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The Effect of Oral Administration of Polyethylene Glycol on Faecal Helminth Egg Counts in Pregnant Goats Grazed on Browse Containing Condensed Tannins

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ABSTRACT

Thirty yearling F_1 Anglo-Nubian × Mubende goats, averaging 21 ± 0.45 kg, kept on free-range feeding in the Ankole range land, Uganda, were screened for health and nutritional status, effectively treated against helminth parasites, mated, and randomly divided into two equal groups during a 3-month preparatory phase. During the 6 months that followed, the goats in one group received a daily oral dose (50 g/goat) of poly(ethylene glycol) (PEG), while the other group acted as the control (no PEG). The goats were monitored for faecal nematode egg counts and body weight gains, along with the quality of their diet, nematode contamination of the pasture, and the prevailing climatic factors in the area. Goats treated with PEG had significantly ($p < 0.05$) higher faecal helminth egg loads. The mean nematode eggs per gram of faeces (epg) of the PEG group (290 epg) was more than double that of the control group (129 epg). All the PEG-treated goats exhibited moderate to severe infections at the end of the experiment. The gain in body weight during gestation was lower ($p < 0.05$) in the PEG group (70.4 g per goat per day) than in the control group (91.8 g per goat per day). The PEG group lost 2.3 g per goat per day in the fifth month. PEG deactivates condensed tannins, and it was concluded that condensed tannins play a significant role in reducing the negative effects of gastrointestinal helminth burdens in the natural free-range feeding system of the Ankole range land in Uganda. Selective feeding on such range lands might expose goats to optimal concentrations of dietary condensed tannins with resultant beneficial effects.

Keywords: acacia shrub, browse, faecal egg counts, goats, *Haemonchus*, poly(ethylene glycol), tannins, *Trichostrongylus*

Abbreviations: CT, condensed tannins; DM, dry matter; epg, eggs per gram of faeces; GI, gastro-intestinal; PEG, poly(ethylene glycol) of molecular weight 4000

INTRODUCTION

In the tropics, high-protein fodder trees and shrubs are a cheap and readily available protein source that form an important basal feed resource for goats. Additionally, they contain condensed tannins (CT), which may further enhance performance. Condensed tannins are abundant in browse plants, particularly in woody species. However, not all

tannin concentrations in herbage are acceptable to goats. During browsing, ungulates, including goats, generally reject feedstuffs containing more than 5% CT (Cooper and Owen-Smith, 1985). Interestingly, this 5% rejection level coincides with the CT ceiling below which improved protein and amino acid utilization in ruminants is observed (Waghorn, 1990). It is, therefore, hypothesized that, under selective feeding in a natural ecosystem such as the range lands, browsing ungulates control the amount of CT ingested and optimize their beneficial effects. Several CT-induced benefits have been reported in ruminants (Verna *et al.*, 1989; Terill *et al.*, 1992; West *et al.*, 1992; McNabb *et al.*, 1993; Streeter *et al.*, 1993; Waghorn *et al.*, 1994). However, reports directly related to benefits in improvements of ruminant health are rare. Besides this, previous studies have tended to concentrate on management systems in developed countries and do not necessarily reflect the situation in the less-developed, but biologically rich, feeding systems prevalent in many developing countries. In this study, the potential benefit of the CT in fed browse in improving the health status and performance of goats managed under a natural, free-range feeding system in Uganda was evaluated by drenching free-range goats with poly(ethylene glycol) (PEG), an adsorbent that deactivates dietary CT in the rumen, and so enables the resultant effects on the goats' performance to be monitored. The study focused on the hypothesis that condensed tannins in grazed browse in the Ankole range land free-range feeding system have a significant effect on the clearance of gastrointestinal (GI) nematodes from goats.

MATERIALS AND METHODS

Study area

The study was conducted in the Ankole range land, in Mbarara district, southern Uganda, 1250 m above sea level. The relevant ecological characteristics of the area have been described by Schwartz and colleagues (1996). The vegetation is typically acacia shrub/woodland. The dominant vegetation species include *Acacia* spp, *Grewia* spp., *Cadaba* spp., *Carissa* spp., *Rhus* spp., *Bracharia* spp., *Themeda triandra*, *Cynodon dactylon* and *Chloris gayana*. The area is seasonally wet, with a long dry season from May to August. Rainfall is bimodal, April–May and September–November. These climatic characteristics were confirmed (Table I). Forage quality and production fluctuate seasonally and grazing of browse species occupies 60–85% of the goats' feeding time (J.D. Kabasa and J. Opuda-Asibo, personal communication).

