Colegio de Postgraduados

Tanniferous trees used for gastrointestinal nematode control in small ruminants in tropical zones

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ABSTRACT

The objective of this review is to present an overview of the potential of tanniferous trees for the control of gastrointestinal nematodes in sheep in the tropics. A systematic review of scientific articles in various databases was carried out on the potential of tropical tanniferous trees, their effect on the control of gastrointestinal parasites and the improvement of weight gain, a range of 16 years (2006-2022) was considered in the publications consulting a total of 150, of which 46 were related to the topic for the selection of information, a total of 31 scientific articles were obtained, which were considered. Table 1 shows that foliage extracts of species considered tanniferous such as *L. leucocephala* cause inhibition of the hatching of eggs and on the infective larva L3 of *H. contortus*. The bibliographic evidence consulted allows us to elucidate that the use of tropical trees with forage potential and high contents of condensed tannins in their tissues can be successfully used for the control of gastrointestinal nematodes *in vitro* and *in vivo*. The largest percentage of those consulted used tannin-bearing plant extracts that have been shown to have anthelmintic properties and high nutrient content, making them a viable and economical alternative for feeding small ruminants in production systems in tropical areas due to their consumption preference and their high nutrient content.

Keywords: Secondary metabolites, food potential, tanniferous trees.

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INTRODUCTION

The diet of ruminants in tropical livestock production systems depends essentially on grasses (Poaceae) which present a seasonal production of biomass; this particularity suggests the need to develop strategies for sustainable feeding through the use of local forage resources with feed production throughout the year. In these agroclimatic regions there is a broad diversity of tropical tanniferous plants (TTP), such as tzalam (*Lysiloma lastisiliquum* L.), huaxin (*Leucaena leucocephala*), chimay (*Acacia pennatula*), jabín (*Piscidia pisipula* L.), carob (*Ceratonia siliqua*), and pixoy (*Guazuma ulmifolia*), among others. The need to identify and take advantage of these resources in every region emerges, to decrease the dependency on inputs and technologies that reduce the profitability in livestock systems (SIAP, 2017). In addition, these tanniferous plants are promising to control gastrointestinal nematodes (GIN) in ruminants (Hoste *et al.*, 2015), when 3-6% of condensed tannins is included in ruminants' supplementation. This is especially important because the infestation by gastrointestinal nematodes is a limitation for development in tropical livestock production, where the economic losses are reflected in high rates of mortality, morbidity, high costs for their control, and reduction of reproductive and productive parameters (Almada-Arturo, 2015)3.

Condensed tannins (CT) are flavonoids that act as principal pigments in many seeds, and they are present in the plant tissues of some forage plants and function as a defense method against insects and herbivores, and an improvement in animal production has been seen due to the diversity in the chemical properties they have (Torres-Acosta *et al.*, 2008). Authors such as Provenza (2006) state that ruminants manage to better satisfy their nutritional needs and regulate the intake of toxins when the diet includes a diversity of natural ingredients, in contrast with diets based on commercial feed. One of the characteristics of tannins is their astringency, caused when the tannins join the saliva proteins and adhere to the mucosa membranes of the animal's mouth and form complexes between the tannins and saliva glycoproteins which, as consequence, increase the salivation and decrease the palatability of the forage (Jon Lasa *et al.*, 2010). Based on this, the study conducted an analysis and updating of the potential of tanniferous tree species for the control of gastrointestinal nematodes of sheep in the tropics.

MATERIALS AND METHODS

A systematic review of scientific articles and publications was carried out with databases such as Refseek, Scielo, Dialnet, Redalyc and Google Scholar on the potential of tropical tanniferous trees and control of gastrointestinal parasites, in addition to variables of improvement in weight gain in sheep. Information consultation was done using the keywords: "taninos condensados" + "nematodos gastrointestinales", "plantas taniníferas" + "ovinos en pastoreo" + "*Haemonchus contortus*" + "zona tropical", "leguminosas ricas en taninos" + "ganancia de peso" + "rumiantes", "metabolitos secundarios" + "potencial forrajero", "concentración" + "taninos" + "en la inclusión" + "en ovinos". A range of 16 years (2006-2022) in the publications was considered, and similarly titles in Spanish and English published within the period were considered.

The number of publications consulted was 150, of which 46 were related to the effect of secondary metabolites of tanniferous plants in small ruminants. Abstracts and complete documents were considered, resulting in 31 scientific articles, whose information was organized into two sub-themes to ease their analysis and discussion.

