Effect of tannins-rich plants to control gastrointestinal nematodes in Zebu cows grazing in a sub-tropical sylvopastoral system

M. A. Galina Hidalgo[1], L. J. Pineda[2], E. Olvera, R. M. Ortiz, A. Cuellar, and E. Galinado[2]

Facultad de Estudios Superiores Cuautitlan, UNAM, Carretera Cuautitlan-Teoloyucan, San Sebastián Xhala, Cuautitlan Izcalli, Estado de México,

Abstract. Two grazing systems were compared, one of a conventional sort limited to grass (GS) and the other a mixed sylvopastoral system (SGS), with respect to their effect on control of gastrointestinal parasitic nematodes. Sixty-two lactating crossbred Zebu cows (457 ± 25 kg bodyweight) were divided into in two groups of 31 each. The GS group was maintained 24 h daily without shade, grazing *Cynodon* or *Brachiaria* herbage, while the SGS cows had access to the above mentioned grasses and to a subtropical forest. All of the animals received 2.5 kg/d of a slow-intake supplement containing urea. The measurements performed were: fecal parasite egg counts on eight occasions over 200d, identification of nematodes by growth of their larvae in culture, packed red blood cell volume (PCV), FARMACHA index value based on coloration of the conjunctiva mucosa, and body condition score (BCS). A greater number of eggs per gram of feces (EPGF) were found in GS cows than in those of SGS (p<0.05). In both systems the PCV remained within the normal range, but the FAMACHA© value was higher under SGS (p<0.05). The BCS of SGS and GS cows were 3.3 and 2.7 respectively (p<0.01). In GS data the following correlations (r) were obtained: negative, EPGF with PCV (-0.77), with BCS (-0.61) and with FAMACHA score (-0.41); and positive, BCS with FAMACHA value (0.62). In SGS data the highest and negative condition was that of PCV with FAMACHA© score (-0.32). The principal nematodes identified in culture for both systems were *Oesophagostomum spp, Haemonchus contortus, Trichostrongylus* and *Cooperia spp*. It was concluded that the mixed sylvopastoral system shows promise for controlling parasitic nematode infection in bovines to the benefit of animal health.

Key words: Grazing, Nematodes, Parasite control, Subtropical forest, Tannins

Efecto de plantas ricas en taninos en el control de nemátodos gastrointestinales en vacas cebuinas pastando en un sistema silvipastoril subtropical

Resumen. Se comparó un sistema de pastoreo convencional limitado a gramíneas (GS) contra otro de tipo mixto silvipastoril (SGS) referente al control de nematodos parasíticos gastrointestinales. Se dividieron 62 vacas cebuinas mestizas lactantes (457 ± 25 kg) en dos grupos de 31 animales. El grupo GS se mantuvo las 24 h al aire libre de pastoreo en forraje *Cynodon* o *Brachiaria*, mientras el grupo SGS tuvo acceso a las citadas gramíneas y también a un bosque subtropical. Todos los animales recibieron 2,5 kg/d de un suplemento de urea de consumo lento. Se realizó el conteo fecal de huevos de parásitos en ocho ocasiones durante 200 d, la identificación de nemátodos por el crecimiento de las larvas, el volumen proporcional de las células rojas sanguíneas aglomerado (PCV), el índice FAMACHA© basado en la coloración de la mucosa de la conjuntiva y la condición corporal (BC). Se verificó una mayor cantidad de huevos por gramo de heces (EPGF) en las vacas GS que en las SGS (P<0,05). En ambos sistemas el PCV se mantuvo dentro de los límites normales, pero el índice FAMACHA© fue mayor bajo el SGS (P<0,05). El marcador BC fue de 3,3 y 2,7 en SGS y GS, respectivamente (P<0,01). En el sistema GS se obtuvieron las siguientes correlaciones: negativas, EPGV con PCV (-0.77); con BC (-0.61) y con índice FAMACHA (-0.41) y positiva BC con índice FAMACHA (0.62). En el SGS la correlación más alta fue la negativa de PCV con

Recibido: 2015-05-07. Aceptado: 2016-10-02

[1] Autor para la correspondencia: Miguel Angel Galina Hidalgo" miguelgalina@unam.mx

[2] Facultad de Medicina Veterinaria y Zootecnia, Universidad de Colima.

índice FAMACHA (-0.32). Los principales nematodos identificados en cultivo de larvas en ambos sistemas fueron *Oesophagostomum* spp, *Haemonchus contortus*, *Trichostrongylus* y *Cooperia* spp. Se concluye que el sistema silvipastoril es promisorio como modo de combatir los nematodos parasíticos y promover mejor salud animal.

Palabras clave: Bosque subtropical, Control de parásitos, Nematodos, Pastoreo, Taninos

Introduction

Increasing interest is directed toward development of alternative methods to reduce the dependence on chemical treatments for controlling parasitic nematode infections (Torres-Acosta and Hoste, 2008). Although many different species of nematode parasites infect ruminant livestock, there are only a relatively few that cause major economic or sanitary problems, examples of which are: *Haemonchus spp, Ostertagia/Teladorsagia spp, Trichostrongylus spp, Nematodirus spp* and *Cooperia spp*. (Waller, 2006). Economic evaluation has shown that the major losses due to parasites are in animal production, rather than mortality (Perry and Randolph, 1999; Perry *et al*., 2002). Conventional methods of controlling gastrointestinal nematode parasites of grazing livestock have relied on the use of chemical anthelmintics (AH) due to the remarkable development of these products in terms of efficacy, safety, spectrum of activity and relatively low cost. However, the spectrum of parasite resistance and the increasing demand by consumers for "clean" and "green" agricultural products to diminish the threat of adverse environmental effects from the use of any chemicals in agricultural production has also driven the agenda (Waller, 2006). Experience and prospects for controlling internal parasites in grazing ruminants without use of AH were reviewed extensively by Niezen *et al*. (1996).

The use of bioactive plants is one such alternative. Plants have been used throughout history for their medicinal properties. This use has often focused on human health but plants are also applied in veterinary practice and animal health management (Rochefort *et al*., 2008).