Experimental animals and design

Thirty yearling F_1 Anglo-Nubian $\times$ Mubende does, of a local stock and averaging 21 ± 0.45 kg body weight, were screened for health and nutritional status, effectively treated against helminth parasites with a broad-spectrum combination of levamisole hydrochloride and oxyclozanide (Nilzan Plus, Wellcome Ltd, Nairobi, Kenya), mated, and randomly divided into two equal groups during a 3-month preparatory phase.

TABLE I
Variation in climatic parameters during the experiment in the Ankole range land

	Monthly mean values											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Rainfall (mm)	40.00	41.00	90.00	145.00	95.00	28.00	28.00	63.00	101.00	130.00	129.00	94.00
Dry bulb temperature (°C)	26.70	26.80	26.10	26.00	25.70	26.20	26.60	26.80	26.40	25.90	25.60	25.70
Wet bulb temperature (°C)	19.20	19.60	20.20	21.00	20.70	19.60	19.00	19.50	20.40	20.90	21.00	20.40
Relative humidity (%)	46.00	49.00	52.00	62.00	62.00	52.00	45.00	49.00	55.00	62.00	64.00	60.00
Temperature–humidity index*	73.65	74.01	73.94	74.44	74.01	73.58	73.43	73.94	74.30	74.30	74.12	73.79

*A biometeorological index of discomfort, calculated according to McDowell (1972) as: Temperature–humidity index = 0.72 (°Cdb+°Cwb)+40.6, where °Cdb = dry bulb temperature in °C and °Cwb = wet bulb temperature in °C

Tables II and III describe the experimental design and plan. Anthelmintic treatment was done at the peak of the first wet season (Table II) to ensure a minimal residual drug effect on the development of worm burdens during the study and a similar infection status in all the goats at the start of the experiment. Does that tested pregnant within the last 2 weeks of the preparatory phase were selected so that gestation could be monitored throughout the long dry season (Table II).

During the 6-month experimental phase (Table II), one group received a daily oral dose of 50 g/goat of PEG (Merck, Germany), while the other acted as the control (no PEG). The nutritional status of the goats and the helminth larval contamination on the pasture (Table IV) were ascertained. Traditional herding was the mode of management. A night shade of 1.2 m^2/doe was provided. Grazing in a 1 square mile range area started at 09:00, followed by watering (13:00) and a midday rest until 15:00, when the goats went back to the pasture. Return to the kraal was at 18:00. Spraying against external parasites was done once a month.

Helminth re-infection model and PEG drench

The helminth re-infection model (Table II) adopted for the goats in this study was based on the principle that pre-immunity against helminths in the host is broken following effective anthelmintic treatment (Bowman, 1995). After that, the role of dietary CT in reducing helminth re-infection and faecal egg load in the experimental goats was assessed by blocking the effect of dietary CT through competitive binding by PEG, given as a drench. A browse rejection level of 5% CT (Cooper and Owen-Smith, 1985), a dry matter intake of 3–4% of the goat's live weight (Devendra, 1980; Morand-Fehr, 1991) and a PEG:CT precipitation ratio of 1:1 (Pritchard *et al.*, 1992) were assumed in calculating the dose of PEG. Each goat received 50 g PEG dissolved in 20 ml fresh drinking water each day, given in two parts (Table III) to avoid excess volumes that would promote faster ruminal emptying (Koes and Phander, 1975) and dilution of the bacterial population (Hemsley *et al.*, 1975; Gihad, 1976). This dose was maintained throughout the experiment.

