiadou, S., I. Kyriazakis, F. Jackson, and R. L. Coop.2001. Direct anthelmintic effects of condensed tannins toward different gastrointestinal nematodes of sheep: *in vitro* and *in vivo* studies. Vet. Parasitol. 99:205-219.

Brunet, S., J. F. J. Torres Acosta, C. A. Sandoval-Castro, A. J. Aguilar-Caballero, C. Capetillo-Leal, and H. Hoste. 2008. The consumption of Tzalam (*Lysiloma latisiliquum*), a tropical tanniferous plant is associated with a reduced larval establishment of parasitic nematodes in goats. In: A. J. Aguilar-Caballero, J. F. J. Torres-Acosta, A. Ducoing-Watty, A. Cerillo-Soto, A. S. Juárez-Reyes, and G. Martínez-Kawas (Eds.) Sustainable Goat Production: Challenges and opportunities of small and large enterprises. Proc. 9th Intl. Conference on Goats. Querétaro. Mexico. p 281.

Burke J. M., A. Wells, P. Casey, and R. M. Kaplan. 2009a. Herbal dewormer fails to control gastrointestinal nematodes in goats. Vet. Parasitol. 160: 168-170.

Burke J. M., A. Wells, P. Casey, and J. M. Miller. 2009b. Garlic and papaya lack control over gastrointestinal nematodes in goats and lambs. Vet. Parasitol. 159: 171-174.

Chevallier, A. 1996. The Encyclopedia of Medicinal Plants. Dorling Kindersley Limited, London.

Conder, G. A., and W. C. Campbell. 1995. Chemotherapy of nematode infections of veterinary importance, with special reference to resistance. In: J. R. Baker, R. Muller, and D. Rollinson (Eds.) Advances Parasitol. 35:1-84.

De Montellano, M. O., C. Fourquaux, I. Brunet, J. F. J. Torres-Acosta, C. A. Sandoval-Castro, and H. Hoste. 2008. Scanning electron microscopy of the changes induced to *Haemonchus contortus* after contact with extracts of two tanniferous plants: Tzalam (*Lysiloma latisiliquum*) and sainfoin (*Onobrychis viciifolia*). In: A. J. Aguilar-

Caballero, J. F. J. Torres-Acosta, A. Ducoing-Watty, A. Cerillo-Soto, A. S. Juárez-Reyes, and G. Martínez-Kawas (Ed.) Sustainable Goat Production: Challenges and Opportunities of Small and Large Enterprises. Proc. 9th Intl. Conference on Goats. Querétaro. Mexico. p 281

Duval, J. 1996. The control of internal parasites in ruminants. Ecological Agriculture Projects, McGill Univ. http://eap.mcgill.ca/AgroBio/abe_head.htm.

Fleming, S. A., T. Craig, R. M. Kaplan, J. E. Miller, C. Navarre, and M. Rings. 2006. Anthelmintic resistance of gastrointestinal parasites in small ruminants. J Vet. Intern. Med. 20: 435–444.

Glennon, H. M. 2004. Effect of copper oxide needles on gastrointestinal parasites in grazing meat goats. MS. Thesis. North Carolina State University. Raleigh, NC.

Grieve, M. 1971. A Modern Herbal. The medicinal, culinary, cosmetic and economic properties, cultivation and folklore of herbs, grasses, fungi, shrubs and trees with all their modern scientific uses. Penguin, London.

Guarrera, P.M., 1999. Traditional antihelmintic, antiparasitic and repellent uses of plants in Central Italy. J. Ethnopharmacol. 68, 183–192.

Hoste, H., F. Jackson, S. Athanasiadou, S. M. Thamsborg, and S. O. Hoskin. 2006. The effects of tannin-rich plants on parasitic nematodes in ruminants. Trends Parasitol. 22:253-261.

Jackson, F., and R. L. Coop. 2000. The development of anthelmintic resistance in sheep nematodes. Parasitology 120, S95–S107.

Kaufmann, J. 1996. Parasitic infections of domestic animals: A diagnostic manual. Birkhauser Verlag, Basel.

Koch, H. P, and L. D. Lawson. 1996. Garlic, The science and therapeutic application of *Allium sativum L.* and related species. (2nd Ed.) Williams and Wilkins. Baltimore.

Lipp, F. J. 1996. Herbalism. Little, Brown and Company, Boston.

Luginbuhl, J. M., J. E. Miller, T. H. Terrill, and H. M. Glennon. 2009. Evaluation of *Sericea lespedeza* as a summer forage and for helminth control of grazing goats. J. Anim. Sci. 87(E-Suppl. 3):37. Abst.

Miller, J. E., 1996. Controlling goat parasites in the Southeast. In: Proc. Southeast Regional Meat Goat Production Symp.: Meat Goat Production in the Southeast—Today and Tomorrow, 21–24 February 1996, A&M University, Tallahassee, Florida, pp. 80–82.