Sub-theme 1: The diet in production systems of small ruminant meat in tropical zones

In tropical zones, sheep and goat production systems are not very competitive compared to temperate zones because the grasses used present high fiber content and low nutritional quality, especially in regions with acid soils of low fertility and long periods of drought (Tiemann *et al.*, 2008), which negatively affect the productive and reproductive parameters of animals. Grasslands in tropical zones in Mexico are a natural resource in livestock production systems (LPS) considered the sustenance of greatest importance for grazing animals. A large part of ruminants in the country depend on this resource as main source of nutrients, although the plants that are most abundant in the grasslands have high nutritional value, it is considered as a limitation for their consumption due to the high content of secondary compounds (Perevolotzky *et al.*, 2006).

The most frequent technological innovations in the diet of small ruminants in the tropics are ensilage of corn stubble, starter feed for lambs (creep feeding), integral diets for the fattening stage, and diets for females in gestation stage and lactation, and also inclusion of urea in traditional diets (Rodriguez-Castillo 2017). The ruminants can satisfy the needs for nutrients and regulate the intake of secondary compounds when they are offered a variety of foods. This fundamental variety is obtained from the TTP that can present beneficial effects on animal health and nutrition at low doses and appropriate mixtures; the variety of foods allows animals to express their dietary preferences, which at the same time improve their wellbeing.

Sub-theme 2: Effect of the inclusion of condensed tannins on forage trees and shrubs on GIN decrease and weight gain in sheep

Tree and shrub species with forage potential in the tropics are characterized by the high concentrations of condensed tannins (CT) with concentrations between 2 and 4% in dry base, and these parameters are optimal to obtain physiological benefits in ruminants (Tiemann et al., 2008). They also present a high protein content (14 to 28%) with fiber contents below 40% which allow a higher voluntary consumption and digestibility obtaining increases of 50% or more in the productive yields, such as weight gain, in comparison to tropical grass species (Poaceae). The tanniferous species contributed to the sustainability of the LPS by controlling erosion and improving the physical and biological conditions of the soil, and the biomolecules that it contains are considered responsible for reducing the levels of gastrointestinal parasites and increasing animal production, particularly in young small ruminants (Rey-Obando *et al.*, 2011).

The sheep kept in grazing are exposed to different diseases; two of the main conditions are gastrointestinal parasite diseases and gas formation in the rumen (Márquez-Lara and Suarez-Lodoño, 2008). After being ingested, the infected larvae are unsheathed in the digestive tract and shed twice until they are pre-adults, where they move freely on the surface of the gastric mucosa and mature sexually; then they copulate and the females begin to lay eggs, thus concluding the cycle (Cepeda-Martinez, 2017; Sepúlveda-Jimenéz *et al.*, 2018).

The effects caused by the consumption of tanniferous plants on the populations of GIN can be classified into direct ones with the interactions they have on the physiological functions of the GIN, and indirect ones that constitute the improvement in protein absorption. It has been shown that a higher assimilation of proteins is associated with the improvement in immunity of the host (Hoste *et al.*, 2012). The action mechanism of tannins on *H. contortus* larvae (L3) prevents the development of its evolutionary cycle and in adult nematodes, tannins join the mouth and reproductive tract of parasites (as a result of the affinity of tannins for the proline-rich proteins in the nematode cuticle) (Torres-Acosta, 2008). The response of animals to the intake of CT depends on their concentration in the plants, since plants with concentrations between 5% and 10% of the DM reduce the consumption and digestibility of the forage, while the concentrations between 2% and 4%

of the DM favor the intestinal absorption of proteins due to the decrease of proteolysis by the ruminal microflora.

Studies carried out by Cristel and Suárez (2006) have shown that the consumption of fodders with medium to high CT contents by parasitized sheep resulted in a reduction of the egg count per gram of feces (EPG) and adult parasites. In a coffee shop test carried out by Torres Acosta (2008), the animals had a consumption preference for TTP that contain a large variety of secondary metabolites such as *Acacia pennatula*, *Lisyloma latisiliquum*, *Piscidia piscipula* and *Leucaena leucocephala* instead of *Brosimum alicastrum* that has good digestibility and scarce amount of tannins. Bonilla-Valverde (2017) evaluated a diet formulated with corn grain, soy flour and corn straw with inclusion of tannin extract from *Schinopsis balansae* and *Castanea sativa* with concentrations of 0.15, 0.30 and 0.45% in sheep fed at free access, showing that the daily weight gain and feed conversion improved with the inclusion of 0.15 and 0.30% of tannin extract in the diet.