Dietary composition and quality

The dietary preference of the goats was observed and the composition of their diet was monitored by the direct-observation rapid-survey technique of Dicko-Toure (1980) with slight modifications. This method was acceptable to the owner of the goats and farm. Observations were done 10 days/month, every third day. Three selected goats, previously conditioned to handling, were watched from a distance of 2–5 m. The plant visited, the parts eaten, the number of bites taken, the size of a single bite and the feeding time at the plant were noted. A similar forage sample was immediately hand-picked from the area of plants being grazed during the observation, being taken to mimic the grazing habits of the goats. Similar observations were made on each of the three goats for periods ranging between 3 h and a whole day. Local persons with a

TABLE II
Plan of activities to monitor the effect of a PEG drench in pregnant goats grazed on browse containing condensed tannins

Parameter/activity	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Herding	x	x	x	x	x	x	x	x	x
Pregnancy service	–	–	x	–	–	–	–	–	–
Anthelmintic treatment	–	x	–	–	–	–	–	–	–
Natural helminth re-infection	x	x	x	x	x	x	x	x	x
PEG drench	–	–	x	x	x	x	x	x	
Diet analysis	x	x	x	x	x	x	x	x	x
Faecal egg counts	x	x	x	x	x	x	x	x	x
Screening health	x	x	x	x	x	x	x	x	x
Climatic parameters	x	x	x	x	x	x	x	x	x
Helminth L_3 counts	x	x	x	x	x	x	x	x	x
Weight measurement	x	x	x	x	x	x	x	x	x
	Dry season	← 1st wet season →			← Long dry season →			← 2nd wet season →	
	← Monitoring buck and serving does →				← Gestation period of selected does			→	
	← Pre-experiment preparatory phase →				← Experimental phase			→	

X, parameter was measured/activity occurred

TABLE III
Dose and schedule for administering PEG to the experimental goats

Group	Drenching time		Days drenched
	09:00	18:00	
PEG group	25 g PEG in 10 ml water per goat per day	25 g PEG in 10 ml water per goat per day	180
Control group (no PEG)	10 ml water per goat per day	10 ml water per goat per day	180

TABLE IV
Mean dietary composition (g/kg DM), grazing time (h) and helminth contamination of the pasture (L_3/kg) during the experiment

Parameter	Dry season value	SEM	Wet season value	SEM
Crude protein	110.00	3.50	184.00	4.20
Insoluble condensed tannin	32.75	1.08	19.35	0.53
Soluble condensed tannin	4.35	0.39	3.67	0.17
CP:CT ratio	2.96	0.19	7.99	0.21
Grazing time	7.62	0.31	6.50	0.46
Pasture helminth larvae ($\times 10^{-3}$)	0.50	0.03	2.51	0.02

CT, soluble and insoluble condensed tannins combined; CP, crude protein; L_3, helminth larval stage 3; DM, dry matter

sound knowledge of the flora of the area were involved. Verification of the data was complemented by cross-checking with the opinions of experienced herdsmen. Each day's samples were taken and processed for laboratory analyses. The nutrient content was analysed using standard methods (Neumann-Nuedamm, 1983), while the methods of Swain and Hills (1959) and Reed and colleagues (1982) were adopted for tannin assays. Absorbency readings for CT were converted into g/kg dry matter (DM) using a purified standard preparation of Quebracho CT provided by Dr Ann E. Hagerman (Miami University, USA).

Faecal helminth eggs and larvae

Faecal samples collected from the rectum into labelled polythene bags were maintained at 4°C until analysed. The flotation technique, complemented by the sedimentation and Baerman procedures (Urquhart *et al.*, 1988), was used to enumerate the faecal nematode eggs. Larval cultures were undertaken, the larvae recovered were counted and the nematode parasites involved were identified.

Statistical analysis

Group comparison tests were done using the Sigmastart statistical package (Jandel Corp., 1995). Differences between the body weight gains of the goats in the two treatment groups were tested for significance by the unpaired Student's *t*-test. The faecal helminth egg loads were evaluated by the non-parametric Mann–Whitney rank sum test. A probability <0.05 was considered significant and the results were presented as mean $\pm$ standard error of the mean (sem).