Tannin-rich (TR) plants have been studied in regard to veterinary medicine (Ramírez-Restrepo and Barry, 2005; Hoste *et al*., 2006). *In vivo* studies have shown an AH effect related to consumption of TR plants (Niezen *et al*., 1996; Athanasiadou *et al*., 2001; Paolini *et al*., 2003a; 2003b). The main TR plant affect reported has been a reduction of L_3 stage establishment (Paolini *et al*., 2003a; Tzamaloukas *et al*., 2006). Plant tannins impair nematode larval development and viability (Hoste *et al*., 2005; 2011) and their AH properties depend on quality and tannin concentration (Landu *et al*., 2010). *In vitro* screenings have related the potential AH properties of several tropical legumes (Hammond *et al*., 1997; Cresswell, 2007; Hoste *et al*., 2008) including various Mexican species (*Acacia gaumeri, Havardia albicans, Pisidia piscipula, Lysiloma latisquum* and *Leucaena leucocephala*) (Alonso-Díaz *et al*., 2008a; 2008b; Hernandez-Orduño *et al*., 2008). However, most of the studies *in vivo* and *in vitro* have been conducted on small ruminants (Martinez-Ortiz-de-Montellano *et al*., 2010). Very little knowledge has been generated on TR plants or their effect on controlling gastrointestinal nematodes in browsing livestock.

Previously, research showed that alternative pasture plants such as *Lotus corniculatus* and *Chicorium intybus* can reduced the gastrointestinal worm burden in ruminants (Rochefort *et al*., 2008). There is a question as to whether this effect is one of plant structure (i.e. higher level grazing resulting in less reinfection in animals through manure ingestion) or is due to biological activity of the polyphenolic phyto-chemicals in the forage (Paolini *et al*., 2003b; Marley *et al*., 2005; Ramirez-Restrepo and Barry, 2005). The AH action of secondary metabolites has been the subject of recent reviews exploring both *in vitro* and *in vivo* effects of plant constituents (Ghisalberti, 2002; Githiori *et al*., 2006). A large number of plants possess documented nematocidity, tough for the majority the bioactives responsible for this activity remain unidentified (Ghisalberti, 2002).

Previous studies have demonstrated the evolution of multiple resistance of parasites to AH treatments, which has become a severe problem in the abatement of parasite infections (Moors and Gauly, 2009). Ovine gastrointestinal parasitism is considered one of the main causes of economic losses in the tropical sheep industry. This situation reaches an alarming dimension when AH resistance appears. Among the alternatives for controlling sheep parasites the FAMACHA© system is useful (Moors and Gauly, 2009). Therefore, the prevention of resistance is an important factor in parasite control. Selective treatment of the most infected and/or anaemic animals helps to prevent the development of drug resistance. The FAMACHA© chart, developed in South Africa by Malan *et al*. (2001), is a simple system to categorized the anaemic status of small ruminants based on a conjunctiva mucosa colour score on a scale from 1 (optimal eye colour, red) to 5 (pale eye colour, white). To the best of our knowledge this method has not been applied to large ruminants. The FAMACHA© system seems to be a suitable method to detect and prevent parasite infections in sheep and goats (Malan *et al*., 2001; Van Wyk and Bath, 2002; Vatta *et al*., 2001; 2002; Kaplan *et al*., 2004), however a similar relationship between conjunctiva mucosa colour and parasite infection in cattle awaits testing.

Therefore, the aim of the present study was to measure the effect of grazing in a pure grass pasture or in a mixed sylvopastoral system on gastro-intestinal nematode infections in cattle and to test the feasibility of the FAMACHA© conjunctiva mucosal colouring principle in large ruminants.

Material and Methods

The experiment was conducted in the dry tropic of Colima, Mexico, at 19°23′ latitude north, 103°41′ longitude west and 1,400 m above sea level. Köppen´s climate classification is Aw1 (w) with rainy season from July to October. Mean annual rainfall is 1,048 mm and temperature 25°C. The tree community is one of subtropical *deciduous* forest.

Animal management

During May to November (200 days), 62 crossbred Zebu cows, all in their second, third or fourth lactation (mean age 3-7 yr), in mid lactation and of 457 ± 25 kg bodyweight, were divided into two groups of 31 each. One group (SGS) was submitted to 24 h sylvopastoral grazing system in which the cows browsed freely in a subtropical deciduous forest located beside fields of grass forage and were obliged to pass through the forest, to drink water directly from a flowing river (Ortiz *et al*., 2002). The SGS grazing area encompassed 8.8 ha of *Cynodon plactostachyus*; 8 ha of *Brachiaria brizantha* and 10 ha of tropical deciduous forest. The second group (GS) was kept outdoors 24 h daily in 9 ha of *C. plactostachyus* and 10 ha of *B. brizantha* pastures with drinking water available *ad libitum*. Each animal group was offered 2.5 kg daily of a slow intake urea supplement (SIUS) (Galina *et al.*, 2003). Stocking rates varied from 3.6 to 5.9 AU/ha. At all times, grass availability exceeded the voluntary dry matter intake (VDMI). The animals grazed for 6 mo, to ensure their contact with the parasites.

Laboratory analyses

The animals were followed and observed during 4 h daily at 7 d intervals to identify the plants ingested. Samples of trees and shrubs consumed were taken for analyses of dry matter (DM) (24 h at 105°C), neutral and acid detergent fibre (NDF and ADF) (Van Soest *et al.,* 1991). The NDF was determined without the use of alpha amylase, as no starch was expected in the plants analyzed, but with the addition of sodium sulphite as recommended by Robbins *et al.* (1987) for tanniniferous forages in order to remove insoluble protein-tannin complexes. Values of NDF, ADF and lignin were not corrected for ash content.

The *in vitro* digestibility of dry matter (IVDDM) was evaluated according to Tilley and Terry (1963). Fermentation residues were analyzed for DM and N only. Condensed tannins (CT) were extracted using the method of Barahona *et al*., 2003).