Other authors such as Martínez-Martínez (2018) included 4% of DM from commercial SilvaFeed® CT in the diet of sheep with consumption of 1200 g d^{-1} of DM and this did not affect the productive variables such as daily weight gain and feed conversion. Maldonado-Peralta (2018) evaluated the fresh forage of *Guazuma ulmifolia* fed to sheep in grazing with *Cynodon nlemfuensis* and supplemented with 0, 25 and 50% of *G. ulmifolia* in proportion to the requirement of DM and obtained a higher consumption of DM in 20% with the treatment of 50% of *G. ulmifolia* improving the feed conversion.

Research carried out by Rodríguez Fernández *et al*. (2013) showed that the design of silvopastoril arrangements with fresh forage of *Guazuma ulmifolia*, *Leucaena leucocephala* and *Crescentia cujete* in grazing goats with grasslands of the guinea grass *Panicum maximum* cv. Tanzania and arrangements based on *G. ulmifolia*, *C. cujete* and *L. leucocephala*, influenced in a higher weight gain when *G. ulmifolia* and *C. cujete* were combined with 22.5 and *L. leucocephala* with 33.6 g day, while with Poaceae (formerly grasses), the weight gain was 13.2 g day. It has been established that young or lactating male lambs fed with species from the Fabaceae family (formerly legumes) increase their weight because their organism responds favorably to the supplementary additions of protein in the diet; in contrast, the same does not happen in adult animals where the amino acids are not a limitation for their performance (Márquez-Lara and Suarez-Lodoño, 2008).

Table 1 shows that the forage extracts from species considered tanniferous such as *L. leucocephala* cause inhibition of egg eclosion (López-Rodriguez 2022; Rivero-Pérez, 2018) and on the infectious larvae L3 of *H. contortus* (López-Rodriguez 2022; Rivero-Pérez, 2018; Castañeda-Ramirez, 2017). Méndez-Ortiz (2019), Sandoval GV (2019), G.I. Ortiz-Ocampo (2016), C. Martínez-Ortíz-de-Montellano (2010) and Felix Heckendorn (2007) tested different plant extracts *in vivo* such as *Gymnopodium floribundum*, *L. leucocephala*, *Schinopsis balansae*, *Cichorium intybus*, *Lotus corniculatus*, *Onobrychis viciifolia* and *Lysiloma latisiliquum* where they agreed in the favorable results of every case with reductions of H. contortus hpg, except for Ortiz-Ocampo (2016) with Coffea arabica extract that did not reduce the hpg value of the nematode.

Table 1. Effect of condensed tannins on gastrointestinal nematodes of sheep.

Reference	Plant species	Parasite	Method of use	Livestock species	Condition of the experiment	Find
López-Rodriguez (2022)	*Leucaena leucocephala*	*H. contortus*	hydroalcoholic extract of foliage	Sheep	*In vitro* with concentrations of 100, 90, 80, 70, 60 and 50 mg mL^{-1}	Hydroalcoholic extract of *L. leucocephala* showed 71% inhibition of egg hatching at 100 mg mL^{-1}.
Nora Antonio-Irineo (2021)	*Gliricidia sepium*, *Leucaena leucocephala*, *Guazuma ulmifolia* and *Bursera simaruba*	*H. contortus*, *Trichostrongylus* spp., Oesophagostomum spp., Cooperia spp., and Nematodirus spp.	Aqueous extracts	Sheep	*In vitro* with three concentrations 0.75, 1.00 and 1.25 mL	Extracts of *Leucaena leucocephala*, *Gliricidia sepium* at doses of 1.25 mL had a higher ovicidal activity.
Méndez-Ortiz (2019)	*Gymnopodium floribundum*	*H. contortus*	Sheet flour	Sheep	*In vivo*, feed with 20, 30 and 40% flour	Leaf meal of *G. floribundum* was 40% in the diet reduced the load of female *H. contortus* worms.
Sandoval GV (2019)	*Schinopsis balansae*	*H. contortus* and *Trichostrongylus*	Aqueous extraction of the heartwood of the Quebracho tree	Goats and sheep	*In vivo*, 500 g of ground corn plus the daily addition of 25 g of TC.	The hpg was low and similar in the first three samplings, the hpg of the control decreased being lower than the group that consumed tannins, the treatment represented a dose without anthelmintic effect.
Rivero-Pérez (2018)	*Leucaena leucocephala*	*H. contortus*	Hydroalcoholic pod extract	Sheep	*In vitro* with concentrations 50, 25, 12.5 and 6.25 mg/mL	The extract had an effect on the inhibition of the hatching of field nematode eggs and on the infective L3 larva.
Castañeda-Ramírez (2017)	*Acacia collinsii*, *Lysiloma latisiliquum*, *Havardia albicans*, *Senegalia gaumeri*, *Mimosa bahamensis*, *P. piscipula*, *Acacia pennatula*, *Gymnopodium floribundum*, *L. leucocephala* and *Bunchosia swartziana*.	*H. contortus*	Methanol Extracts:Water	Sheep and goats	*In vitro*, egg hatching and L3 establishment were tested.	No effect was found on the hatching of *H. contortus* eggs, but it did on L3 establishment.
G.I. Ortiz-Ocampo (2016)	*Acacia Pennatula* and *Coffea arabica*	*H. contortus*	Acetone extract:water	Sheep	*In vitro*, inhibition of larval unsheathing was tested	*H. contortus* tolerated *A. pennatula* extract at concentrations of 150 and 300 μg extract/mL PBS and *C. arabica* extract reduced unsheathing from 150 μg extract/mL.