RESULTS

Helminth egg counts

Goats treated with PEG had significantly ($p<0.05$) higher numbers of helminth eggs per gram of faeces (Figure 1) than the control group (no PEG). The mean faecal egg count over the entire gestation period of 290 epg in the PEG group was more than twice that of 129 epg in the control group. Similarly, the mean egg count (554 ± 14 epg) over the last 4 months of gestation in the faeces of goats in the PEG group exceeded that of the control (181 ± 6 epg) by well over 200%. All the PEG-treated goats exhibited moderate to severe infections by the end of the experiment. Two goats in this group exhibited diarrhoea and had faecal egg counts of 1020 and 1050 epg, while the rest of the goats in the PEG group had soft faeces and faecal egg counts of between 510 and 690 epg. They also lost weight and condition (Figure 2).

Prevalence of helminth parasites

The monthly prevalence of helminth parasites in the faeces of the experimental goats is summarized in Table V. *Trichostrongylus* spp. were the most prevalent nematode parasites during the first 4 months of gestation (mean prevalence 83.3%), followed by *Haemonchus* spp. (mean prevalence 71%) and lastly *Strongyloides* spp. (mean prevalence 5%).

Re-infection of all the goats in the PEG group with *Trichostrongylus* spp. was observed in the third month of gestation, earlier than in the control group. In the control group, re-infection with this species was limited to 86.7% of the goats and was

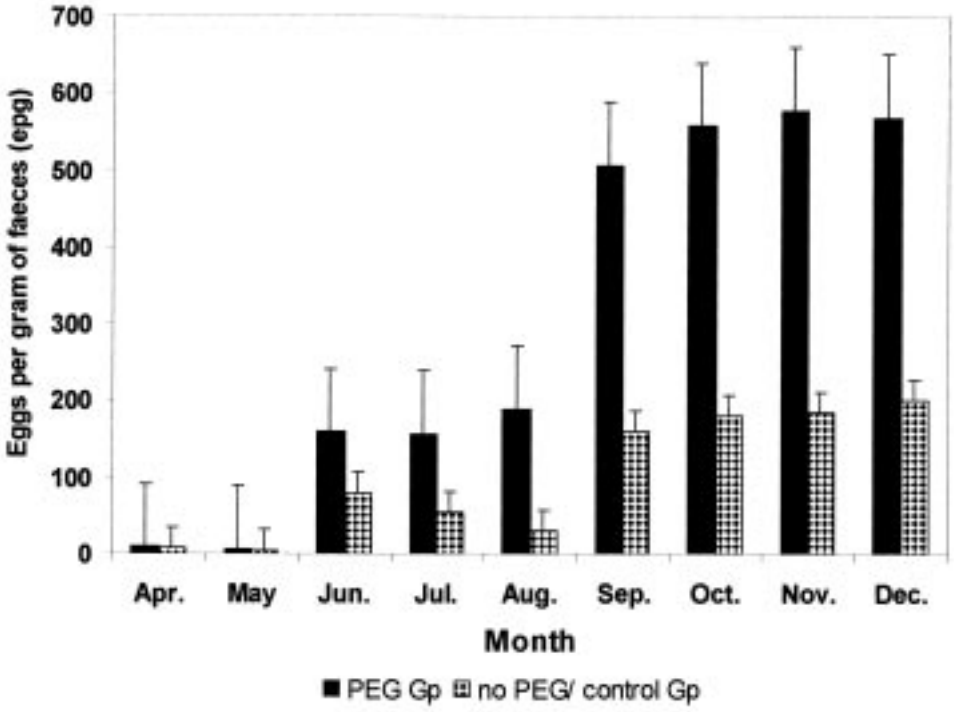

Figure 1. Mean faecal helminth egg counts in pregnant goats drenched daily with or without PEG and selectively fed browse containing condensed tannins

delayed until the fourth month of gestation. Similarly, re-infection of all goats with *Haemonchus* spp. was observed in the fourth month of gestation in the PEG group, rather earlier than in the control group (fifth month of gestation). Neither fluke eggs nor lung worm larvae were recovered during the experiment.

Body weight gain

Goats treated with PEG had significantly ($p < 0.05$) lower body weight gains during gestation (Figure 2). The mean weight gain in this group during the first 4 months of gestation was 70.4 g/day, while that for the control group (no PEG) was 91.8 g/goat per day. The weight gain in the last month of gestation was low in both groups (Figure 2), but only the goats treated with PEG lost weight, with an average weight loss of 2.3 g/goat per day.

