Worms, Sheep & Goats, & Copper Oxide Wire Particles

Dr. Dwight Bowman

Haemonchus

- Major problem in sheep
  - Adults in abomasum of
    - Adults
      - 1 to 3 cm long
      - males red, female - white ovaries wrapped around intestine of worm giving a barber pole appearance
- Life cycle
    - Direct
    - Larvae not as resistant to cold as are *Trichostrongylus* and *Teladorsagia*
    - Egg to infectious larvae (L3) in about 1 week
    - Prepatent Period (PPP) time from the infection of the sheep or goat until mature worms produce eggs

Haemonchus contortus

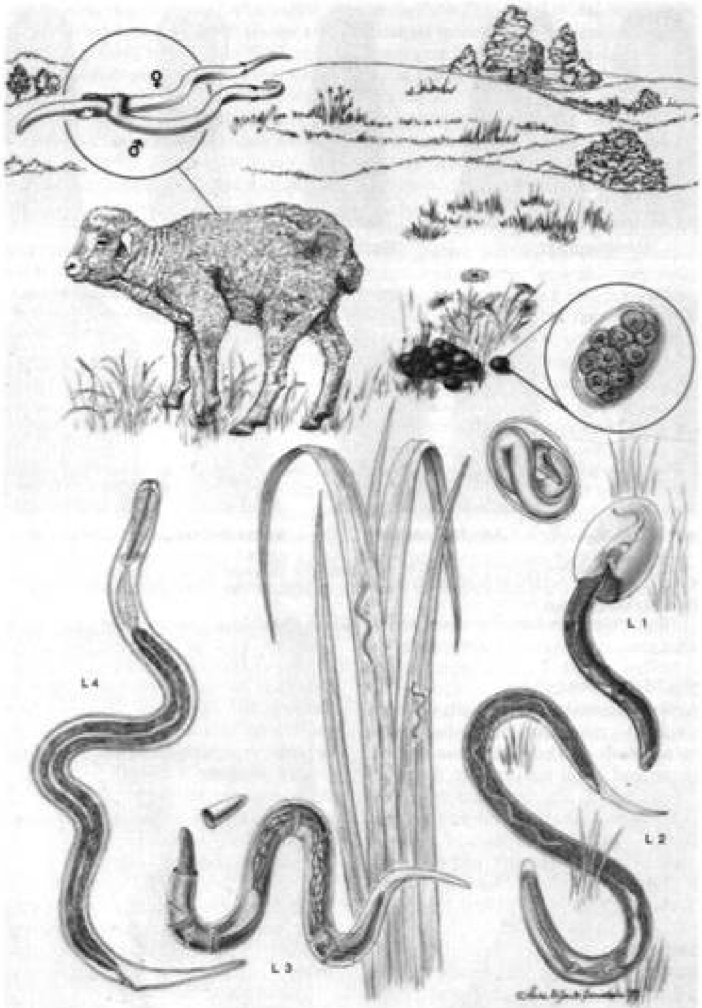
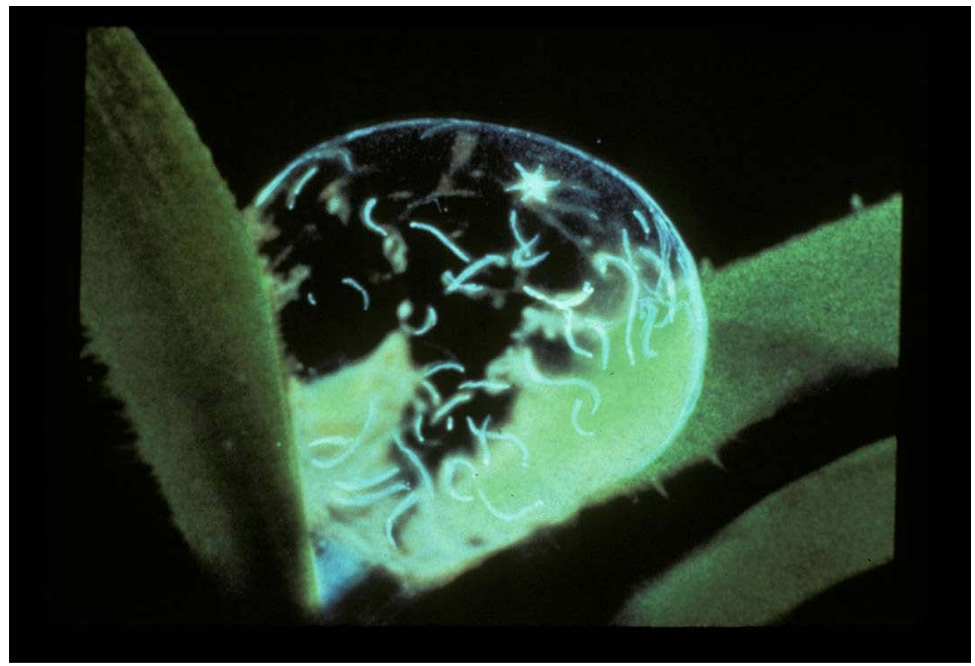


FIGURE 3-70 Life history of a typical strongylid nematode, *Haemonchus contortus*. Eggs are shed in the feces in the morula stage of development. First-stage larvae develop and hatch in a day or two to feed on microorganisms in the feces. After a molt, the resulting second-stage larva also feeds on microorganisms. The second molt is started but not completed in the external environment, so the infective third-stage larva remains encased in the cuticle of the second stage until it is ingested by a sheep. The sheath is cast off in the abomasum of the sheep and the now parasitic third-stage larva undergoes a molt to the fourth stage. The fourth stage sooner or later molts to the fifth or adult stage, depending on whether it enters a period of arrested development.



Haemonchus

- Pathogenesis
  - Anemia
    - 50 ul of blood lost/worm/day beginning 6 days after infection
    - lamb may lose 1/10th to 1/5th of blood volume per day
  - Also lose serum protein
  - Feces often well formed - may even have constipation (of course, with mixed infections with *Trichostrongylus* & *Teladorsagia* may have diarrhea

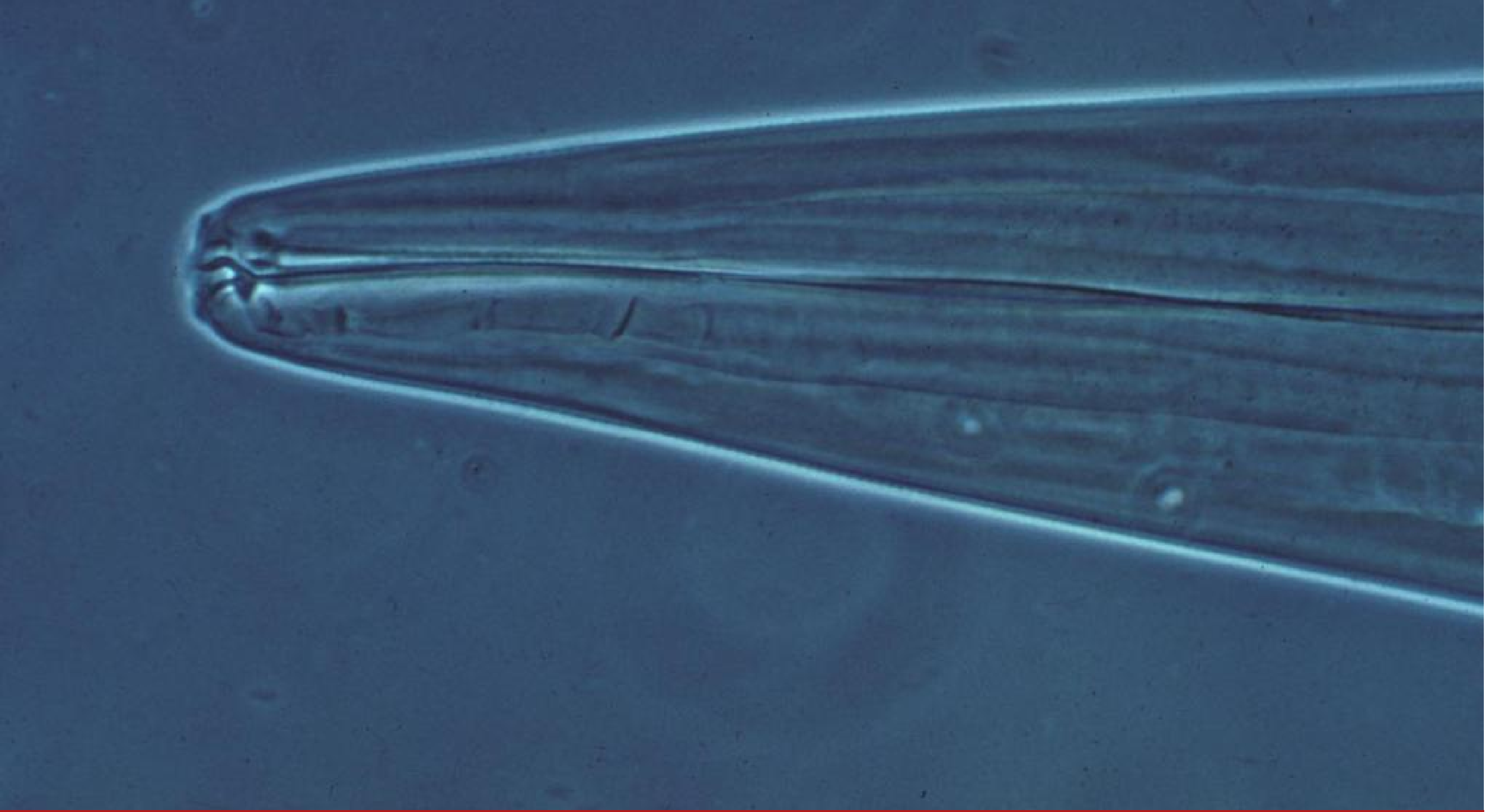
CLINICAL SIGNS

- HYPERACUTE
  - Seen in new animals released onto heavily contaminated pasture
  - Disease before patency
  - Atypical in that no eggs
- ACUTE
  - Mainly in young animals
  - Anemia
  - Hypoproteinemia and submandibular edema
  - High egg counts, >10,000 epg
  - Many adults
- CHRONIC
  - Most common
  - Unthrifty animal
  - Few adult worms, less than 1,000
  - Egg counts <2,000 epg

Haemonchus

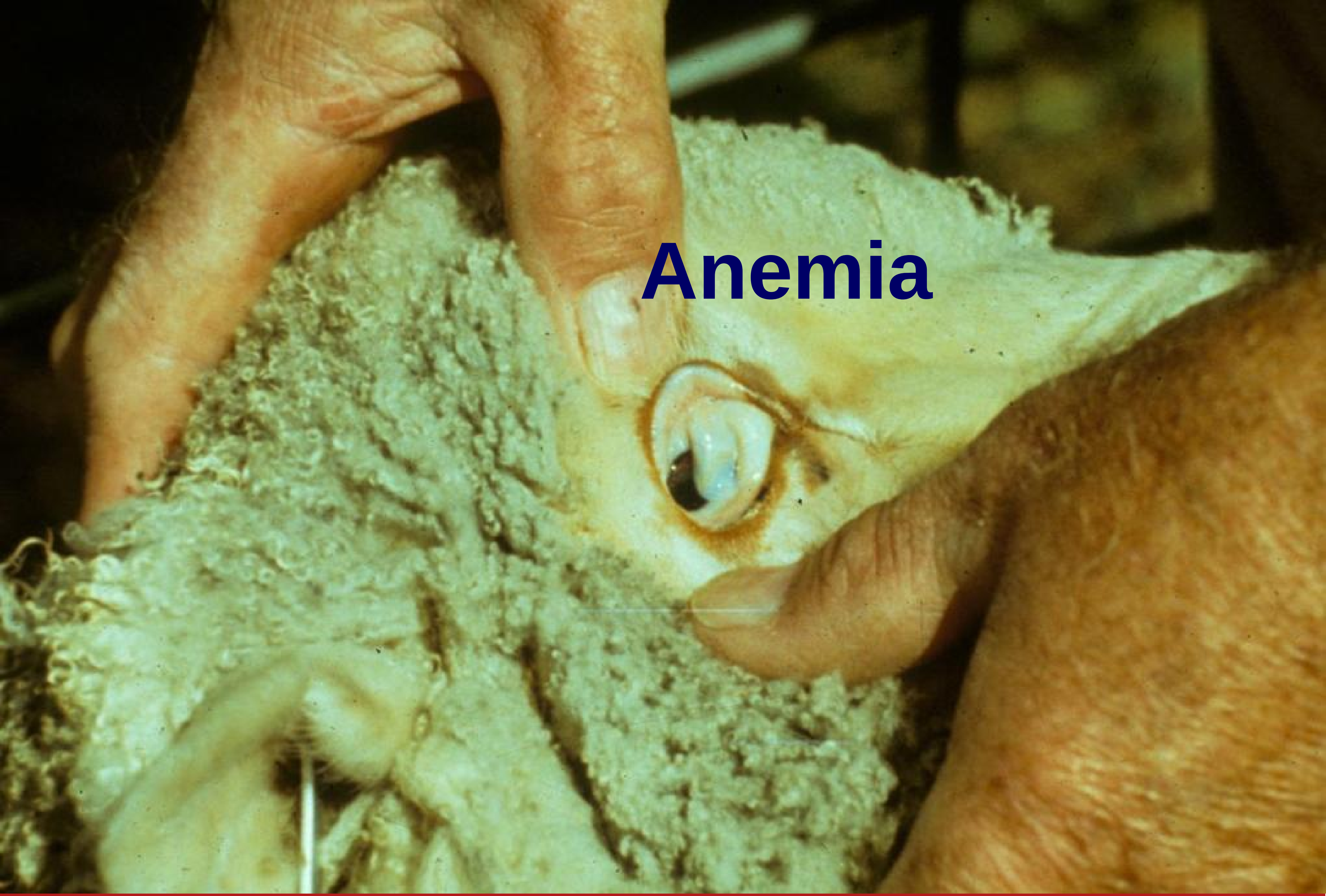
- Diagnosis
  - Anemia
  - High egg counts with anemia
  - Larval culture
  - Necropsy