Table 1. continues...

Reference	Plant species	Parasite	Method of use	Livestock species	Condition of the experiment	Find
G.I. Ortiz-Ocampo (2016)	*Coffea arabica*	*H. contortus*	Acetone extracts:water from the precast by-product	Sheep	*In vivo* with the inclusion of 10% of the precast by-product extract	*C. arabica* extract did not reduce the value of hpg *H. contortus*.
C. Martínez-Ortíz-de-Montellano (2010)	*Lysiloma latisiliquum*	*H. contortus*	Fresh foliage	Sheep	*In vivo*, it was consumed *ad libitum*	*L. latisiliquum* directly influences the biology of adult *H. contortus* by affecting nematode size and female fecundity.
JA Calderón-Quintal *et al*. 2010	*A. pennatula*, *L. latisiliquum*, *Piscidia piscipula* and *Leucaena leucocephala*	*Haemonchus contortus* strains CENID-INIFAP and UNAM	Acetone extracts:water from foliage	Sheep	*In vitro*, inhibition of larval migration was tested	*A. pennatula* and *L. latisiliquum* inhibited larval migration in two strains of *H. contortus*, the CENID-INIFAP strain. *A. pennatula*, *L. latisiliquum* and *P. piscipula* had an effect on the UNAM strain.
Abdul Jabbar (2007)	Commercial CT*	*H. contortus*	TC Commercial Extract	Sheep	*In vivo*. Diets with 2% and 3% TC	HPGs had a gradual reduction, differing significantly on days 60-120 in both diets.
Felix Heckendorn (2007)	*Cichorium intybus*, *Lotus corniculatus*, *Onobrychis viciifolia*.	*H. contortus* and *Cooperia curticei*	Fresh forage	Sheep	*In vivo*	There was a significant reduction of 89, 63 and % hpg of *H. contortus* with *C. intybusachicory*, *L. corniculatus* and *O. viciifolia*. No anthelmintic effect was found against *C. curticei*.
Abdul Jabbar (2007)	*Chenopodium album* and *Caesalpinia crista*	*H. contortus*	Raw aqueous methanolic extract of *Chenopodium album* foliage and seeds of *Caesalpinia crista*	Sheep	*In vitro*, inhibition of egg hatching was tested	*C. crista* (0.134 mg/mL) is more potent in egg hatching than *C. album* (0.449 mg/mL).
Abdul Jabbar (2007)	*Chenopodium album* and *Caesalpinia crista*	*H. contortus*	Crude aqueous methanolic extract	Sheep	*In vivo*	The maximum reduction in hpg of *H. contortus* was observed with *C. crista* (93.9%). In 93.9 and 82.2% with and *C. album* at 3.0 g/kg, respectively.

*Commercial CT prepared from commercially available tannin {Kenya source, used in the textile industry and which contains 1.19% g CT/kg DM according to what was determined by the reagent Butanol-HCl method (Porter *et al*., 1986)}.

The bibliographical evidence consulted allows elucidating that the use of tropical trees with forage potential and high content of condensed tannins in their tissues can be successfully used to control gastrointestinal nematodes in vitro and in vivo, primarily against *H. contortus*. It seems that the antagonistic effect on any of the stages of the physiological process of gastrointestinal nematodes is associated to the type and concentration of condensed tannins in the plants studied, as well as the application method. However, experimentation under conditions of conventional productive management of tropical regions is necessary to discern the anthelminthic potential of tanniferous species, and to develop a practical and inexpensive method to facilitate the adoption by producers.

CONCLUSIONS

In the highest potential of studies consulted, extracts from tropical tanniferous plants were used that proved to have anthelmintic properties and high nutrient content. Because of this, the suggestion is to evaluate the effect of consumption of these plants fresh or in flours on the incidence of GIN in ruminants. The use of tanniferous plants is a viable and economic alternative for the diet of small ruminants in the production systems of tropical zones due to their consumption preference and high nutrient content.

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