TABLE V
The monthly prevalence (%) of nematode larvae which developed in the faeces of experimental goats (June–October = gestation period)

	June		July		Aug.		Sept.		Oct.		Nov.	
	PEG	Control	PEG	Control	PEG	Control	PEG	Control	PEG	Control	PEG	Control
Haemonchus	60	67	60	60	67	67	100	86.7	100	100	100	100
Trichostrongylus	67	67	86.7	80	100	80	100	86.7	100	86.7	100	86.7
Strongyloides	0	0	0	0	0	0	40	0	40	0	40	0

PEG, PEG-treated group; Control, no PEG treatment

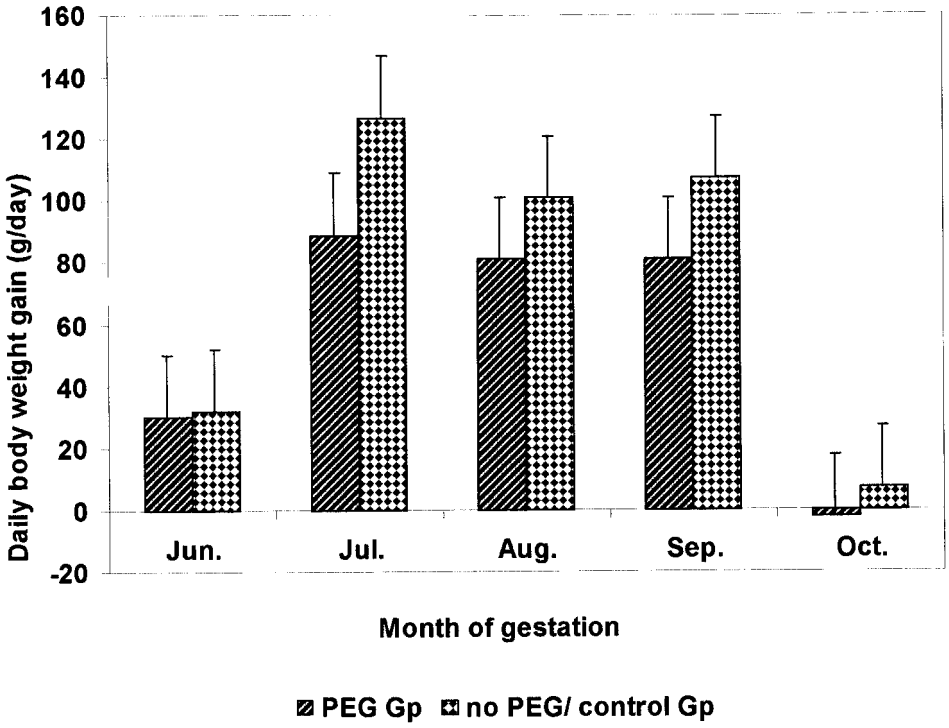

Figure 2. Rate of body weight gain of pregnant goats drenched daily with or without PEG and fed browse containing condensed tannins

DISCUSSION

This study tested the effects of a PEG (a deactivator of condensed tannin) drench on faecal helminth egg loads of goats browsing in a natural free-range feeding system in a tropical savannah (Ankole range land) in Uganda. There were significantly ($p < 0.05$) higher faecal helminth egg counts in goats treated with PEG (Figure 1). These findings suggest that the presence of PEG in the gut had limited the beneficial effects of condensed tannin in goats browsing in the ecosystem. It is known that the effects of PEG are mediated through the formation of competitive complexes with dietary condensed tannins in the rumen. As a result, the amount of tannin-precipitated forage protein passing through to the abomasum and small intestines (bypass protein) for digestion will be reduced. Condensed tannins are reported to enhance the availability and utilization of protein and amino acids in ruminants at CT concentrations below 5% (Waghorn *et al.*, 1994). On the other hand, biologically active polyphenols in the browse may elicit activities that contribute to the observed effects through other