Haemonchus




Normal

Anemia



FAMACHA

- LIVING WITH WORMS

Haemonchus

Haemonchosis

- Diagnosis of haemonchosis is made based upon the characteristic clinical signs of anemia, submandibular anemia, weight loss, and ill thrift along with finding large numbers of eggs in the feces.
- Female *Haemonchus* produce approximately 5,000 eggs per day and goats/sheep can be infected with thousands of these worms.
  - This results in tens to hundreds of thousands of eggs being shed onto pasture by each animal each day.
- Because the life cycle is so short (< 3 weeks), this cycle of infection— pasture contamination - reinfection - more pasture contamination— can rapidly transform pastures into very dangerous places for goats.
  - This is especially true in a warm humid environment such as the southern US, because transmission of *H contortus* occurs throughout most of the year.

Kaplan RM. 2010. Small ruminant recommendations for control of parasites. Large animal. Proceedings of the North American Veterinary Conference, Orlando, Florida, USA, 16-20 January 2010 Pages: 348-356

SPRING RISE

- Ewes and does lose much of their protective immunity to GIN around the time of kidding/lambing (–2 to +8 weeks) causing the number of parasites infecting the does to increase.
- Subsequently, parasite egg production and contamination of the environment with infective larvae increases, creating a dangerous situation for the highly susceptible young kids.
- This phenomenon, known as the **periparturient rise** (PPR) [OR SPRING RISE] is an extremely important part of the epidemiology of *Haemonchus* and must be considered when designing control programs.

Kaplan RM. 2010. Small ruminant recommendations for control of parasites. Large animal. Proceedings of the North American Veterinary Conference, Orlando, Florida, USA, 16-20 January 2010 Pages: 348-356

Copper Oxide Wire Particles (COWP)

Copper Oxide Wire Particles

- Developed for copper deficiency in cattle and sheep.
- Sheep very susceptible to copper toxicity, which can result in death.
- Form of copper in COWP is poorly absorbed, reducing the risk of copper toxicity. In contrast copper sulfate crystals are more readily absorbed and carry more risk of toxicity.
- Exact mechanism of how copper wire particles control internal parasites is not fully understood.

Copper deficiency in sheep

- Copper deficiency is not diagnosed nearly as frequently as copper toxicity, but it may occur in regions where soils and forages are low in copper or have elevated levels of molybdenum.
  - In adult sheep, signs of copper deficiency are usually sub-clinical.
    - Severe deficiencies may result in "steely" or "stringy" wool that lacks crimp and tensile strength.
- Young animals are more susceptible to copper deficiency, as milk is a poor source of copper.
  - Affected lambs may show signs of "swayback" or have difficulty standing or walking (known as ataxia).
  - Oral administration of copper sulfate or other chelated forms of copper is the usual treatment for copper deficiency.

Copper toxicity in sheep

- Sheep are ten times more susceptible to copper toxicity than cattle.
- When consumed over a long period of time, excess copper is stored in the liver.
  - No damage occurs until a toxic level is reached at which time there is a hemolytic crisis with destruction of red blood cells.
  - Most outbreaks of copper poisoning in sheep can be traced to feeding supplements containing copper levels that have been formulated for cattle or swine.
- Copper is closely related to molybdenum, and copper toxicity occurs when the dietary ratio of copper to molybdenum increases about 6-10:1.
  - Affected animals suddenly go off feed and become weak.
  - An examination of their mucous membranes and white skin will reveal a yellowish brown color.
  - Their urine will be a red-brown color due to hemoglobin in the urine.
  - Treatment of copper toxicity involves the use of ammonium molybdate and sulfate compounds.

Department of Agriculture
No. 28/2004
Replaces Farmnote 15/94
Farmnote

Copper deficiency in sheep and cattle

Reviewed by Colin White, CSIRO. Authored by John Gartrell, Principal Officer, Plant Nutrition, Plant Industries and Brian Beetson, formerly of Sheep and Wool Branch, South Perth

Summary

This farmnote looks at the symptoms of copper deficiency in livestock; its causes (soils low in copper, excessive molybdenum and sulphur intake); laboratory tests for copper levels; and preventative measures that can be taken (using fertilisers, injections and other means).

There are two main causes of copper deficiency in sheep and cattle:

- low copper levels in plants due to a lack of copper fertiliser in naturally copper deficient soils;
- an induced deficiency caused by the ingestion of excessive levels of molybdenum and sulphur in pasture or feed supplements.

In Western Australia, naturally occurring copper deficiency is not often seen in black-woolled sheep because most farmers have applied enough copper as fertiliser to ensure an adequate supply for grazing livestock for decades.

In contrast, before 1940, neonatal ataxia in lambs and falling disease in cattle were crippling livestock enterprises on many copper-deficient soils in the Gingin, Dandaragan, Dongara, Vasse, west coastal and Albany areas. There were also scattered incidences on lateritic and sandy soils throughout other agricultural districts.

Recent cases of low copper status

Sheep

- Swayback or enzootic ataxia of lambs. Lambs with this condition cannot coordinate their legs. They may be severely affected at birth and may be unable to stand; some may be born dead. Other lambs appear normal at birth but between one and six months they develop an uncoordinated gait. This condition is caused by impaired development of the central nervous system in the foetus and cannot be reversed by copper treatment to the lamb once signs appear;
- loss of pigmentation in black-woolled sheep. Because there is usually a wide variation in susceptibility to copper deficiency between individuals within any flock, normal pigmentation in one or two marker black sheep does not guarantee copper sufficiency among the white-woolled individuals. Other conditions can occasionally cause loss of pigmentation;
- loss of crimp, secondary crimping and steeliness of wool are poor guides to copper deficiency because they are not solely caused by lack of copper and experts cannot consistently differentiate between steely and doggy wool. Copper deficiency is rarely the cause of the poorly crimped wool often seen in Western Australia.

Causes of copper deficiency in sheep and cattle

Recent Cases of Low Copper Status

- Low copper levels have been found in the blood or liver of animals that have eaten large amounts of soil during a drought or when stocking rates have been excessive, and in cattle with heavy *Ostertagia* infestations.
- Copper therapy increased liveweight when the deficiency was due to excess molybdenum (that is, responsive or true metabolic copper deficiency), but not where the cause was *Ostertagia*, starvation or the ingestion of soil (marginal copper deficiency or low status).

Effect of ostertagiasis on copper status in sheep: a study involving use of copper oxide wire particles.

- Lambs infected with *Ostertagia circumcincta* larvae and uninfected controls were either dosed with 5 g copper oxide wire particles (COWP) or remained undosed.
- The change in abomasal pH was monitored from duodenal digesta and that in liver copper concentration from initial liver biopsy samples and liver obtained at necropsy after 22 days.
- Infection increased the pH of digesta from 2.5 to 4.5.
- The change in liver copper content in sheep not treated with COWP was +6.1 mg (12.6%) and -6.8 mg (13.8%) in control and infected sheep, respectively.
- Significantly greater amounts of COWP were recovered from the abomasa of infected than from control animals (3.6 0.23 and 1.6 0.55 g, respectively) and hepatic uptake of copper from COWP was 0.7 and 1.8% of the dose, respectively.
- There were significant relationships between the pH of duodenal contents and COWP retained, soluble copper concentration in duodenal digesta and hepatic uptake of copper.
- **It was concluded that, through causing an increase in pH in abomasal and duodenal digesta, gastrointestinal nematodes interfere with copper metabolism**.

Bank KS, et al 1990. Res Vet Sci 49: 306-314

Aust. J. Agric. Res., 1982, **33**, 1073–83

Oxidized Copper Wire Particles for Copper Therapy in Sheep

G. J. Judson[AB], *T. H. Brown*[C], *D. Gray*[AB], *D. W. Dewey*[D], *J. B. Edwards*[A] *and J. D. McFarlane*[C]

[A] Institute of Medical and Veterinary Science, Box 14, Rundle Street Post Office, Adelaide, S.A. 5000.
[B] Present address: Department of Agriculture, c/- Institute of Medical and Veterinary Science, Box 14, Rundle Street Post Office, Adelaide, S.A. 5000.
[C] Department of Agriculture, Box 1671, G.P.O., Adelaide, S.A. 5001.
[D] 91 Cross Road, Hawthorn, S.A. 5062.

Copper Oxide Particles

- Mounting evidence that oral dosing of copper oxide as cupric oxide particles or oxidized copper wire particles is the most effective method for prophylaxis in copper inadequacy in ruminants (Deland et al. 1979 ; Suttle 1979, 1981 ; Whitelaw et al. 1980, 1982; Judson et al. 1981; Murphy et al. 1981).
- Dewey (1977) showed that a considerable elevation of copper concentration in the liver of sheep will result from a single oral dose of 10 g cupric oxide particles.
- Suspected that the copper particles are retained in the abomasum long enough to permit acid solubilization of the copper.
- Apparently release of copper is slow, which is advantageous to the sheep for it reduces the risk of copper toxicity.

Judson GJ et al 1982 Oxidized copper wire particles for copper therapy in sheep.
aust J Agric Res 33 1073-1083

COWP Boluses

- COWP boluses can be made and administered on farm.
- Copper boluses (Copasure©) are available for use for copper deficiency in cattle.
- These boluses can be repackaged into doses suitable for growing sheep and goats.
- The minimum dose that has demonstrated control in some studies is 0.5 g, but as much as 2-4 g may be necessary for adult animals. However, always work with your veterinarian in determining dosages.

Use of COWP

- Animals can be treated again after 4-6 weeks, if necessary.
- During the year (i.e. over the worm season), animals should receive no more than

  4 (if 0.5 or 1 g is used) treatments or

  2 (if 2 or 4 g is used) treatments. However dosages of 2 to 4 grams are too high for immature sheep.
- COWP has been found to be effective in reducing *H. contortus* only.
- COWP effective against *H. contortus* in mature goats most of the time, though sometimes marginally effective.
- Other control strategies may be more effective in mature animals.

How to make COWP boluses for parasite control in sheep and goats

- Purchase copper boluses (Copasure©, available in 12.5 g and 25 g boluses)
- Obtain smaller gel capsules
  - o Available at your local pharmacy or health food store, also available from veterinary supply houses at times.
- Repackage cattle bolus into smaller gel capsule to make 0.5g dose
  - o Size 1 gelatin capsules filled 1/3 full
  - o Size 3 capsules filled ¾ full
- Administer bolus with a pill gun designed for pets or wooden dowel with PVC pipe

Gelatin capsules, Size 3 and Size 1, filled with 0.5 g or 500 mg of COWP. Photo courtesy of Dr. Joan Burke.