Min, B. R., T. N. Barry, G.T. Attwood, and W. C. McNabb. 2003. The effects of condensed tannins on the nutrition and health of ruminants fed fresh temperate forages: a review. Anim. Feed Sci. Technol. 106:3-19.

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 gastrointestinal nematode parasite infections in grazing wether goats. Technical note. Small Rum. Res. 51:279-283.

Molan, A. L., G. C. Waghorn, and W. C. McNabb. 1999. Condensed tannins and gastrointestinal parasites in sheep. Proc. N. Z. Grassl. Assoc. 61:57-61.

Molan, A. L., G. C. Waghorn, B. R. Min and W. C. MacNabb.2000. The effects of condensed tannins from seven herbages on *Trichostrongylus colubriformis* larval migration *in vitro*. Folia Parasitol. 47:39-44.

Mortensen, L. L., L. H. Williamson T. H. Terrill, R. A. Kircher, M. Larsen, and R. M. Kaplan. 2003. Evaluation of prevalence and clinical implications of anthelmintic resistance in gastrointestinal nematodes in goats. JAVMA 223, 495–500.

Mosjidis, C. O'H., C. M. Peterson, and J. A. Mosjidis. 1990. Developmental differences in the location of polyphenols and condensed tannins in the leaves and stems of *Sericea lespedeza*, *Lespedeza cuneata.* Ann. Botany 65:355-360.

Niezen, J. H., W. A. G Charleston, H.A. Robertson, D. Shelton, G. C. Waghorn, and R. Green. 2002. The effect of feeding sulla (*Hedysarum coronarium*) or lucerne (*Medicago sativa*) on lamb parasite burdens and development of immunity to gastrointestinal nematodes. Vet. Parasitol. 105:229–245.

Paolini, V., P. Dorchies, and H. Hoste. 2003. Effects of Sainfoin hay on gastrointestinal infection with nematodes in goats. Vet. Record 152:600-601.

Paracount-EPG™. 1984. Veterinary Quantitative Fecal Analysis Kit. Professional modified McMaster egg counting technique for calculating parasite egg per gram (EPG) of feces samples. Olympic Equine Products. Issaquah, WA.

Phillips, L. and S. Gladden. 1996. Farmstead Health Supply. Information packet. Hillsborough, NC.

SAS. 2009. The SAS System for Windows. Release 9.1. SAS Institute, Cary NC.

Shaik, S. A., T. H. Terrill , J. E. Miller, B. Kouakou, G. Kannan, R. M. Kaplan, J. M. Burke, and J. A. Mosjidis. 2006. *Sericea lespedeza* hay as a natural deworming agent against gastro-intestinal nematode infection in goats. Vet. Parasitol. 139: 150-157.

Steel, R. G. D., J. H. Torrie, and J. H. Dickey, 1997. Principles and procedures of statistics: A biometrical approach. McGraw-Hill Series in Probability and Statistics, (3rd Ed.) WCB/ McGraw-Hill Co., New York.

Stevens, J. B., K. L. Anderson, M. T. Correa, T. Stewart, and W. E. Braselton, Jr. 1994. Hematologic, blood gas, blood chemistry, and serum mineral values for a sample of clinical healthy adult goats. Vet. Clin. Path. 23:19-24.

Terrill, T. H., R. M. Kaplan, M. Larsen, O. M. Samples, J. E. Miller, and S. Gelaye. 2001. Anthelmintic resistance on goat farms in Georgia: efficacy of anthelmintics against gastrointestinal nematodes in two selected goat herds. Vet. Parasitol. 97, 261–268.

.

Thompson, D. P. and T. G. Geary. 1995. The structure and function of helminth surfaces. In: J J. Marr and M. Mueller (Eds.) Biochemistry and Molecular Biology of Parasites. Academic Press. London. pp 203-232.

United States Dept. of Agric., Soil Conservation. Service, and North Carolina Agric. Exp. Station. 1970. Soil Survey of Wake County, North Carolina. U.S. Gov. Printing Office, Washington, DC.

Waller, P. J., G. Bernes, S. M. Thamsborg, A. Sukura, S. H. Richter, K. Ingebrigtsen, and J. Höglund. 2001. Plants as deworming agents of livestock in the Nordic countries: historical perspective, popular beliefs and prospects for the future. Acta Vet. Scand. 42:31–44.

Waller, P. J. and S. M. Thamsborg. 2004. Nematode control in green ruminant production systems. Trends Parasitol. 20:493–497.

Zajac, A. M. 2006. Gastrointestinal nematodes of small ruminants: life cycle, anthelmintics, and diagnosis. Vet. Clin. Food Anim. 22: 529–541.