mechanisms (Reed, 1995). A relatively low protein content and high condensed tannin:protein ratio was characteristic of the goats' diet throughout the dry season during the experiment (Table IV). Improvements in the dietary protein content and in the protein:condensed tannin ratio observed in the later October–November wet season (Tables II and IV) did not improve the re-infection status (Table V and Figure 1) in the PEG group. The helminth egg counts in the PEG group became high in the final phase of gestation, and this was maintained in the month following delivery. On the other hand, the control goats (no PEG) had lower faecal helminth egg counts throughout gestation (Figure 1). While the goats in the control group had only *Trichostrongylus* and *Haemonchus* infections, those of the PEG group had *Strongyloides* in addition (Table V) during the last month of gestation. In all cases, the highest prevalence level for each GI helminth genus recovered (Table V) was observed much earlier in goats treated with PEG, suggesting a higher re-infection rate in this group.

There are several possible explanations for these observations. Besides a potential deficiency in protein utilization, the demands from the rapid fetal development and the accompanying competition for nutrients between the fetal and maternal organisms during the critical period of gestation (normally 90–120 days), combined with the rising level of pasture contamination (Table IV) during the second wet season (Table II), may be implicated. Dietary CT are directly implicated in the present findings because no CT adsorbent (PEG) was provided to the control group of goats, while all other experimental factors remained constant for both groups. CT at low dietary concentrations ($< 5\%$ of DM) improve the nutritive value of forage by binding to plant proteins and protecting them from excessive degradation in the rumen. Bypass protein is thereby increased and the supply of essential amino acids is enhanced. In addition, the efficiency of utilization of blood urea nitrogen in the formation of bacterial protein is improved. Thus, pregnant goats with a reduced feed supply may, through the beneficial effects of CT, overcome a marginal protein deficiency and so be less predisposed to helminth infections (Table V), besides experiencing a reduction of their harmful effects (Figure 2).

Predisposition to heavy or light helminth infections is an important epidemiological factor in the occurrence of helminth infections in goats, and is modulated by genetic, behavioural, environmental and nutritional factors, either singly or in combination (Maizels *et al.*, 1993). These combined factors explain the differences in responses to individual helminth antigens often observed among subjects experiencing similar exposure to infections. However, in the present study, a single factor, namely the effect of PEG in goats grazing on fresh CT-containing browse in a natural range land ecosystem, was tested in goats of a single breed type (F_1 Anglo-Nubian $\times$ Mubende goat), sex (female) and physiological status (pregnant), from a single source and under the same management system. Thus, the observed effects in the goats are probably attributable to nutritional factors, presumably involving the condensed tannins and related polyphenols. It may be further suggested that the faecal helminth egg loads observed in this study, as well as the differences in the live weight gains of the goats, may be a reflection of differences induced by the condensed tannins on the size of the helminth burdens, on the fecundity of the parasites, on the ability of the individual goats to withstand or curtail the harmful effects of the helminth, or on a combination

of any of these. Necropsy studies would have complemented these findings, but the sacrifice of crossbreed goats was unacceptable to the owner of the goats and farm. Nevertheless, the observed, apparently tannin-induced, reductions in the faecal helminth egg counts of the goats in the control group, and the well-sustained body weight during pregnancy in this group (Figure 2), indicates the possible role of the condensed tannins in fed fresh browse in reducing pre-parturient immunosuppression among the flocks, and may partly explain the high faecal GIT helminth egg counts observed among the wild opportunistic browsers (especially impalas) during periods when their diet in the Lake Mburo National Park range land, adjacent to the study area in Uganda, was predominantly herbage rather than browse (Ocaido, 1995). Similar observations in goats have been documented by Urquhart and colleagues (1988), who reported that goats precluded from browsing, and left to derive their food intake entirely from pasture, suffer more severe helminth infestation in the tropics and subtropics.