Illustrates the fate of COWP boluses in the animal. (adapted from www.animax-vet.com)

Things you should know about copper…

- Copper is important for immune function in livestock.
- Sheep are very sensitive to copper accumulation in the liver, which causes toxicity.
- The amount of copper required by sheep is not greatly different from the toxic level, making copper level an important consideration when mixing sheep rations or feeding mineral.
    - The margin of safety between the required amount of copper (10 ppm) and toxic level (25 ppm) is very narrow in sheep.
- Some sheep breeds are more susceptible to copper toxicity than others (Texel and dairy breeds).
- Copper sulfate is more readily absorbed than copper oxide, creating a greater risk for copper toxicity.
    - Recommending COWP use for controlling worms does not endorse the use of high copper sulfate mineral mixes to control parasites.
- There are complex mineral interactions that affect copper absorption; deficiencies in other minerals can increase the risk for copper toxicity.
    - Low levels of molybdenum can increase risk of copper toxicity
- Pastures fertilized with poultry waste may have high copper levels.
    - Sheep should not be fed poultry wastes, due to the high copper levels
- Goats are less susceptible to copper toxicity, tolerating up to 80 ppm.
    - While not common, copper toxicity in goats can occur (13).

Animals Used	Treatment	Results	Notes
Crossbred (Katahdin, Dorper, St. Croix cross) ram lambs	0.5 g or 1 g COWP every 6 weeks (May-October)	Fecal egg counts (FEC) reduced, fewer *H. contortus* found in fecals of lambs treated with COWP	Lower COWP doses just as effective at reducing internal parasites as higher doses in other studies. COWP was highly effective in reducing nematode infection for 4-6 weeks (3)
5-6 month old hair breed lambs	0, 2, 4, or 6 g COWP	FEC reduced in lambs receiving 2, 4, or 6 g COWP; *H. contortus* numbers in the abomasums were reduced (5)	
Mature Katahdin ewes, prior to lambing	0, 2, or 4 g COWP	FEC reduced for those receiving COWP (2 g-66%; 4 g- 55%), FEC increased in untreated animals	Evidence that lambs received copper from treated ewes (in utero and through milk) (4)
Lactating Polypay ewes and their offspring	Mature ewes—0, 0.5, 1, or 2 g COWP 60 days after lambing Offspring—0, 0.5, 0.75, 1 or 2 g COWP at 2 months of age	Ewes—FEC were lower for those treated with 1 or 2 g COWP Offspring—All doses of COWP lowered FEC	In this study, a beneficial effect for ewes was seen with 2 g COWP. COWP appear to be less effective in mature ewes compared with lambs. (7)

Animals Used	Treatment	Results	Notes
Boer-cross yearling goats	0, 5, or 10 g COWP bolus	FEC were lower for animals treated with COWP	While FEC were lower for animals treated with COWP, they still were over 2000 eggs/g. (9)
Boer-cross weanling goats	0 or 2.5 g COWP	FEC initially decreased by ~50% (from 2930 eggs/g to 1525 eggs/g) for those treated with COWP, but then rose to over 3000 eggs/g	FEC started to rise 3 weeks after COWP treatment. (10)
Mature Spanish does grazing winter pasture	0 or 4 g COWP	Overall FEC were similar between 0 and 4 g COWP.	On days 0, 7, and 14 FEC of untreated goats increased while FEC of COWP treated goats remained low. (8)
Yearling Spanish x boer cross bucks	0, 5, or 10 g COWP	FEC were similar in 0, 5, or 10 g COWP treated goats and decreased between day 0 and 35.	Concentrations of copper in the liver were greater in COWP-treated goats than untreated goats. (8)
Boer x Spanish doe and wether kids	0, 0.5, 1, 2, or 4 g COWP	FEC were lower on days 7, 14, and 21 compared with untreated kids, but were similar by day 28.	Average daily gain tended to increase with dose of COWP up to 2 g then decreased at 4 g. (8)

Animals Used	Treatment	Results	Notes
Boer x Spanish wether kids	0 g COWP, 5 g COWP, apple cider vinegar drench, or vinegar drench and 5 g COWP	There was no effect of vinegar drenching on FEC in 0 or 5 g COWP treated kids. FEC were reduced in COWP treated kids. (8)	
Boer and Spanish x Boer does	0 or 2 g COWP while supplemented with 220 g of corn and soybean meal or 220 g of cottonseed meal	FEC were reduced in COWP treated goats and remained lower than untreated does until day 21 for corn soybean meal-supplemented does and day 28 in cottonseed meal-supplemented does. FEC were lower in CSM than corn soybean meal-supplemented does that received COWP.	At the end of this study, 2 g COWP was administered to all goats and resulted in a 79% reduction in FEC 7 days later. (8)
Boer yearling does	0 or 5 g COWP grazing either tall fescue or sericea lespedeza	Doses of 5 g COWP decreased FEC and sericea lespedeza grazing tended to decrease FEC.	By day 28 approx. 50% of untreated does required deworming, but no COWP-treated does required deworming. (8)
Yearling Spanish does, prior to breeding	Multi-trace element/vitamin ruminal bolus containing copper oxide	Fecal egg counts were reduced (by 80%) and remained low, while untreated animals' FEC increased (6)	
Spanish and Boer does, 6 weeks before kidding	Multi-trace element/vitamin ruminal bolus containing copper oxide	*H. contortus* decreased; FEC were reduced (by 60%)	Reduction in FEC lasted 3-4 weeks, similar to anthelmintic treatments (6)

Treating *Haemonchus* – 2000

- Pen trial, where the effect of COWP on established worm burdens and the effect of copper on the fungus were studied.
  - Six-month-old lambs were divided into 7 groups of 6.
    - Four groups were treated with either 2 or 4 g of copper, with or without a Danish isolate of *D. flagrans*.
    - Two groups received either a Danish or a Brazilian isolate of *D. flagrans*,
    - 7th group acted as controls.
  - COWP at 4 g significantly reduced all the abomasal nematodes studied
  - 2 g of COWP was only effective against T*. axei.*
- Dose-dependent effect on all abomasal nematodes studied, although the effect was especially marked for *T. circumcincta*.
- No effect on any of the small intestinal nematodes.
- Due to lack of fungal activity, the interaction between copper and fungus could not be studied.

Nyman H. 2000. Alternative methods of treating gastrointestinal nematodes in sheep, using *Duddingtonia flagrans* and copper wire particles. Minor Field Studies - International Office, Swedish University of Agricultural Sciences Issue: 99 Pages: 54 pp.

France – 2000

- Curative effect of copper oxide needles (COWP, 2-4 g) on existing worm burdens was assessed in goats experimentally infected with *Teladorsagia circumcincta*, *Haemonchus contortus* and *Trichostrongylus colubriformis* (n=11, including controls).
- Preventive effect of COWP (4 g) on worm establishment was monitored for 2 months in animals
  - Experimentally infected with *H. contortus* (n=10, including controls) and
  - For 3 months in naturally infected animals on a farm exhibiting predominant infections with *T. circumcincta* and *Oesophagostomum venulosum* (n=38, including controls).
- In both experimental and natural conditions, the efficacy of COWP was nil against *Teladorsagia*, *Trichostrongylus* and *Oesophagostomum* infections.
- In contrast, the efficacy of COWP against *Haemonchus* was clearly established in reducing the worm burden (75%) as well as in lowering the egg output (37-95%) in relation to the establishment of new infections over several weeks.
- Concluded that COWP may represent an alternative to conventional anthelmintics in the control of *Haemonchus* infection in some goat farms.

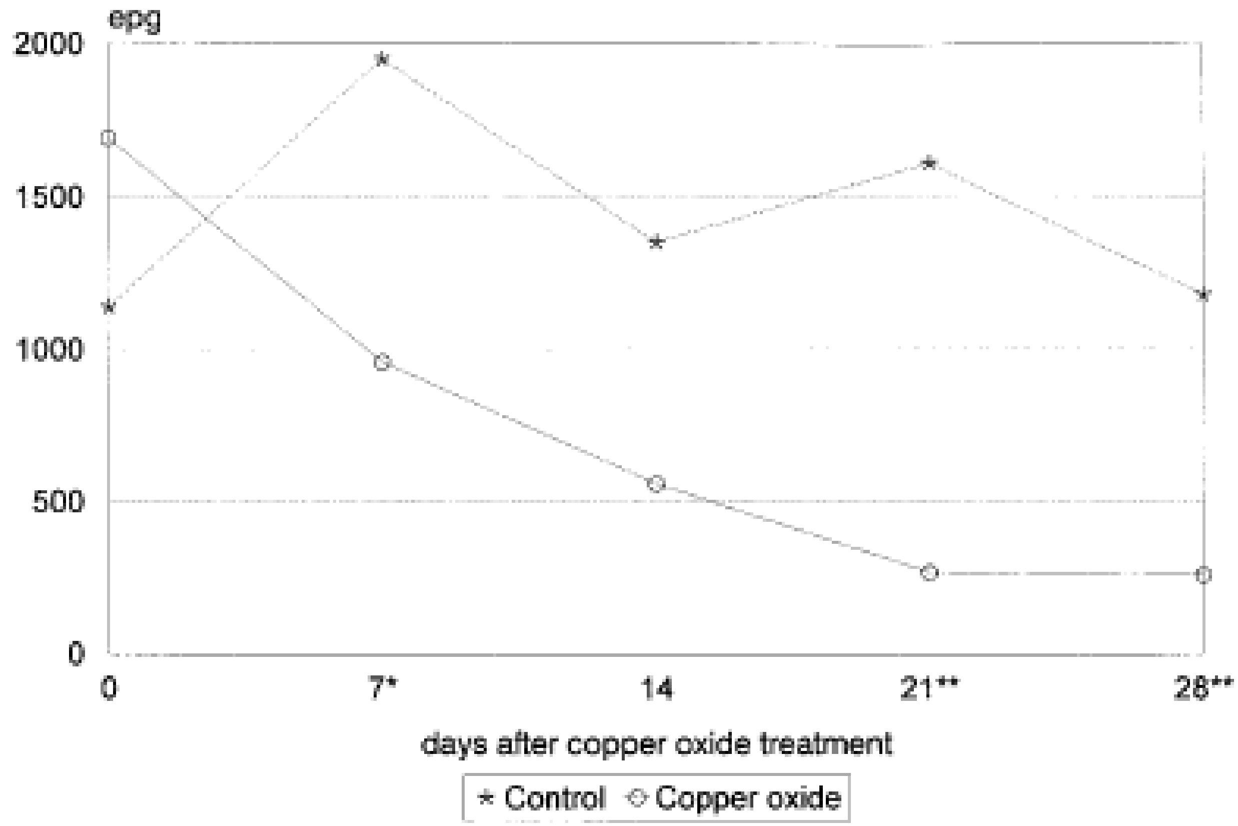


Figure 1. Faecal egg counts in experimentally infected goats (*H. contortus*, *T. circumcincta*, *T. colubriformis*) in the control and copper oxide-treated groups from 0 to 28 days after the treatment (experiment 1). $*p < 0.05$; $**p < 0.01$