Fecal egg count and larval culture

Fecal samples were taken monthly directly from the rectum of 12 cows selected randomly and kept in plastic bags properly marked. Egg counts were performed using a modified McMaster technique with a detection level of 50 eggs per gram of feces (EPGF) (Morales and Pino, 1977). Identification of larval growth was according to the method of Morales *et al*. (2001).

Packed red cells volume (PCV)

Blood samples of 12 animals selected randomly were taken directly from the coccygeal vein, using vacuum tubes containing EDTA. PCV (%) was determined by microhaematocrit centrifuge technique (Camus, 1983).

FAMACHA© index

The coloration of eye conjunctiva mucosa of 12 cows was evaluated according to the scale of the FAMACHA© system developed for small ruminants (Malan *et al.,* 2001; Molento *et al.,* 2004), which estimates clinical anemia, using a scale from 1 (normal) to 5 (fatal).

Body condition score (BCS)

Body condition was evaluated on a scale from 1 (very thin) to 5 (obese) (Martinez *et al*., 1998; Wildman, *et al*., 1982).

Statistical analysis

Linear regressions were calculated to estimate the associations between pairs of the variables EPGF, PCV, BCS and FAMACHA© index (clinical anemia). Linear regression slopes obtained from sylvopastoral system and conventional grazing system were compared by T test.

Results

Laboratory analyses

Forage plants consumed by the cows and various criteria for their characterization are summarized in Table 1. Crude protein content ranged from 18.0% to 25.9% in the 13 legumes and was 9.9% and 10.7% in the two grasses *C. plactostachyus and B. brizantha* respectively. The crude protein digestibility was high in all cases ranging from 71.6% to 92.7%. *Desmodium spp* had the highest content of ADF (49.2%) and *Bunchosia palmeri* the lowest (16.8%). Condensed tannins content ranged from 3.65% in *Platymiscium lasiocarpum* to 12.5% in *Plumera rubra*, whereas in the grasses CT content was no higher than 0.64%.

Fecal egg count and larval culture

Over the course of the experiment (Figure 1) a progressive and significant increase of EPGF occurred in both systems, but with consistently lower levels in SGS. Observations began during the peak of the dry season (May) and continued till the end of the rainy season (November).

Linear regression quantified this trend in EPGF in both systems, with respective coefficients (b) of 2.47 and 1.40 EPGF daily in GS and SGS ($P<0.05$).

Larval culture identified three types of nematodes present in SGS *Oesophagostomum spp, Haemonchus contortus, Trichostrongylus* and *Cooperia spp*. In GS the nematodes recovered were mainly *Haemonchus contortus Oesophagostomum spp, Strongyloides spp* and *Chabertia spp*.

Packed red cells volume (PCV)

The packed red cells volume measured in both systems remained within normal ranges, but the percentage in SGS did not vary as much as in GS. However, there was no statistical correlation between parasite infection and the measured values for hemoglobin and PCV (Figure 2).

FAMACHA© index

Student T test to compare the conjunctiva color index (FAMACHA©) between the two systems (SGS and GS), demonstrated a difference of 0.7 ($P<0.05$) in the FAMACHA © scale, indicating that SGS was superior to GS (3.4 vs. 2.7), demonstrating better health.

A negative correlation was obtained between the EPGF and index of conjunctiva color (-0.41) proving the feasibility of using the latter in large ruminants.

Body condition score. The mean BCS in SPS remained steady at 3.3, while GS showed a lower value of 2.7 ($P<0.01$).

Correlations.

Linear regression analysis showed that under the conventional management of GS, EPGF was negatively correlated with PCV (-0.77) BCS (-0.61) and FAMACHA index (-0.41).

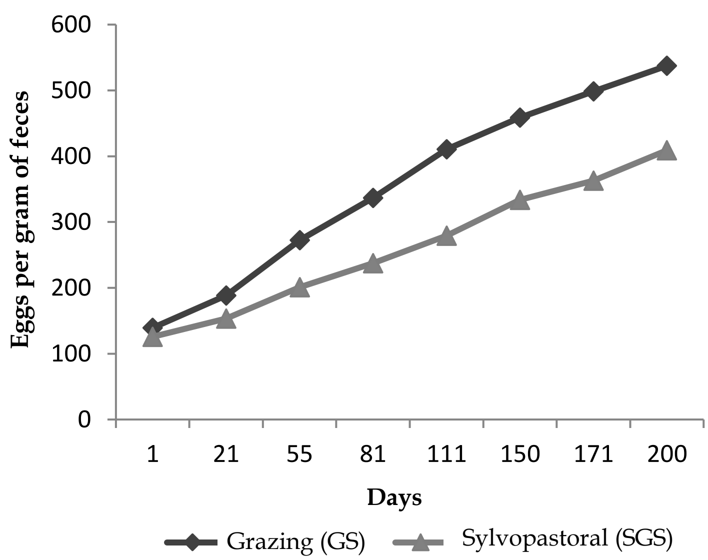

Figure 1. Trend estimated by linear regression of the number of eggs per gram of feces under each treatment.

Table 1. Characterization of the identified plants as to chemical composition, metabolizable energy, crude protein digestibility, condensed tannin content and anatomical part consumed by Zebu cattle