It has long been assumed that browsing influences the gastroenteric nematode burdens in goats simply by reducing the intake of infective larvae from the ground herbage. However, this study has revealed another possibility, the ability of condensed tannins in the browse to enhance the animals' nutrition and thereby their ability to resist the development of or the effects of helminth infections. The demonstration that the CT in browse benefit goats under selective feeding in the Ankole range land has considerable nutritional and practical significance, especially in Uganda where feeding practices under the traditional feeding systems (tethering and free range) are often badly managed. Access to optimal quantities of diverse CT-containing browse may not only minimize nutritional stress among goats but also reduce their dependence on anthelmintic drenches to improve productivity. The study has demonstrated that selective feeding in the natural ecosystem may expose goats to optimal concentrations of dietary CT with resultant beneficial effects. However, such natural ecosystems with diverse CT-containing forage for goats feeding under communal grazing practices may not be an option in many parts of sub-Saharan Africa in the long run owing to growing pressure for arable land. Thus, feed and feeding management strategies adapted or developed for improving goat production should consider feeding goats on a variety of fresh CT-containing browse forages at levels that would elicit the beneficial effects.

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Effet de l'administration orale de PEG sur le nombre d'oeufs helminthes fécaux chez des chèvres en gestation et se nourrissant de feuilles concentrées en tannins.

Résumé – 30 chèvres d'un an croisées Anglo-Nubian × Mubende de près de $21 \pm 0{,}45$ kg furent gardées de façon libre dans la région d'Ankole en Ouganda. Les apports nutritifs et leur état de santé furent suivis après avoir été traitées contre des helminthes parasites, s'être accouplées et avoir été divisées en 2 groupes pendant une phase préparatoire de 3 mois.

Pendant les 6 mois suivants, les chèvres du groupe 1 reçurent une dose orale quotidienne de PEG (50 g/chèvre) alors que le second groupe ne reçut rien du tout. Les oeufs de nématodes furent comptés ainsi que les gains de poids, la qualité de leur nourriture, la contamination des prairies en nématode et les facteurs climatiques de cette région. Les chèvres traitées avec le PEG eurent de façon significative plus d'oeufs dans leurs déjections (290 oeufs par gramme de fécès, au lieu de 129 pour le groupe de contrôle). Le gain en poids pendant la grossesse fut plus faible pour le groupe PEG (70,4 g/jour/chèvre) que pour le groupe de contrôle (91,8 g/jour/chèvre). Le groupe PEG perdit 2,3 g par jour et par animal pendant le cinquième mois. Le PEG désactive les tannins qui semblent avoir un effet réducteur sur les nématodes. La sélection de la nourriture donnent des effets améliorateurs pour la production animale.

Efecto de la administración oral de polietilenglicol sobre el recuento fecal de huevos de helminto en cabras gestantes alimentadas con arbustos con taninos condensados

Resumen – Un total de 30 cabras F_1 Anglo-Nubianas × Mubende de un peso medio de $21 \pm 0{,}45$ kg se mantuvieron en condiciones de pastoreo libre en la zona de Ankole, Uganda; se valoró su estado sanitario y nutricional, se trataron de forma efectiva frente a helmintos, se aparearon y se dividieron al azar en dos grupos iguales durante una fase preparatoria de 3 meses. Durante los 6 meses sigguientes, las cabras de un rupo recibieron una dosis oral diaria (50 g/cabra) de polietilenglicol (PEG), mientras que el otro grupo sirvió de control (no PEG). Se monitorizó el contaje fecal de huevos de nematodo, la ganancia de peso, la calidad de la dieta, la contaminación de los pastos con nematodos y las condiciones climáticas predominantes en la zona. Las cabras tratadas con PEG tuvieron una carga fecal de huevos de helminto significativamente superior a la de las cabras del grupo control ($p < 0{,}05$). El número medio de huevos de nematodo por gramo de heces (epg) del grupo PEG (290 epg) fue más del doble que el del grupo control (129 epg). Todas las cabras del grupo PEG tenían una infestación moderada a severa al final del experimento. El aumento de peso durante la gestación fue inferior en el grupo PEG (70,4 g por cabra y día) que en el grupo control (91,8 g por cabra y día) ($p < 0{,}05$). Los animales del grupo PEG perdieron 2,3 g por animal y día durante el quinto mes. El polietilenglicol inactiva los taninos condensados y se concluyó que dichos taninos desempeñan un papel significativo en la reducción de los efectos negativos de los helmintos gastrointestinales en las condiciones de pastoreo libre de la zona de Ankole de Uganda. El pastoreo selectivo en dicha zona podría exponer a las cabras a una concentración óptima de taninos condensados en la dieta, lo que tendría efectos beneficiosos.