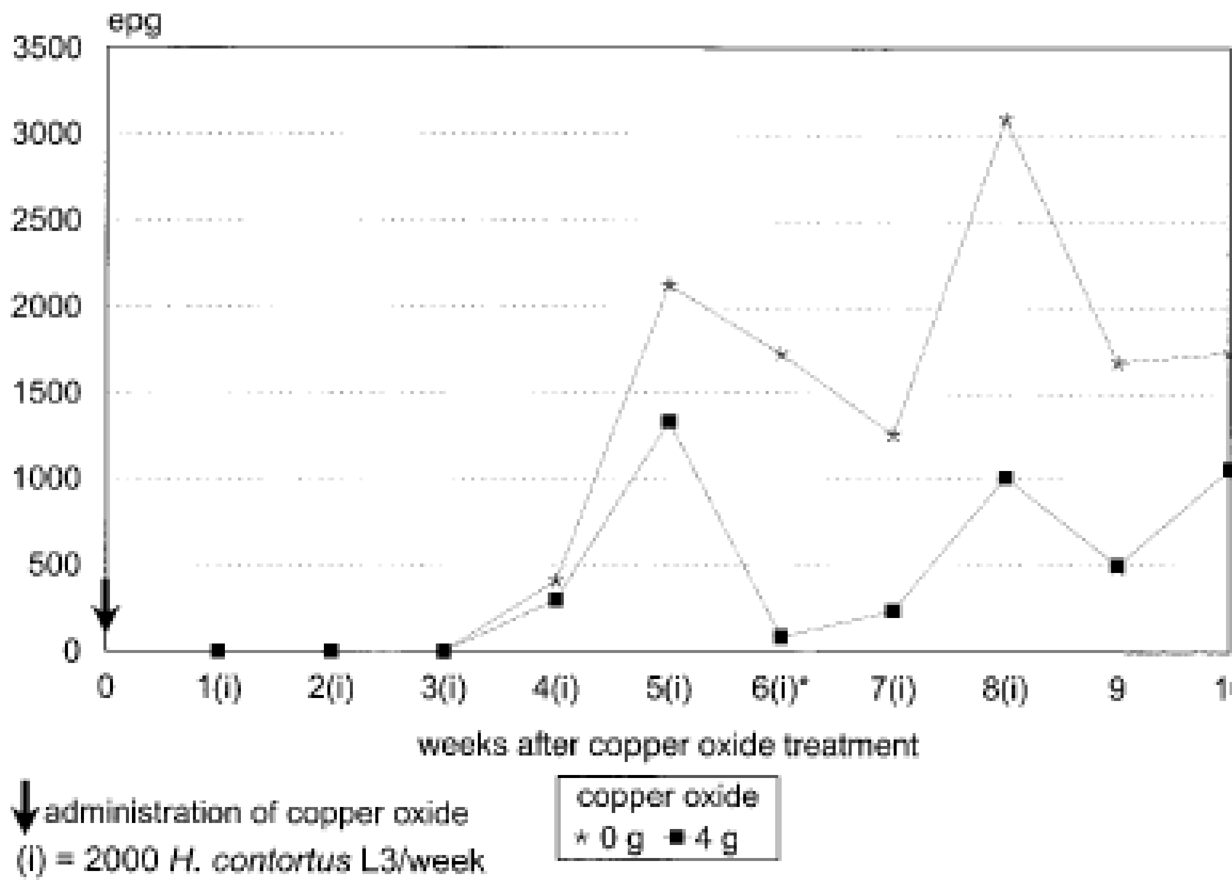


Figure 2. Faecal egg counts in control goats and goats treated with copper oxide (4 g) receiving repeated infections of *Haemonchus contortus*: weekly infection starting 7 days after the administration of the copper oxide needles (experiment 2). $*p < 0.05$

Australia – 2002

- In experiment 1, forty worm-free Merino hoggets (11 to 12 months of age) were divided into four equal groups and allocated to separate 0.8 ha pasture plots.
  - Two groups received 2.5 g COWP
  - Two groups were untreated.
  - From 1 week after COWP treatment all lambs received a weekly infection of 2000 *H. contortus* larvae.
  - At week 8, six sheep from the untreated group were then allocated to two groups and treated with either 2.5 or 5.0 g of COWP to establish therapeutic efficacy of treatment.
- In experiment 1 no significant difference in faecal worm egg counts was observed between treatments and faecal worm egg counts remained less than 3000 epg in all animals.
  - Total worm counts were reduced by 37% by COWP treatment (P=0.055).
  - Both 2.5 g and 5.0 g doses of COWP at 8 weeks of infection reduced faecal worm egg counts by >85% with the higher dose giving an earlier response to treatment.

Knox, M. R. 2002. Effectiveness of copper oxide wire particles for Haemonchus contortus control in sheep. Austral Vet J 80 224-227.

Australia – 2002

- Experiment 2 was conducted with 40 worm-free Merino lambs (3 to 4 months of age) and no assessment of therapeutic efficacy was made.
- Fecal worm egg counts at 4 and 6 weeks were reduced by more than 90% in the COWP treated lambs and worm numbers were 54% lower after 6 weeks when all remaining untreated lambs had to be treated for haemonchosis.
  - Mean fecal worm egg counts in the COWP lambs remained below 3500 epg and clinical disease did not develop in the majority of lambs before the end of the experiment at 10 weeks.

Knox, M. R. 2002. Effectiveness of copper oxide wire particles for Haemonchus contortus control in sheep. Austral Vet J 80 224-227.

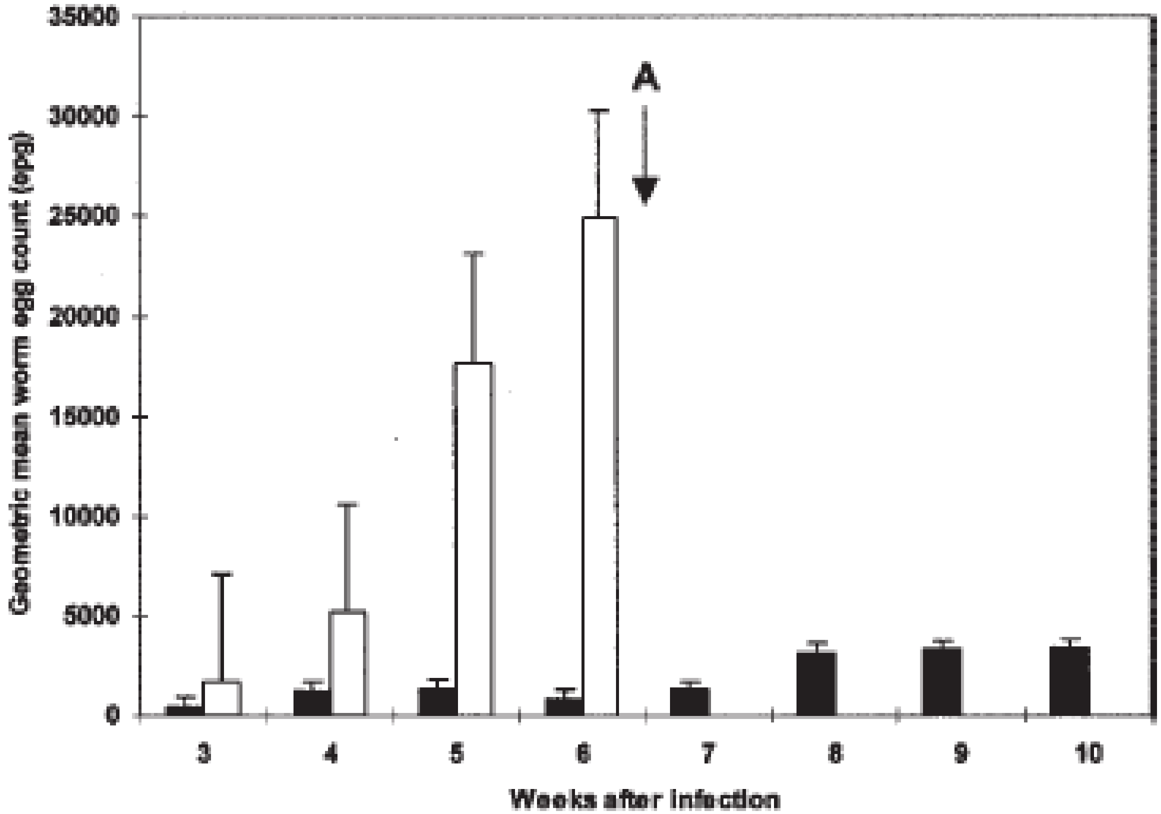


Figure 1. Geometric mean faecal worm egg counts (mean + SE) for young Merino lambs treated with COWP (■) or untreated (□) during infection with 2000 L_3 *H contortus*/week for 10 weeks (Experiment 2).

A = anthelmintic treatment given to untreated sheep.

Cornell University
College of Veterinary Medicine

Australia – 2002

- Treatment with COWPs appears to have the potential to reduce establishment and worm fecundity of *Haemonchus* spp for an extended period
- May offer livestock producers a supplementary means of reducing larval contamination of pasture particularly in areas where anthelmintic resistance is a problem and copper supplementation is likely to be beneficial.

Knox, M. R. 2002. Effectiveness of copper oxide wire particles for Haemonchus contortus control in sheep. Austral Vet J 80 224-227.

Safety for ewes and lambs USA

- Mature Katahdin ewes were administered 0 (n=14), 2 (n=15), or 4 (n=15) g of COWP 331.6 days before lambing in late March
  - EPG and PCV determined between Days 0 (day of COWP administration) and 35.
  - Lambs weighed within 24 h after birth, at 30 and 60 days of age, and in mid-September (~120 days of age).
  - Blood was collected from lambs within 24 h after birth and at 30 days of age for determination of the activity of the liver enzyme, aspartate aminotransferase (AST) in plasma.
- Within 7 days after COWP administration, EPG fell to 1308 and 511 eggs/g (epg) in the 2 and 4 g groups, respectively, compared with an increase of 996 epg in the control group ($P<0.02$).
  - PCV was similar among groups between Days 0 and 35.
  - Lamb plasma AST activity at birth increased with increasing dose of COWP in dams ($P<0.001$). Plasma AST activity at 30 days of age was similar for lambs from ewes treated with 0 and 2 g COWP, but was slightly greater in lambs from ewes treated with 4 g COWP ($P<0.02$).
  - Birth weights decreased with increasing COWP ($P<0.003$).
  - By 30 (COWP * birth type, $P<0.02$) and 60 (COWP * birth type, $P<0.02$) days of age, weight of multiple-born lambs decreased with increasing COWP, while weight of single-born lambs was similar among treatments.
- In mid-September (~120 days of age) weights of multiple-born lambs from ewes treated with 4 g COWP tended to be lightest compared with lambs from ewes treated with 0 or 2 g COWP or single-born lambs ($P<0.09$).
- Lamb survival to 30, 60, or 120 days of age was not affected by COWP treatment to ewes.
- Administration of 4 g COWP to late pregnant ewes may negatively impact multiple-born offspring, but the 2 g appears to be safe for production.

Burke JM et al. 2005. The effectiveness of copper oxide wire particles as an anthelmintic in pregnant ewes and safety to offspring. Vet Parasitol 131 291-297.

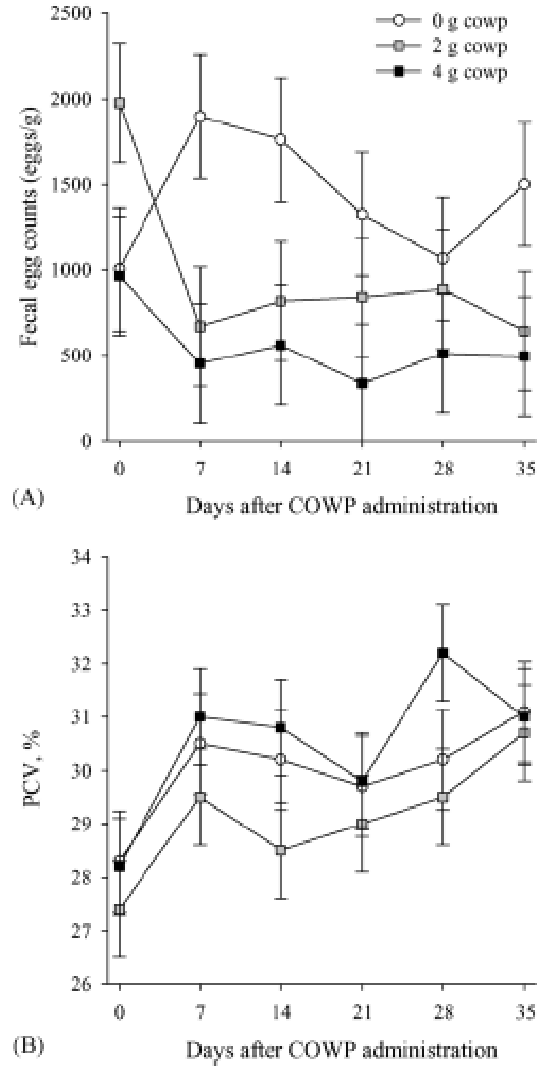


Fig. 1. Least squares means and standard errors of fecal egg counts (FEC; A) and packed cell volume (PCV; B) of ewes administered 0 ($n = 14$; open circle), 2 g ($n = 15$; shaded square), or 4 g ($n = 15$; closed square) copper oxide wire particles (COWP) during late pregnancy (Day 0). Effect of COWP over time tended to be significant for FEC ($P < 0.07$).