Plants	DM (%)	OM (%)	CP (%)	ADF (%)	NDF (%)	ME (Mcal/kg DM)	CPD (%)	CT (% DM)	Consumed Part
Mimosa púdica	25.4	93.3	19.8	37.6	50.4	2.1	85.4	8.30	Leaf
Plumera rubra	32.3	91.7	19.0	36.2	54.5	2.1	75.2	12.50	Leaf
Bunchosia palmeri	37.6	89.9	23.8	16.8	23.1	1.9	71.6	11.30	Leaf
Cordia alliodora	27.1	95.3	18.0	40.5	48.8	1.9	78.3	7.80	Leaf
Platymiscium lasiocarpum	40.7	94.7	20.4	38.5	33.4	2.0	80.4	3.65	Leaf, stem
Erythroxylum mexicanum	23.3	97.2	24.3	27.3	37.3	1.9	83.8	4.17	Leaf, flowers
Cordia dentate	45.9	94.6	25.9	16.4	28.2	2.0	81.2	5.36	Leaf, stem
Erythroxylum rotundifolium	38.4	91.9	19.5	20.8	26.2	2.0	84.9	6.70	Leaf
Caeselpina plumeria	35.8	93.6	21.6	26.4	36.1	1.9	92.7	5.20	Leaf
Guettarda elliptica	21.3	94.7	19.6	37.9	53.6	2.2	91.5	6.40	Leaf, Flowers
Randia capitata	35.3	92.8	18.7	41.7	43.7	2.1	80.8	7.10	Leaf
Caesalpina coriaria	35.5	93.1	21.4	21.0	31.3	1.7	87.8	6.25	Leaf, stem
Desmodium spp	20.1	95.1	22.4	41.5	49.2	2.0	92.2	3.90	Leaf, stem, flowers
Cynodon plactostachyus	24.5	82.7	9.9	40.1	75.7	2.4	85.8	0.64	---
Brachiaria brizantha	25.2	87.0	10.7	43.2	71.8	2.5	89.3	0.16	---

DM=Dry matter; OM=Organic matter; CP= Crude protein; ADF=Acid detergent fibre; NDF=Neutral detergent fibre; ME=Metabolizable energy; CPD= Crude protein digestibility; CT= Condensed tannins.

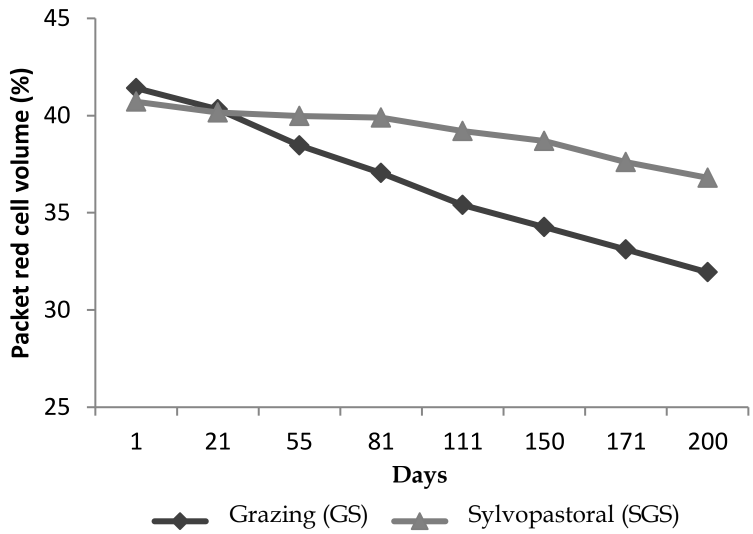

Figure 2. Trends estimated by linear regression of blood packed red cells volume under each treatment.

The positive and significant correlation between BCS and FAMACHA index (0.62) shows that animals with a high BCS are usually not anemic as judged by colour of the eyelid (Table 2).

Correlations determined for the sylvopastoral system showed no significant association of the EPG with any of the indicators of anemia (PCV, BC or FAMACHA index), and in fact the third of these correlations was unexpectedly positive (Table 3).

Table 2. Linear correlations for the conventional grazing system

Variables	Correlations coefficient
EPGF-PCV	-0.77
EPGF-Body Condition Score	-0.61
EPGF- FAMACHA© index	-0.41
PCV-Body Condition Score	0.18
PCV- FAMACHA© index	0.01
Body Condition Score- FAMACHA© index	0.62

EPGF= eggs per gram of faeces. PCV=Packed red cells volume.

Table 3. Linear correlations for the sylvopastoral system

Variables	Correlations coefficient
EPGF-PCV	-0.14
EPGF -Body condition score	-0.14
EPGF- FAMACHA© index	0.22
PCV - Body condition score	-0.25
PCV - FAMACHA© index	-0.32
Body condition score- FAMACHA© index	-0.16

EPGF= eggs per gram of faeces. PCV=Packed red cells volume.

Discussion

The present results showed a greater EPGF under conventional grazing compared to the SGS system. Hoste *et al*. (2011) mentioned that inclusion of sylvopastoral plants in the diet contributes to the restoration of appetite and less frequent diarrhea, which is related to a reduction of gastrointestinal adult worms and eggs in feces.

Thus the SGS promoted better health with lower nematode infection, due to reduced risk of parasitic contamination, as discussed by Soca and Areco (2000). Sylvopastoral systems involve significant changes in survivability of free-living parasite stages. In work with cattle by Soca *et al*. (2002) demonstrated a decrease in the number of gastrointestinal parasite eggs and more rapid decomposition of feces under a sylvo-pastoral system, compared with grazing of grasses only. In the present study the trend of EPGF showed an increase with time in both systems. Torres-Acosta and Hoste (2008) found a reduced charge of nematodes parasites when goats browsed leguminous trees, which is consistent with the present findings. Probably the parts of trees consumed by cattle in the present study were rich in tannins and this effected the growth and presence of nematodes.

The normal values of packed red cells volume, in bovines lie between 24% and 46%. Mean PCV measured in both systems remained within normal limits, but in SGS the variability was less than in GS. Other studies (Vasquez *et al*., 2006) have shown that PCV values are not always affected by the number amount of gastrointestinal parasites present.

The blood is composed of a clear fluid called plasma and a cellular component (mainly red cells). The proportion of red cells/plasma determines the degree of anemia present in the animal. This ratio can be estimated by observing the change in coloration of the mucous membranes of the eyes. Studies in Cuba showed the applicability of this methodology in the detection of anemia in sheep infected by *Haemonchus spp* (Arece, 2007). However, the applicability of this to bovine is unknown. The present study evaluated the feasibility of detecting anemic cows by use of FAMACHA© methodology in a sylvopastoral system.

Upon comparing the FAMACHA© index between the two systems (SGS and GS), a difference of 0.7 is found, in favor of SGS. In CS a negative correlation was obtained between the EPGF and intensity of conjunctiva color (-0.41), meaning that a higher egg count was associated with a greater degree of anemia. Malan and Van Wyk (1992) found associations between the color of conjunctiva of the eye, the PCV and the presence of *H. contortus*. Van Wyk *et al*. (1997) also associated PCV values with color intensity of the ocular conjunctiva.