Cornell University
College of Veterinary Medicine

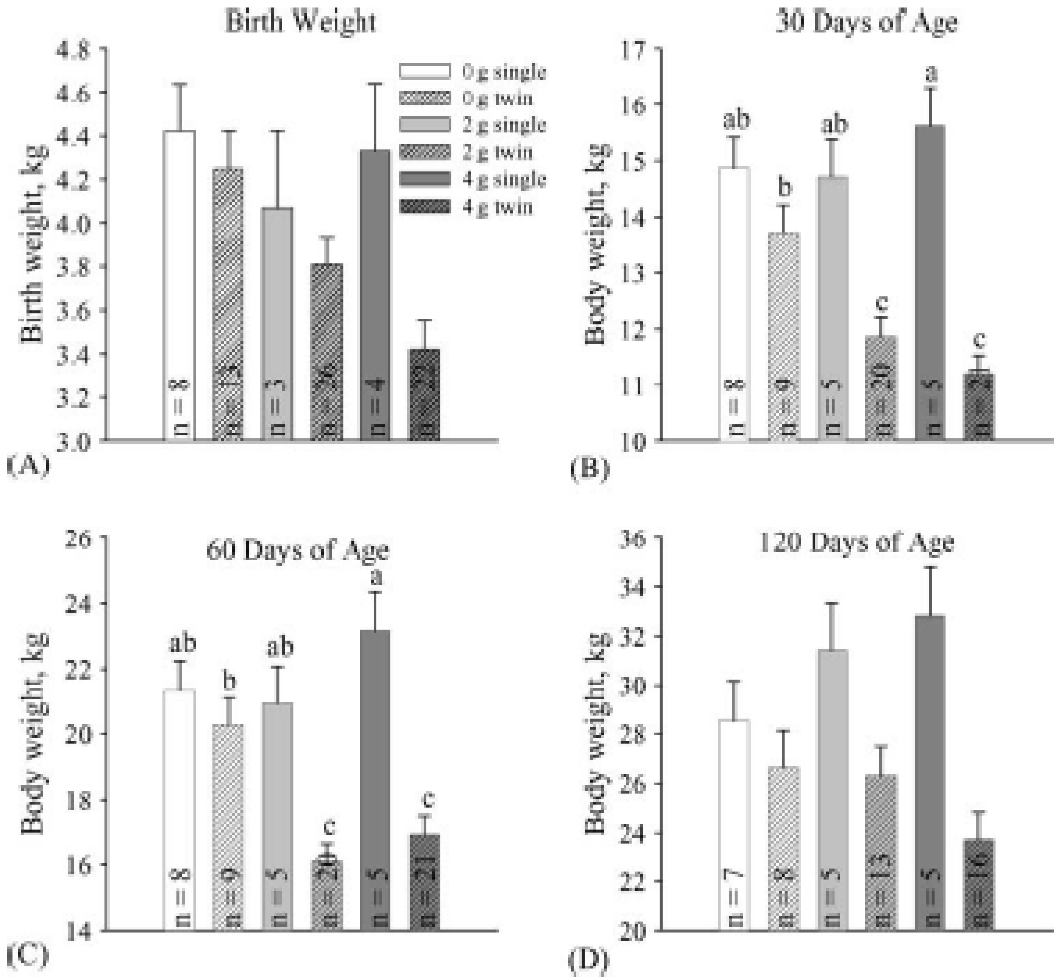


Fig. 4. Least squares means and standard errors of body weight of lambs born from ewes administered 0 (white bars), 2 g (light gray bars), or 4 g (dark gray bars) copper oxide wire particles (COWP) during late pregnancy. Body weights of single (no hatch) and multiple (hatched bars) born lambs are presented at birth (A), 30 (B), 60 (C), and 120 (D) days of age. Within an age category least squares means lacking a common letter differ ($P < 0.05$). Numbers of lambs for each group are included within bars. Between birth and 30 days of age three lambs died and five lambs were orphaned. At 60 days of age 11 lambs were culled and three lambs died after weaning.

COWP vs Levamisole

- Recently, smaller doses (0.5 and 1 g) have proven effective in nematode control, reducing the risk of toxicity.
- Objective was to examine the effectiveness and risk of toxicity using multiple small doses of COWP for nematode control in lambs between weaning and market weight.
- Dorper crossbred ram lambs were orally administered levamisole (Levasol, 8.0 mg/kg; n=8), 0.5 g (n=9), or 1 g COWP (n=9) at weaning (Day 0; 1182 days of age; late May 2005) and again at 6-week intervals for a total of four treatments.
  - A pooled faecal culture determined that *Haemonchus contortus* was the predominant gastrointestinal parasite at weaning.
  - Lambs grazed bermuda-grass pastures and were supplemented with up to 500 g corn/soybean meal and free choice trace mineralized salt.
  - EPG, PCV, and plasma AST activity determined every 14 days and lambs weighed every 28 days.

Burke JM , Miller JE. Evaluation of multiple low doses of copper oxide wire particles compared with levamisole for control of *Haemonchus contortus* in lambs. Vet Parasitol 139 145-149.

COWP vs Levamisole

- GI nematode infection reached a peak at Day 42 (high FEC, low PCV).
- COWP effectively reduced FEC on Days 0 and 42 compared with the previous week, but did not reduce FEC on Days 84 and 126 (treatment by time interaction, $P<0.005$).
- Plasma AST activity and weight gains were similar among treatment groups throughout the study period.
- Concentrations of copper in the liver on Day 155 were greater in COWP-treated lambs ($P<0.001$), but all concentrations were normal.
- Multiple doses of COWP were as effective as levamisole for control of *H. contortus* without risk of copper toxicity.

Burke JM , Miller JE. Evaluation of multiple low doses of copper oxide wire particles compared with levamisole for control of *Haemonchus contortus* in lambs. Vet Parasitol 139 145-149.

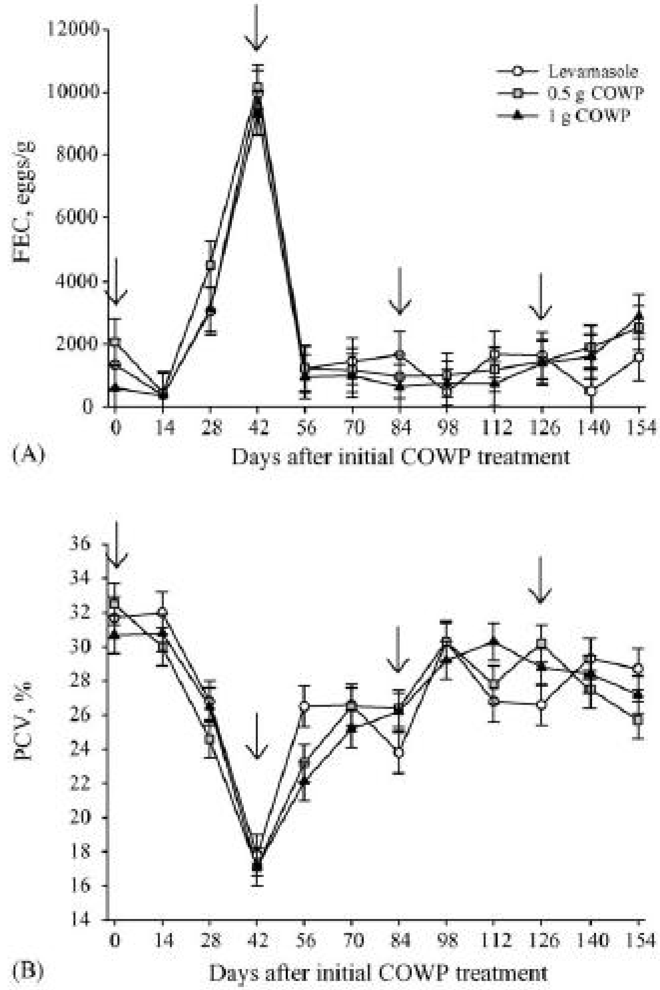


Fig. 1. Least squares means and standard errors of fecal egg counts (FEC; A) and packed cell volume (PCV; B) of lambs treated with levamisole ($n = 8$; open circle), 0.5 g copper oxide wire particles (COWP; $n = 9$; shaded square), or 1 g COWP ($n = 9$; closed triangle) on Day 0. Arrows represent days on which treatment was administered.

Nematodes, COWP, Lactating Polypay ewes

- Objective to determine the effectiveness and safety of COWP in lactating Polypay ewes and their offspring grazing alfalfa/bluegrass pasture in a rotational grazing system.
  - Mature Polypay ewes were administered 0, 0.5, 1, or 2 g (n=8 or 9/dose) COWP approximately 60 days after lambing in mid-July 2005.
  - Offspring were administered 0 (n=6), 0.5 or 0.75 g (n=9), 1 or 2 g (n=6) COWP 2 weeks later in late July.
  - The primary gastrointestinal nematode was *H. contortus* (70%).

Burke JM, et al. 2007. Control of gastrointestinal nematodes with copper oxide wire particles in a flock of lactating Polypay ewes and offspring in Iowa, USA. Vet Parasitol 146 372-375.

Nematodes, COWP, Lactating Polypay ewes

- Ewes: Between Days 7 and 35, FEC were greater in 0 and 0.5 g COWP groups compared with ewes administered 2 g COWP (COWP * day, P <0.004).
  - PCV decreased in all groups of ewes between Days 0 and 21 (day, P<0.001).
  - AST activity, a measure of liver copper levels, and body weight was similar among groups of ewes.
  - Administration of 2 g COWP to ewes prevented a rise in FEC, but a dose of 0.5 g was ineffective as an anthelmintic.
- Lambs: FEC decreased within 7 days in COWP-treated compared with untreated lambs and remained low throughout experiment (COWP * day, P<0.05).
  - PCV increased in COWP-treated lambs between Days 7 and 35 and decreased in untreated lambs between Days 0 and 21 (COWP * day, P<0.009).
  - AST activity was similar among groups of lambs.
  - Administration of all doses of COWP to lambs decreased FEC and increased PCV compared to untreated lambs.
- There were no signs of copper toxicity in ewes or lambs.
- Alternative suppression of *H. contortus* infections may be necessary in ewes, but COWP was effective in *H. contortus* management for lambs.

Burke JM, et al. 2007. Control of gastrointestinal nematodes with copper oxide wire particles in a flock of lactating Polypay ewes and offspring in Iowa, USA. Vet Parasitol 146 372-375.

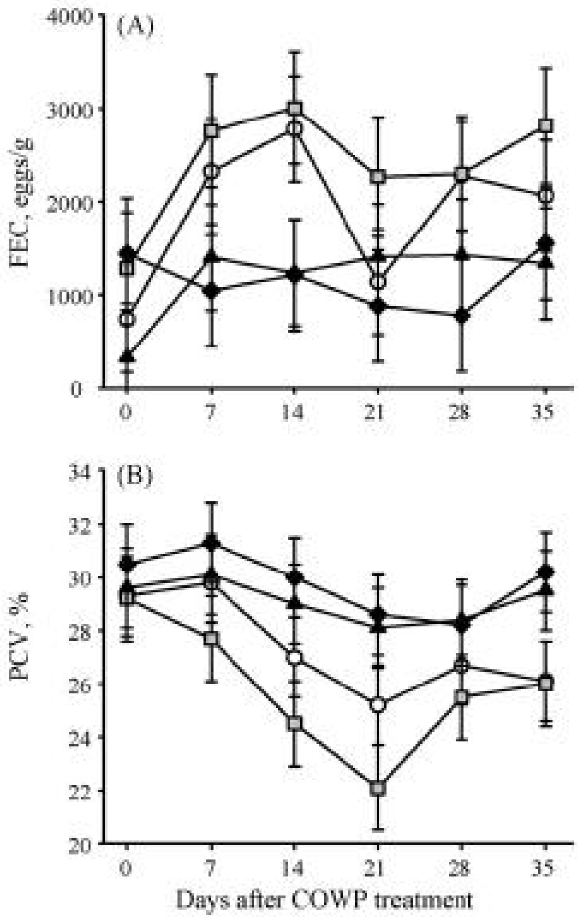


Fig. 1. Least squares means and standard errors of fecal egg counts (FEC; A) and packed cell volume (PCV; B) of ewes administered no ($n = 9$; open circles), 0.5 g ($n = 8$; shaded squares), 1 g ($n = 9$; closed triangles), or 2 g copper oxide wire particles (COWP; $n = 9$; closed diamonds) on Day 0.

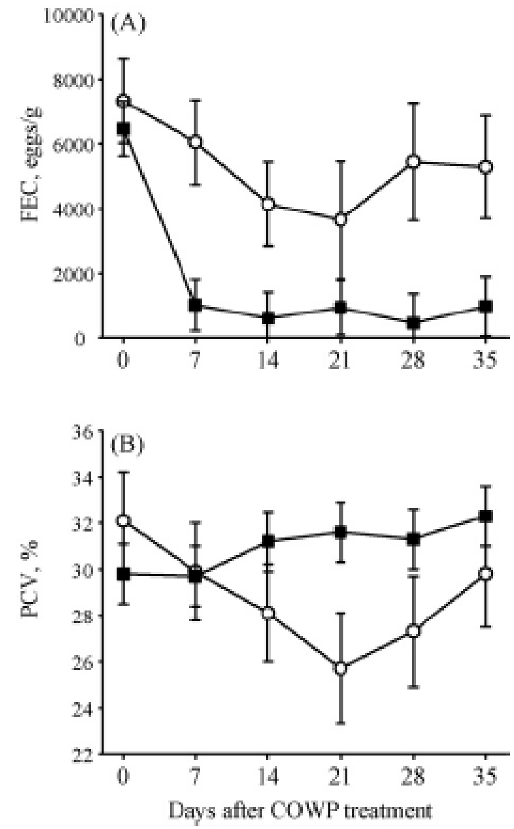


Fig. 2. Least squares means and standard errors of fecal egg counts (FEC; A) and packed cell volume (PCV; B) of lambs administered no ($n = 6$; open circles) or 0.5–2 g copper oxide wire particles (COWP; $n = 15$; closed squares) on Day 0.

COWP in Goats

- To determine the optimal dose of COWP necessary to reduce gastrointestinal nematode infection in young and mature meat goats naturally infected with *Haemonchus contortus* or a mixed infection and to determine whether the effectiveness could be enhanced through feeding management.
  - 2 experiments conducted during cooler months in Georgia
  - 4 experiments conducted during warmer spring or summer months in Arkansas.
- Goats received 0 up to 10 g of COWP under a variety of management conditions.
- In all experiments, blood and feces were collected every 3 or 7 d from 6 to 42 d to determine PCV and FEC

Burke JM, et al. 2007. Use of copper oxide wire particles to control gastrointestinal nematodes in goats. J Anim. Sci 85 2753-2761.

COWP in Goats

- In mature goats grazing fall pasture:
  - Mean FEC of 0 g of COWP-treated goats increased
  - Mean FEC of 4 g of COWP-treated goats remained low
  - Mean FEC of 5 and 10 g of COWP-treated goats decreases, PCV increased, but FEC and PCV remained unchanged over time in control goats.
- FEC were similar among all low doses (0.5, 1, 2, 4 g) of COWP administered to weaned kids for all dates examined, which were lower on days 7 through 21 but similar to controls by day 28.
- Packed cell volume was lower in 0 g compared to all COWP-treated kids
- Feeding management in combination with COWP for nematode control had little effect compared with COWP alone for these short-term studies.
- In conclusion, a dose of COWP as low as 0.5 g, which was considered optimal to reduce the risk of copper toxicity, was effective in reducing FEC in young goats, and 5 g of COWP was effective in older goats.
- Copper oxide does not appear to be effective in controlling newly acquired L4 stage (preadult) larvae, which also feed on blood, leading to decreased PCV in newly infected goats.

Burke JM, et al. 2007. Use of copper oxide wire particles to control gastrointestinal nematodes in goats. J Anim. Sci 85 2753-2761.

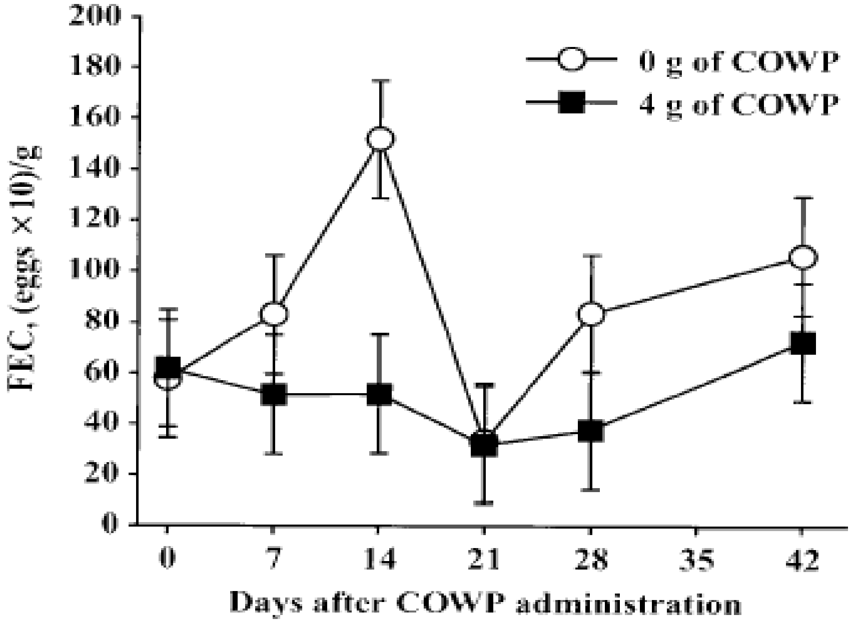


Figure 1. Effect of administration of 0 or 4 g of copper oxide wire particles (COWP; n = 11/group) on fecal egg counts (FEC) in mature goats (Exp. 1) from d 0 through 42 after administration of COWP. Least squares means and SE are presented, and statistical analysis of FEC was performed on logarithm-transformed values. The COWP in gelatin capsules was administered orally with a balling gun on d 0. Considering d 0 through 14 (a period of biological relevance for an anthelmintic), FEC of untreated goats increased and those of COWP-treated goats remained low (COWP × d, $P < 0.03$). However, for the entire observation period, FEC was similar between groups ($P = 0.12$).

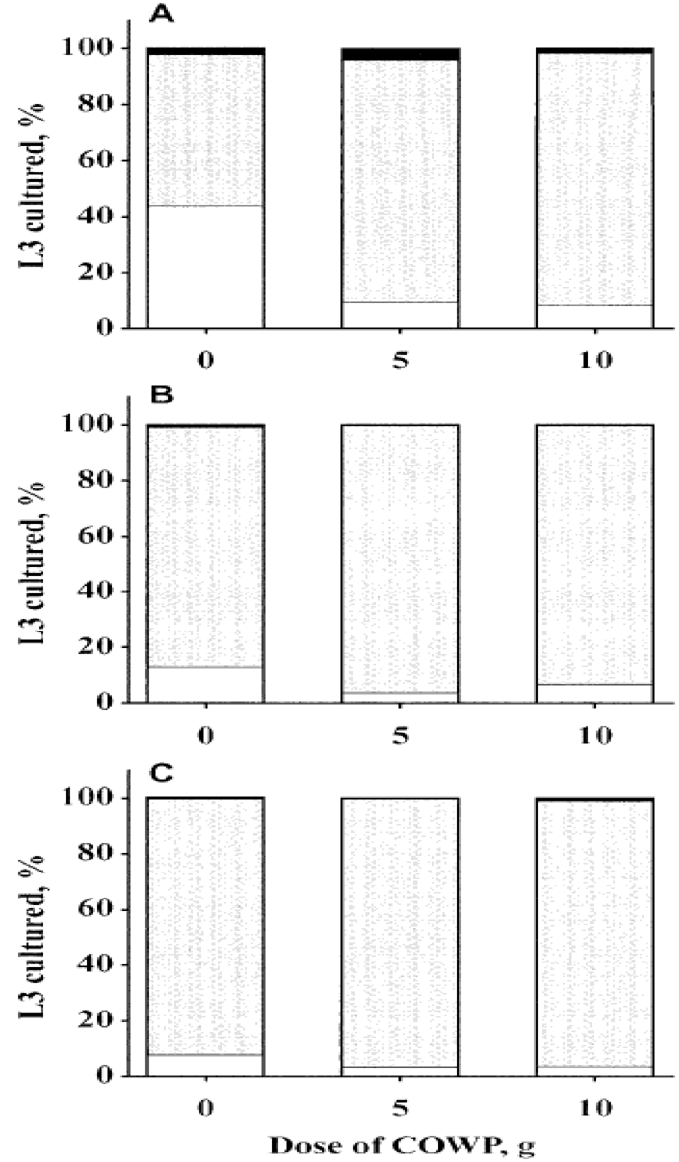


Figure 2. Effect of increasing doses of copper oxide wire particles (COWP; n = 6/dose) on the proportion of *Haemonchus contortus* (white), *Trichostrongylus* (gray), or *Oesophagostomum* (black) L3 larvae cultured from feces collected on d 7 (A), 21 (B), and 35 (C) after administration of COWP to mature goats (Exp. 2). Least squares means (SE were 4.5, 9.2, and 1.0 for *H. contortus*, *Trichostrongylus*, and *Oesophagostomum*, respectively) are presented for each treatment group and day.

Weaned kids

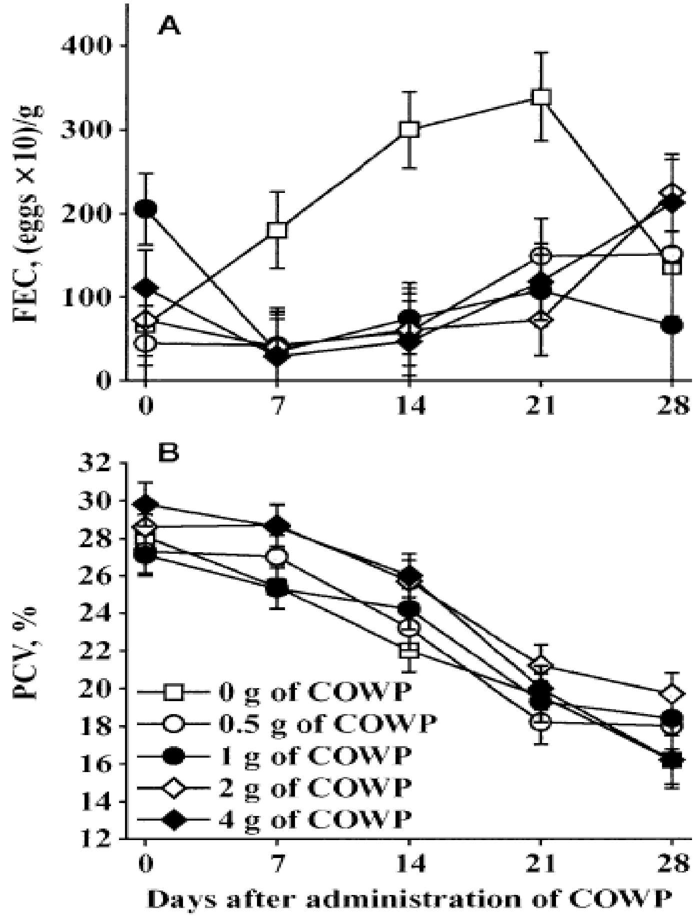


Figure 3. Effect of increasing dose of copper oxide wire particles (COWP; n = 8/dose) on fecal egg counts (FEC; A) and blood packed cell volume (PCV; B) from d 0 through 21 after administration of COWP in weaned kids on pasture (Exp. 3). Least squares means and SE are presented, and statistical analysis of FEC was performed on logarithm-transformed values. The COWP in gelatin capsules was administered orally with a balling gun on d 0. When all COWP treatments were pooled, FEC was reduced (COWP × date, $P < 0.05$) in COWP-treated kids compared with controls on d 7, 14, and 21.