Few studies have been conducted on grazing systems in the dry tropics with regard to sylvopastoral gastrointestinal nematode infection in cattle, but the present results show promise for nematode control. Although the development of free-living stages of parasites is generally faster in tropical than in temperate regions, their longevity is shorter. Cattle grazing under humid tropical climates are exposed to peak larval concentrations of *H. contortus* and *Trichostrongylus spp* about one week after contamination, but concentrations fall to barely detectable levels within 4-6 wks (Banks *et al*., 1990, Barger *et al*., 1994, Sani and Chandrawathani, 1996, Sani *et al*., 1996). Most research on effects of bioactive plants against gastrointestinal nematodes have focused on grazing sheep, including studies in which grazing animals were fed forage herbs freshly picked, or tree fodder. Most of the published work is focused on forage legumes, including *Coronarium* (Athanasiadou *et al*., 2005), *Sainfoin spp*, and *Onobrychis viciifolia* (Athanasiadou *et al*., 2005; Hoste, *et al*., 2006), *Serradella, Lotus corniculatus, Lotus pedunculatus)* and *Sericea lespedeza* (Hoste *et al*., 2006); *Cichorium intybus* (Hoste *et al*., 2006). Few data relate to the woody plants from a wide range of botanical families, which are consumed by goats, deer and, to a lesser extent, sheep grazing or browsing in tropical and temperate environments (Kabasa, 2000; Kahiya, 2003). No data on this issue of gastrointestinal nematode control in cattle by tannins were found in the literature reviewed.

Body conditions score is a subjective assessment of energy stored as fat and muscle at a given time. Changes in BCS are a reliable and practical guide to establish the nutritional status of the animal. Changes in the proportion of fatty tissue and muscle are not easily detected directly, but the estimates of BCS status represent a helpful tool (Roche *et al*., 2009). In the present work SGS resulted in higher BCS in comparison with GS, which suggests that the dairy cows lost less energy due to a high parasite load in their digestive system and therefore did not decline in BCS (Baños *et al*., 2004). In another study (Conti *et al*., 2007) dairy cows grazing on temperate Italian rye grass *(Lolium multiflorum),* and offered CT in the diet showed no change in BCS. Waghorn and Shelton, (1997) mentioned that the improved animal performance observed when the diet contains low levels of tannins has generally been attributed to the protection of feed protein from forming indigestible complexes in the rumen, leading to increased flow of essential amino acids to the small intestine and their absorption into the blood.

Larval culture undertaken in the present study identified three types of nematodes present that were similar to those reported by Soca *et al*., (2007) as being dangerous to cattle (*Haemonchus, Ostertagia/ Teladorsagia, Trichostrongylus, Nematodirus* and *Cooperia spp*). However, infections of gastrointestinal nematodes in grazing cattle almost always consist of a mixture of species. All have adverse effects and collectively produced a chronic low BCS score. Economic evaluations consistently show that the main losses caused by gastrointestinal parasites are from decreases in animal production, and to a lesser degree due to mortality (Hawkins, 1993; McLeod, 1995, Perry and Randolph, 1999, Perry *et al*., 2002).

Conventional methods to control this group of parasites have relied on AH. These products have initially shown efficacy, safety, a wide spectrum of activity and relatively low cost, thus livestock producers have relied almost exclusively on their use for control of nematodes (Waller, 2006). However, the increasing parasite resistance to all major groups of broad-spectrum AH has lessened the usefulness of this methodology in the control of parasites, particularly for ruminant livestock worldwide (Waller, 2006).

Many consumers now demand agricultural products that must be "clean" "green" and free of pharmaceuticals and agrochemicals. Interest in animal products of this type has grown due to the adverse publicity on the effects of these chemicals on human health and welfare. Also of concern is the development of new microbial pathogens "resistant" to the antibiotics used in intensive systems of livestock production (Milera *et al*., 2004). The present results suggest that a change in the system can be a non-aggressive, environmentally friendly mechanism, without using drugs or chemicals for control of gastrointestinal nematodes in ruminants.

The mechanism of the beneficial effects on internal parasites control through TR plants could involve a combination of the following factors: First, the tannins might form complexes with non-biodegradable protein in the rumen, which dissociate in the low pH of the abomasum, to produce more protein available for metabolism in the small intestine (Min *et al*., 2003; Hernandez-Orduño *et al*., 2008). This could indirectly improve host resistance and resilience to parasite infections. Secondly, the tannins might exert a direct AH effect on the worm populations present in animals. And third, the tannins and/or their associated metabolites in manure can have a direct effect on the development of eggs and viability of the free-living stages up to that of infectious larvae. The CT contents determined in the forage used in the present work were within the range reported in several studies (3-6% DM) in association with positive effects on host physiology, antiparasitic activity, growth, and wool or milk production (Min, *et al*., 2003; Waghorn and McNabb, 2003; Hoste, *et al*., 2006). Although there is evidence to support tannin AH activity, a direct plant de-worming effect remains unclear (Heckendorn *et al*., 2007).

The potential value of TR plants, as supported by results of *in vitro* and *in vivo* studies needs to be established and quantified in more detail (Hoste *et al*., 2006). These studies present difficulties, particularly in grazed TR plants. Other active compounds need to be identified and their mechanisms of actions delucidated, to enable development of efficient methods for controlling gastrointestinal nematodes. These are essential in order to use the TR plants more effectively and promote sustainable farming systems. It is essential to defend potential sources of both temperate and tropical TR plant resources. A better understanding of the mode of action of bioactive compounds of plants and their effects on specific forms and/or specific process control of parasites should also provide some indication of the risk of development of parasite resistance against tannins. Previous studies with the use of chemical AH has highlighted the fact that the control of gastrointestinal nematodes in ruminants cannot rely on a single alternative, but the TR plants have a potential role as a component of an integrated approach to control the gastroenteric verminosis (Hoste *et al*., 2006).