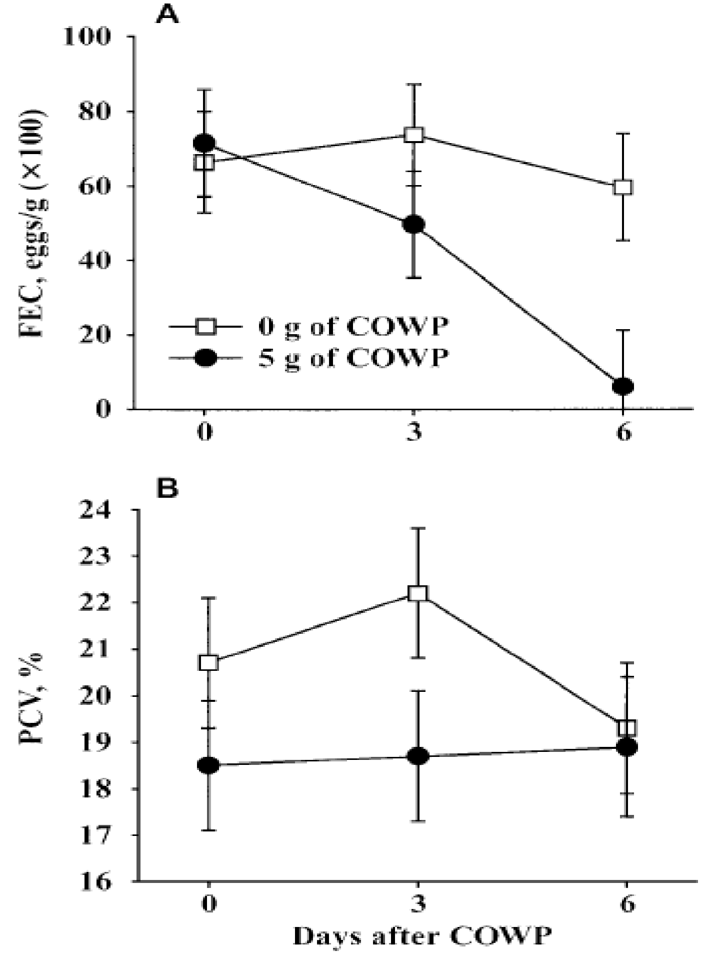


Figure 4. Effect of 0 (n = 10) or 5 g of copper oxide wire particles (COWP; n = 9) on fecal egg counts (FEC; A) and blood packed cell volume (PCV; B) from d 0 through 6 after administration of COWP in wether kids (Exp. 4). Least squares means and SE are presented, and statistical analysis of FEC was performed on logarithm-transformed values. The COWP in gelatin capsules was administered orally with a balling gun on d 0. The FEC was reduced (COWP × date, $P < 0.001$) in COWP-treated kids compared with controls on d 3 and 6.

supplemented
kids

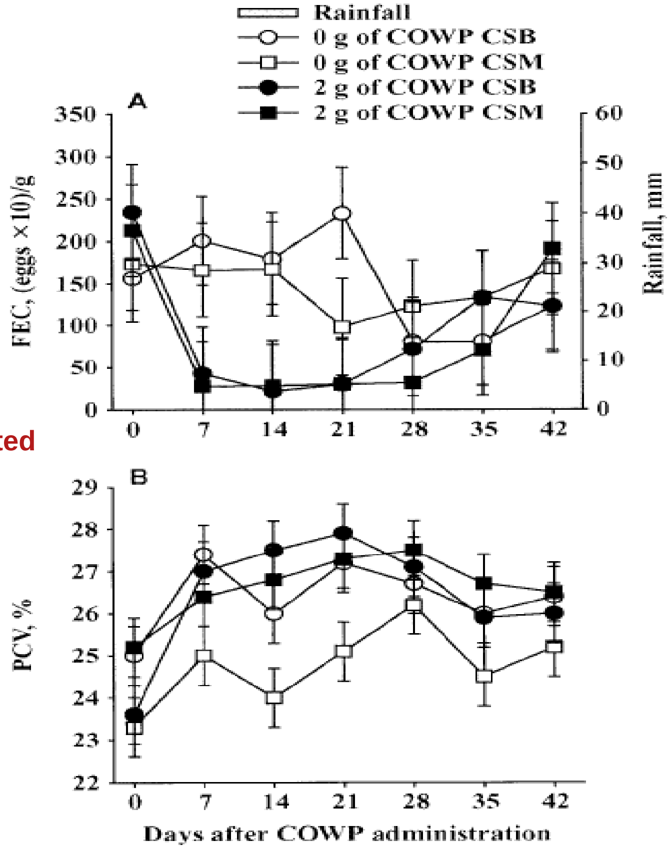
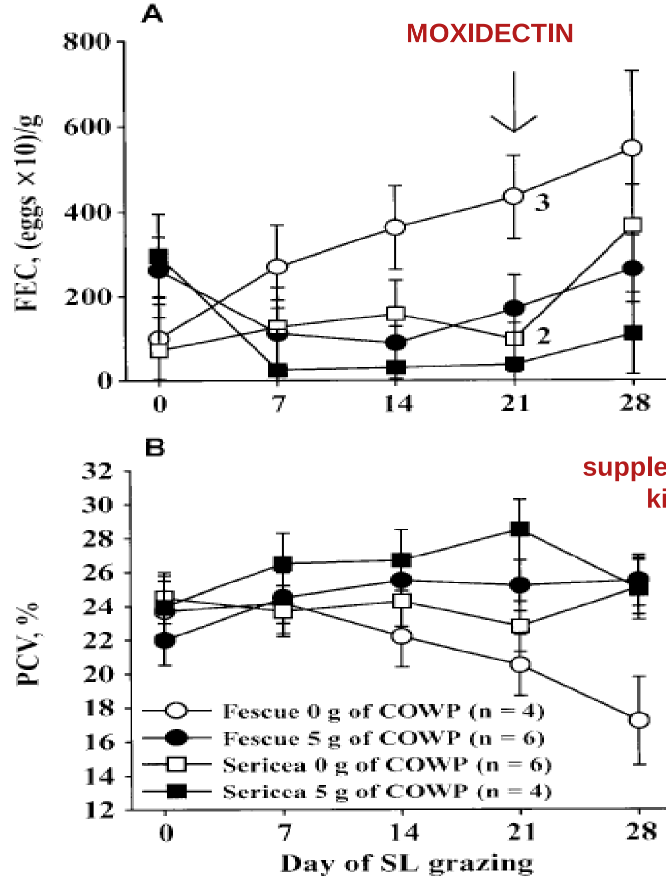


Figure 5. Effect of 0 or 2 g of copper oxide wire particles (COWP; n = 17/treatment) in kids supplemented with corn and soybean meal (CSB) or cottonseed meal (CSM; n = 17/supplement) on fecal egg counts (FEC; A) and blood packed cell volume (PCV; B) from d 0 through 42 after administration of COWP (Exp. 5). Least squares means and SE are presented, and statistical analysis of FEC was performed on logarithm-transformed values. The COWP in gelatin capsules was administered orally with balling gun on d 0 and does were supplemented with CSB or CSM from d 0 to 42. The FEC were reduced in COWP-treated kids (COWP × d, $P < 0.001$).

indicated a reduction in *H. contortus* but not other GIN species, as observed in the current study.

During warmer months (Exp. 3 through 6), all doses



supplemented
kids

Figure 6. Effect of 0 or 5 g of copper oxide wire particles (COWP; n = 10/treatment) in yearling does grazing tall fescue or sericea lespedeza (SL; n = 10/forage) on fecal egg counts (FEC; A) and blood packed cell volume (PCV; B) from d 0 through 28 after administration of COWP (Exp. 6). Arrow indicates day goats were removed from SL. A number to the right of a symbol indicates number of does that were dewormed with moxidectin on that day, which were removed from the data set the following week. Least squares means and SE are presented, and statistical analysis of FEC was performed on logarithm-transformed values. The COWP in gelatin capsules was administered orally with a balling gun on d 0. The COWP decreased FEC (COWP × d, $P = 0.01$) on d 7, 14, and 21 in treated compared with control goats.

Kids versus Lambs

- Weaned
  - Kids (Kiko X Spanish cross, 6 months old)
  - Lambs (Katahdin or Dorper X Blackface crosses, 5 months old)
  - Grazing the same pasture area in Central Georgia
- 2 g of COWP in a gel capsule given to half the animals of each species, while the other half given no COWP.
- Weekly FEC and PCV.
- After COWP treatment, animals were grazed for 4 weeks and then slaughtered, with adult nematodes recovered from the abomasum and small intestines for counting and identification to species.

Soli F, et al. 2010. Efficacy of copper oxide wire particles against gastrointestinal nematodes in sheep and goats. Vet Parasitol 168: 93-96.

Kids versus Lambs

- For both sheep and goats, COWP treatment reduced EPG, increased PCV, and lowered abomasal nematode numbers
- For EPG, differences were 82.5% for sheep and 90.5% for goats 26 days after treatment
- Adult *H. contortus* were
  - 67.2% lower for COWP-treated sheep
  - 85.8% lower for COWP-treated goats
- COWP treatment was equally effective against *H. contortus* infection in lambs and kids and appears to be an effective method of controlling *H. contortus* infection for up to 6 weeks in small ruminants following weaning.

Soli F, et al. 2010. Efficacy of copper oxide wire particles against gastrointestinal nematodes in sheep and goats. Vet Parasitol 168: 93-96.

HALF FLOCK TAKEN TO SLAUGHTER

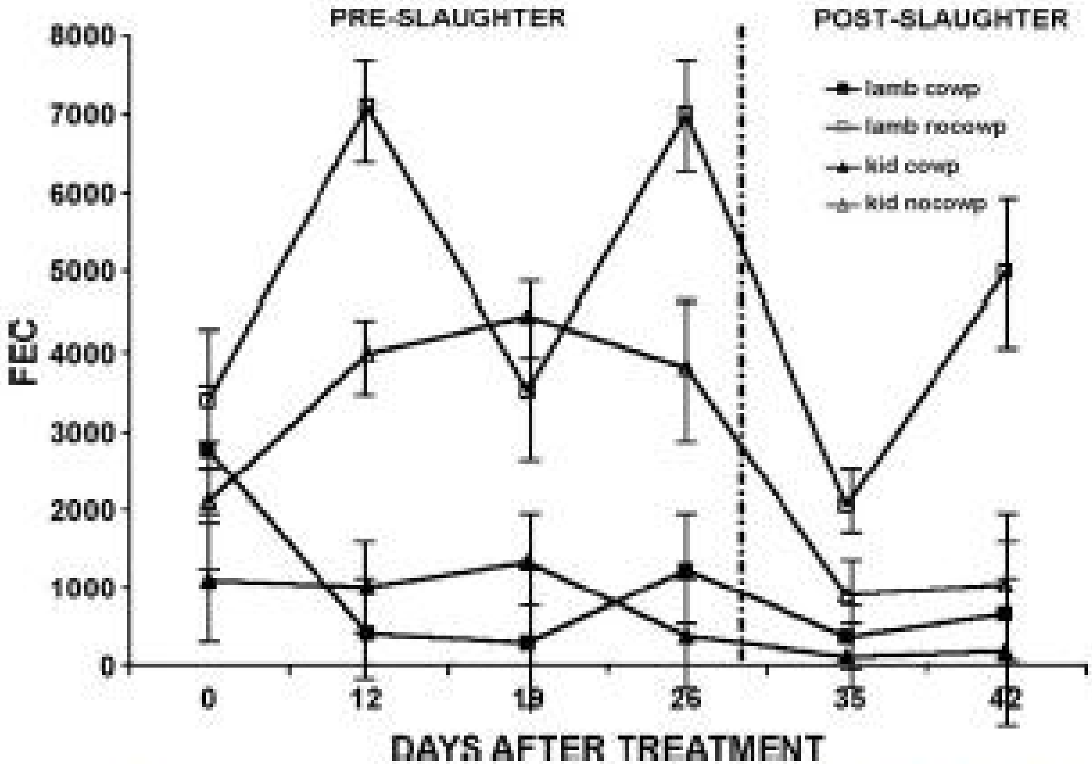


Fig. 1. Effect of copper oxide wire particles (COWP, 2 g bolus) on fecal egg counts (FEC) of naturally infected lambs (COWP-treated, solid squares; no COWP treatment, open squares) and kids (COWP-treated, solid triangles; no COWP treatment, open triangles) grazing summer pasture in Georgia. Least squared means and standard errors are presented, and statistical analysis of FEC was completed on log-transformed values.

Soli F, et al. 2010. Efficacy of copper oxide wire particles against gastrointestinal nematodes in sheep and goats. Vet Parasitol 168: 93-96.