Conclusions

The present results provide evidence that SGS is a better alternative than GS for cattle production because the combination of microclimatic factors and grazing of TR plants, shrubs and trees, decreases the animals' parasite load, thus providing improved conditions for productive functioning, of animals in better health, as reflected in a lower burden of nematode eggs, and a higher PCV.

A high negative correlation was found between nematode infection and color of the conjunctiva mucosa, thus giving support to use of the FAMACHA© method in large ruminants.

Acknowledgments

Research supported by PAPPIT IN200809 UNAM

Literature Cited

Alonso-Díaz, M.A., J. F. J. Torres-Acosta, C. A. Sandoval-Castro, A. J. Aguilar-Caballero, and H. Hoste. 2008a. *In vitro* larval migration and kinetics of exsheathment *of Haemonchus contortus* exposed to four tropical tanniferous plants. Vet. Parasitol. 153:313-319.

Alonso-Díaz, M. A., J. F. J. Torres-Acosta, C. A. Sandoval-Castro, C. Capetillo-Leal, S. Brunet, and H. Hoste. 2008b. Effects of four tropical tanniferous plant extracts on the inhibition of larval migration and the exshearhment process of *Trichostrongylus colubriformis* infective stage. Vet. Parasitol. 153:187-192.

Arece, J. 2007. La metodología FAMACHA©: una estrategia para el control de estrongilidos gastro-intestinales de ovinos. Estudios preliminares. (The FAMACHA©: a strategy for gastrostrongiloid control on sheep. Preliminary studies) Rev. Salud Anim. (Cuba) 29(2):91-94.

Athanasiadou, S., O. Tzamaloukas, L. Kyriazaki, F. Jackson, and R. L. Coop. 2005. Testing direct anthelmintic effects of bioactive forages against *Trichostrongylus colubriformis* in grazing sheep. Vet. Parasitol. 127: 233-243.

Banks, D. J. D., R. Singh, I. A. Barger, B. Pratap, and L. F. Le Jambre. 1990. Development and survival of infective larvae of *Haemonchus contortus* and *Trichostrongylus colubriformis* in a tropical environment. Int. J. Parasitol. 20:155–160.

Baños, G., S. Brotherstone, and M. Coffey. 2004. Evolution of body condition score measured throughout lactation as an indicator of fertility in dairy cattle. J. Dairy Sci 87:2669-2676.

Barahona, R., C. E. Lascano, N. Narvaez, E. Owen, P. Morris, and M. K. Theodorou, 2003. *In vitro* degradability of mature and immature leaves of tropical forage legumes differing in condensed tannin and non-starch polysaccharide content and composition. J. Sci. Food Agric. 83:1256–1266.

Barger, I. A., K. Siale, D. J. D. Banks, and L. F. LeJambre. 1994. Rotational grazing for control of gastrointestinal nematodes of goats in a wet tropical environment. Vet. Parasitol. 53:109–116.

Bath, G., J. Hansen, R. Krecek, J. Vanwyk, and A. Vatta. 2001. Sustainable approaches for managing haemonchosis in sheep and goats. Final Report FAO technical cooperation in Africa. Project No. TCP/ SAF/8821 (a), FAO, Roma.

Camus, E. 1983. Diagnostic de la trypanosomose bovine sur le terrain par la méthode de centrifugation hematocrit. Rev. Sci. Tech. Off. Int. Epiz. 2(3):751–769.

Conti, G., O. Garnero, J. Bértoli, M. Gallardo, E. Gatti y O. Zoratti. 2007. Efecto de los taninos condensados sobre la producción y composición de leche de vacas lecheras en pastoreo de verano. Rev. Arg. Prod. Anim. 27(Supl. 1).

Cresswell, K. J. 2007. Anthelmintic effects of tropical shrub legumes in ruminant animals. PhD Thesis. James Cook University. 293 pp.

Dimander, S. O., J. Höglund, A. Uggla, E. Spörndly, and P. J. Waller. 2003. Evaluation of gastrointestinal nematode parasite control strategies for first-season grazing cattle in Sweden. Vet. Parasitol. 117:173-183.

Galina, M., F. P. Perez-Gil, J. D. Hummel, R. M. A. Ortiz, and E. R. Ørskov. 2003. Effect of slow intake urea supplementation on fattening of steers feed sugar cane tops (*Saccarum officinarum)* and maize (*Zea mays*) with or without SIUS. Ruminal fermentation, feed intake and digestibility. Lives Prod Sci. 83 (1): 1-11.

Ghisalberti E. L. 2002. Secondary metabolites with antinematodal activity. In: Attaur-Rahman, (Ed.) Studies in Natural Products Chemistry 26:425–506.

Githiori, B., S. Athanasiadou and S. M. Thamsborg. 2006. Use of plants in novel approaches for control of gastrointestinal helminthes in livestock with emphasis on small ruminants, Vet. Parasitol. 139:308–320.

Hammond, J. A., D. Fielding, and S. C. Bishop. 1997. Prospect for plant anthelmintics in tropical veterinary medicine. Vet. Res. Commun 21:213-228.

Hawkins, J. A. 1993. Economic benefits of parasite control in cattle. Vet. Parasitol. 46:159-173

Heckendorn, F., D. A. Haring, V. Mauer, M. Senn, and H. Hertzberg. 2007. Individual administration of three tanniferous forage plants to lambs artificially infected with *Haemonchus contortus* and *Cooperia curticei*. Vet. Parasitol. 146:123-134.

Hernandez-Orduño, G., J. F. J. Torres-Acosta, C. A. Sandoval-Castro, A. J. Aguilar-Caballero, R. R. Reyes-Ramírez, H. Hoste, and J. A. Calderón-Qiintal. 2008. *In vitro* anti-helminthic effect of *Acacia goumeri*, *Havaradia albicans* and quebracho tannin extracts on a Mexican strain of *Haemonchus contortus* L. Trop. Subtrop. Agroecosystem. 8:191-197.

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

Hoste, H., S. Sotiraki, and J. F. Torres-Acosta. 2011. Control of endoparasitic nematode infection in goats. Vet. Clin. Food Anim. 27:163-173.

Hoste, H., J. F. Torres-Acosta, V. Paolini, A. Aguilar-Caballero, E. Etter, Y. Lefrileux, C. Chartier, and C. Broqua. 2005. Interaction between nutrition and gastrointestinal infections with parasitic nematodes in goats. Small Rumin. Res. 60:141-151.

Hoste, H., J. F. J. Torres-Acosta, and A. J. Aguilar-Caballero. 2008. Nutrition-parasite interaction in goats: Is immunoregulation involved in the control of gastrointestinal nematodes? Parasite Immunol. 30:79-88.

Kabasa, J.D. 2000. The effect of oral administration of polyethylene glycol on faecal helminth egg counts in pregnant goats grazed on browse containing condensed tannins. Trop. An. Health. Prod 32: 73–86.

Kahiya, C. 2003. Effects of Acacia nilotica and Acacia karoo diets on Haemonchus contortus infection in goats. Vet. Parasitol. 115:265–274.

Kaplan, R.M., J. M. Burke, T. H. Terril, J. E. Miller, W. R. Getz, S. Mobini, E. Valencia, M. J. Williams, L. H. Williamson, M. Larsen, and A. F. Vatta. 2004. Validation of FAMACHA© eye color chart for detecting clinical anemia in sheep and goats on farms in the southern United States. Vet. Parasitol. 123:105-120.

Landu, S., H. Azaizeh, H. Muklada, T. Glasser, E. D. Ungar, H. Brarm, N. Abbas, and A. Markovics. 2010. Anthelmintic activity of *Pistacia lentiscus* foliage in two Middle Eastern breeds of goats differing in their propensity to consume tannin-rich browse. Vet. Parasitol. 173:280-286.

Malan, F. S., and J. A. Van Wyk. 1992. The packed cell volume and colour of the conjunctivae as aids for monitoring *Haemonchus contortus* infestations in sheep. In: Proceedings of the South Africa Veterinary Association Biennial National Veterinary Congress. Grahamstown, FAO. 139.

Malan, F. S., J. A. Van Wyk, and C. D. Wessels. 2001. Clinical evaluation of anaemia in sheep early trials. Onderstepoort J. Vet. Res. 68:165-17.

Marley, C. L., M. D. Fraser, R. Fychan V. J. Theobald, and R. Jones. 2005. Effect of forage legumes and anthelmintic treatment on the performance, nutritional status and nematode parasites of grazing lambs, Vet. Parasitol. 131**:** 267–282.

Martínez N., P. Herrera, B. Birbe, y C. Domínguez. 1998. Relación entre la condición corporal y la respuesta reproductiva de hembras bovinas de doble propósito. En: Madriz N. y E. Soto (Eds.) Mejora de la Ganadería Mestiza de Doble Propósito. Astro Data, Maracaibo, Venezuela. pp. 398-412.

Martinez-Ortíz-de-Montello, C., J. J. Vargas-Magaña, H. L. Cantú-Ku, H. Hoste, J. F. and G. Torres-Acosta. 2010. Effect of a tropical tannin-rich plant *Lysiloma latisiliquum* on adult population of *Haemonchus contortus* in sheep. Vet. Parasitol. 172:283-290.

McLeod, R. S. 1995. Costs of major parasites to the Australian livestock industries. Int. J. Parasitol. 25:1363-1367.

Milera, M., H. Machado, O. López, T. Sánchez, y S. Sánchez. 2004. Producción de leche en sistemas de pastoreo biosostenibles y/o biodiversos. Av. Invest. Agropecuaria, 1(8):12-24.

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

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

Molento, M., C. Tasca, A. Gallo, M. Ferreira, R. Bonont y E. Stecca. 2004. Método FAMACHA© como parâmetro clínico individual de infecçâo por *Haemonchus contortus* em pequenos rumiantes. Ciencia Rural 34(4):1391-1145.

Moors, E. and M. Gauly. 2009. Is the FAMACHA© chart suitable for every breed? Correlations between FAMACHA© scores and different traits of mucosa colour in naturally parasite infected sheep. Vet. Parasitol. 166:108-111.

Morales, G., L. A. Pino, E. Sandoval, L. Moreno, L. D. Jiménez, y C. Balestrini. 2001. Dinámica de los niveles de infección por estrongilidos digestivos en bovinos a pastoreo. Parasitología al Día. 25(3-4):115-120.

Morales, G., y L. Pino. 1977. Manual de diagnóstico helmintológico en rumiantes. Caracas. Venezuela. 99 pp.

Niezen, J. H., W. A. G. Charleston, J. Hodgson, A. D. Mackey, and D. M. Leathwick. 1996. Controlling internal parasites in grazing ruminant without recourse to anthelmintics: approaches, experiences and prospects. Int. J. Parasitol. 26:983-992.

Ortiz, R. M. A., M. A. Galina, and M. M. A. Carmona. 2002. Effect of a slow non-protein nitrogen ruminal supplementation on improvement of *Cynodon nlemfuensis* or *Brachiaria brizanta* utilization by Zebu steers. Lives. Prod. Sci. 78 (2)125-131.

Paolini, V., J. P. Bergeaud, F. Grisez, P. Prevot, Ph. Doriches, and H. Hoste. 2003a. Effects of condensed tannins on goats experimentally infected with *Haemonchus contortus*. Vet. Parasitol. 113:331-339.

Paolini, V., A. Frayssines, F. De La Farge, Ph. Doroches, and H. Hoste. 2003b. Effects of condensed tannins on estabilished populations and incoming larvae of *Trichostrongilous colubriformis* and *Teladorsagia circumcincta* in goats: Vet. Res. 34:331-339.

Penn, B., C. Sar, B. Mwenya, K. Kuwaki, R. Morikawa, and J. Takahashi. 2006 Effects of *Yucca schidigera* and *Quillaja saponaria* extracts on in vitro ruminal fermentation and methane emission, *Anim. Feed Sci. Technol.* 129**:** 175–186.

Perry, B. D. and T. F. Randolph. 1999. Improving the assessment of the economic impact of parasitic diseases and of their control in production animals. Vet. Parasitol. 84:145-168.

Perry, B. D., T. F. Randolph, J. J. McDermott, K. R. Sones, and P. K. Thornton. 2002. Investing in animal health research to alleviate poverty. International Livestock Research Institute (ILRI), Nairobi, Kenya p 148.

Ramirez-Restrepo., C. A., and T. N. Barry. 2005. Alternative temperate forages containing secondary compounds for improving sustainable productivity in grazing ruminants. Anim. Feed Sci. Technol. 120:179-201.

Roche, J. R., N. C. Friggens, J. K. Kay, M. Fisher, K. J. Stafford, and D. P. Berry. 2009. Body condition score its association with dairy cow productivity, health and welfare. Review Article. J. Dairy Sci. 92:5769-5801.

Rochefort, S., A. Parker, and F. Dunshea. 2008. Plant bioactives for ruminants health and productivity. Photochemistry 69: 299-322.

Sani, R. A. and P. Chandrawathani. 1996. Gastrointestinal parasitism in small ruminants in Malaysia. In: Le Jambre, L. F., Knox, M. R. (Eds.), Sustainable Parasite Control in Small Ruminants, Proceedings No. 74.

Australian Centre for International Agricultural Research (ACIAR), pp. 98–100.

Sani, R. A., M. Mazila, M. Zaki, D. T. Chong, and I. Tajuddin. 1996. Grazing management for worm control in sheep–rubber integrated systems. In: Proceedings of the 18th Malaysian Society for Animal Production Annual Conference, 28–31 May 1996, Sarawak.

Soca, M. y J. Arece. 2000. Efectos de los sistemas silvopastoriles sobre el comportamiento de las nematodosis gastrointestinales de los bovinos jóvenes. En: Chamorro, D., (Ed.). Memorias Primer Curso intensivo de Silvopastoreo Colombo- Cubano. 24 agosto a 2 de septiembre de 2000. Corporación Colombiana de Investigación Agropecuaria, CORPOICA Estación Experimental de Pastos y Forrajes, Indio Hatuey, Cuba. CD-ROM.

Soca, M., L. Simón, D. García, Y. Roche, A. Aguilar y L. Carmona. 2002. Efecto de la velocidad de descomposición en el comportamiento del HPG en excretas de bovinos jóvenes bajo condiciones silvopastoriles. En: Memorias del V Taller Internacional sobre Utilización de los Sistemas Silvopastoriles en la Producción Animal. Estación Experimental de Pastos y Forrajes Indio Hatuey, Cuba. CD-ROM.

Soca, M., L. Simon y E. Roque. 2007. Árboles y nematodos gastrointestinales en bovinos jóvenes. Pastos y Forrajes, 30(5):1.

Tilley, J. M. A. and R. A. Terry. 1963. A two stage technique for the *in vitro* digestion of forage crops. J. Br. Grassl. Soc. 18:104-111

Torres-Acosta, J. F. J., and H. Hoste. 2008. Alternative or improved methods to limit gastrointestinal parasitism in grazing sheep and goats. Small Rumin. Res. 77:159-173.

Tzamaloukas, O., S. Athanasidou, I. Kyreazakis, J. F. Huntley, and F. Jackson. 2006. The effect of chicory (*Cichorium intybus*) and sulla (*Hedysarum coronarium*) on larval development and mucosal cell responses of growing lambs challenged with *Teladorsagia circumcincta*. Parasitology 132:419-426

Van Wyk, J. A. and G. F. Bath. 2002. The FAMACHA© system for managing *heamonchus* in sheep and goats by clinically identifying individual animals for treatment. Vet. Res. 33 (5):509-529.

Van Wyk, J. A., F. S. Malan, and G. F. Bath. 1997. Rampant anthelmintic resistance in sheep in South Africa –What are the options? In: Van Wyk, J. A., Van Shalkwyk, P. C. (Eds.) Managing Anthelmintic Resistance in Endoparasites. Workshop held at the 16th International Conference of the World Association for the Advancement of Veterinary Parasitology. Sun City, South Africa. 51-63.

Vasquez, H. M., G. R. González, H. G. Torres, P. Mendoza de Gives y R. J. Ruiz. 2006. Comparación de dos sistemas de pastoreo en la infestación con nematodos gastrointestinales en ovinos de pelo. Veterinaria México, 37:15-27.

Vatta, A. F., R. C. Krecek, M. J. Van der Linden, P. W. Morswatswe, R. J. Grimbeek, E. F. Van Wijk, and J. W. Hensen. 2002. *Haemonchus spp*. in sheep farmed under resources-poor conditions in South Africa-effect on haematocrit, conjunctive mucosa membrane colour and body condition. J. S. Afr. Vet. Assoc. 73:119-123.

Vatta, A. F., B. A. Letty, M. J. Van der Linde, E. F. Van Wijk., J. W. Hansen, and R. C. Krecek. 2001. Testing for clinical anaemia caused by *Haemonchus* spp. in goats farmed under resource-poor conditions in South Africa using an eye colour chart developed for sheep. Vet. Parasitol. 99:1–14.

Waghorn, G. C., and W. C. McNabb. 2003. Consequences of plant phenolic compounds for productivity and health of ruminant. Proc. Nutr. Soc. 62:383-392.

Waghorn, G. C., and I. D. Shelton. 1997. Effect of condensed tannins in *Lotus corniculatus* on the nutritive value of pasture for sheep. J. Agric. Sci. (Camb.) 128, 365–372.

Waller, P. 2006. Sustainable nematode parasite control strategies for ruminant livestock by grazing management and biological control. Animal Feed Sci. Techn. 126:277-289.

Wildman, E. E., G. M. Jones, P. E. Wagner, R. L. Boman, H. F. Troutt, and T. N. Lesch. 1982. A dairy cow body condition scoring system and its relationship to selected production characteristics. J Dairy Sci. 65: 495.

Wood, C. and C. K. Knipmeyer. 1998. Applied Environmental Science: global climate change and environmental stewardship by ruminant livestock producers, National Council for Agricultural Education p. 14.