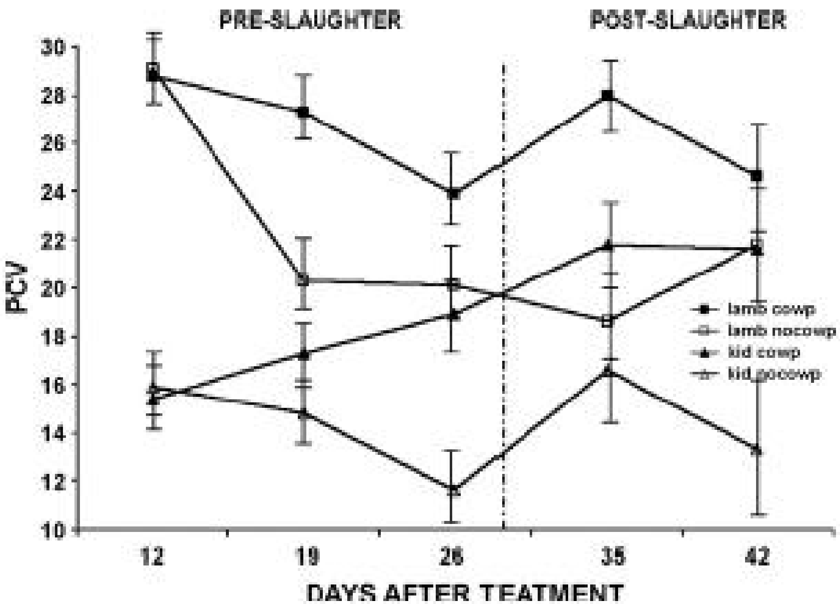


Fig. 2. Effect of copper oxide wire particles (COWP, 2 g bolus) on blood packed cell volume (PCV) of naturally infected lambs (COWP-treated, solid squares; no COWP treatment, open squares) and kids (COWP-treated, solid triangles; no COWP treatment, open triangles) grazing summer pasture in Georgia. Least squared means and standard errors are presented.

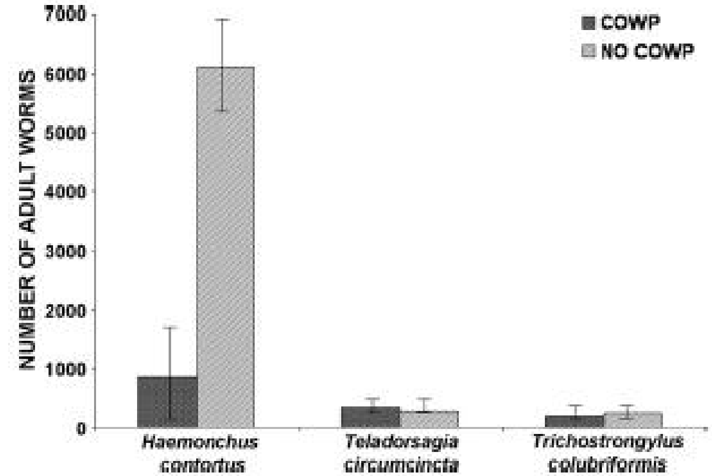


Fig. 3. Effect of copper oxide wire particles (COWP, 2 g bolus) on adult gastrointestinal nematodes (worms) of naturally infected goats grazing summer pasture in Georgia.

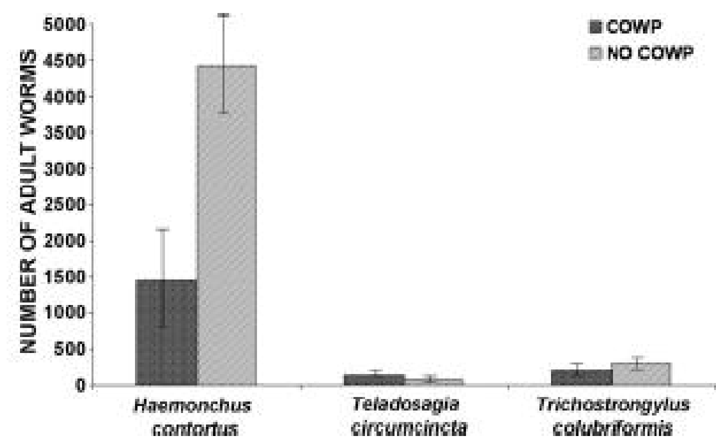


Fig. 4. Effect of copper oxide wire particles (COWP, 2 g bolus) on adult gastrointestinal nematodes (worms) of naturally infected sheep grazing summer pasture in Georgia.

Soli F, et al. 2010. Efficacy of copper oxide wire particles against gastrointestinal nematodes in sheep and goats. Vet Parasitol 168: 93-96.

COWP in Capsules or Feed

- Objective to determine the effectiveness of COWP administered as a gelatin capsule or in a feed supplement to control gastrointestinal nematodes in goats.
- 4 separate experiments:
  - peri-parturient does (n=36)
  - yearling does (n=25)
  - weaned kids (n=72)
  - yearling bucks (n=16)
- Randomly assigned to remain untreated or administered 2 g COWP in a capsule (in Experiments 1, 2, and 3) or feed supplement (all experiments).
- Feces and blood were collected every 7 days between Days 0 and 21 (older goats) or Day 42 (kids) for FEC and PCV analyses.

Burke JM, et al. 2010. Administration of copper oxide wire particles in a capsule or feed for gastrointestinal nematode control in goats. Vet Parasitol 168 346-350.

COWP in Capsules or Feed

- A peri-parturient rise in FEC was evident in the untreated does, but not the COWP-treated does.
- In yearling does, FEC of the COWP-treated does tended to be lower than the untreated.
- FEC of COWP-treated kids were reduced compared with untreated kids
- FEC of treated and untreated bucks were similar, but *Haemonchus contortus* was not the predominant nematode in these goats.
  - Total worms were reduced in COWP-fed bucks.
- In summary, **it appeared that COWP in the feed was as effective as COWP in a gelatin capsule to reduce FEC in goats.**
- COWP administration may have a limited effect where *H. contortus* is not the predominant nematode.

Burke JM, et al. 2010. Administration of copper oxide wire particles in a capsule or feed for gastrointestinal nematode control in goats. Vet Parasitol 168 346-350.

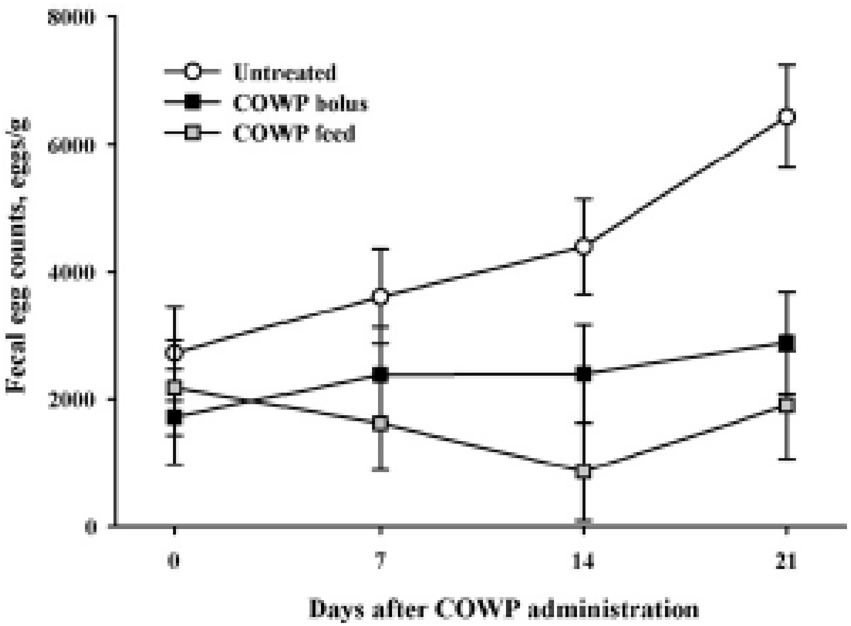


Fig. 1. Effect of administration of copper oxide wire particles (COWP) as a 2 g capsule or incorporated in the feed to deliver 2 g/goat (untreated: open circles, *n* = 12; COWP in capsule: black squares, *n* = 11; COWP in feed: gray squares, *n* = 12) on fecal egg counts (FEC) in peri-parturient does (Experiment 1). Least squares means and standard errors are presented and statistical analysis of FEC was performed on log transformed values.

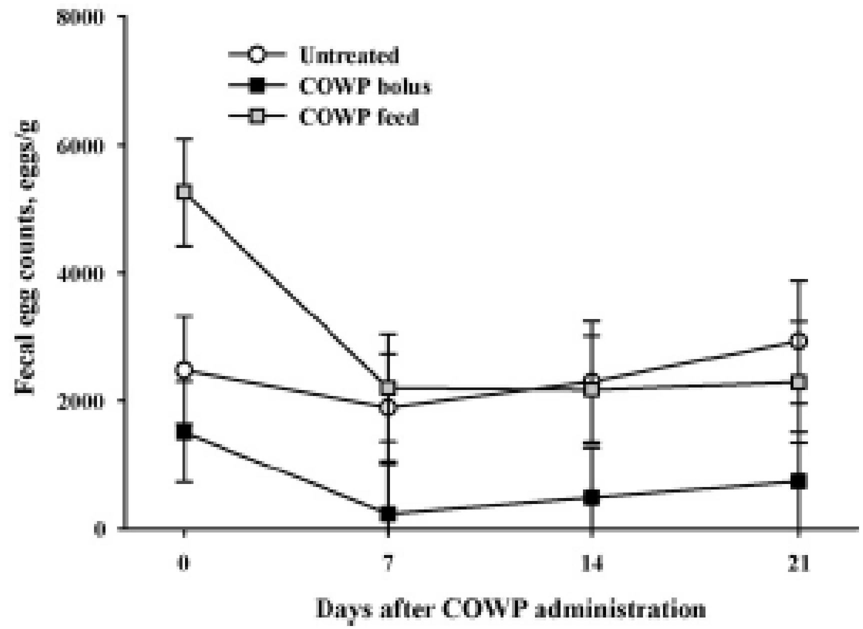


Fig. 2. Effect of administration of copper oxide wire particles (COWP) as a 2 g capsule or incorporated in the feed to deliver 2 g/goat (untreated: open circles, *n* = 8; COWP capsule: black squares, *n* = 9; COWP in feed: gray squares, *n* = 8) on fecal egg counts (FEC) in yearling does (Experiment 2). Least squares means and standard errors are presented and statistical analysis of FEC was performed on log transformed values.

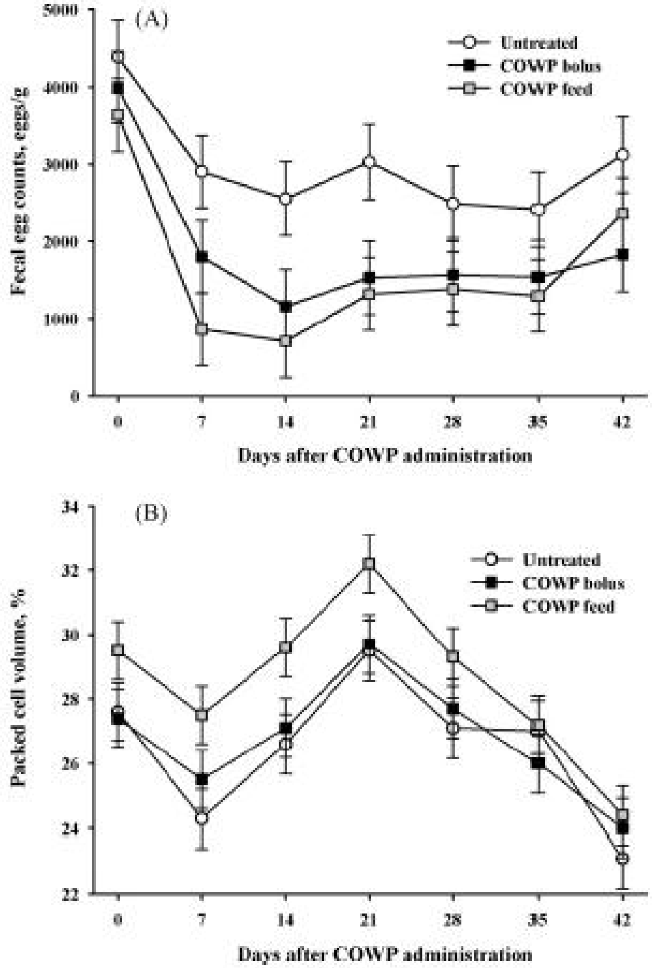


Fig. 3. Effect of administration of copper oxide wire particles (COWP) as a 2 g capsule or incorporated in the feed to deliver 2 g/goat (untreated: open circles, COWP capsule: black squares, COWP in feed: gray squares, n = 24/treatment) on fecal egg counts (FEC; A) and packed cell volume (PCV; B) in weaned kids (Experiment 3). Least squares means and standard errors are presented and statistical analysis of FEC was performed on log transformed values.

Burke JM, et al. 2010. Administration of copper oxide wire particles in a capsule or feed for gastrointestinal nematode control in goats. Vet Parasitol 168 346-350.

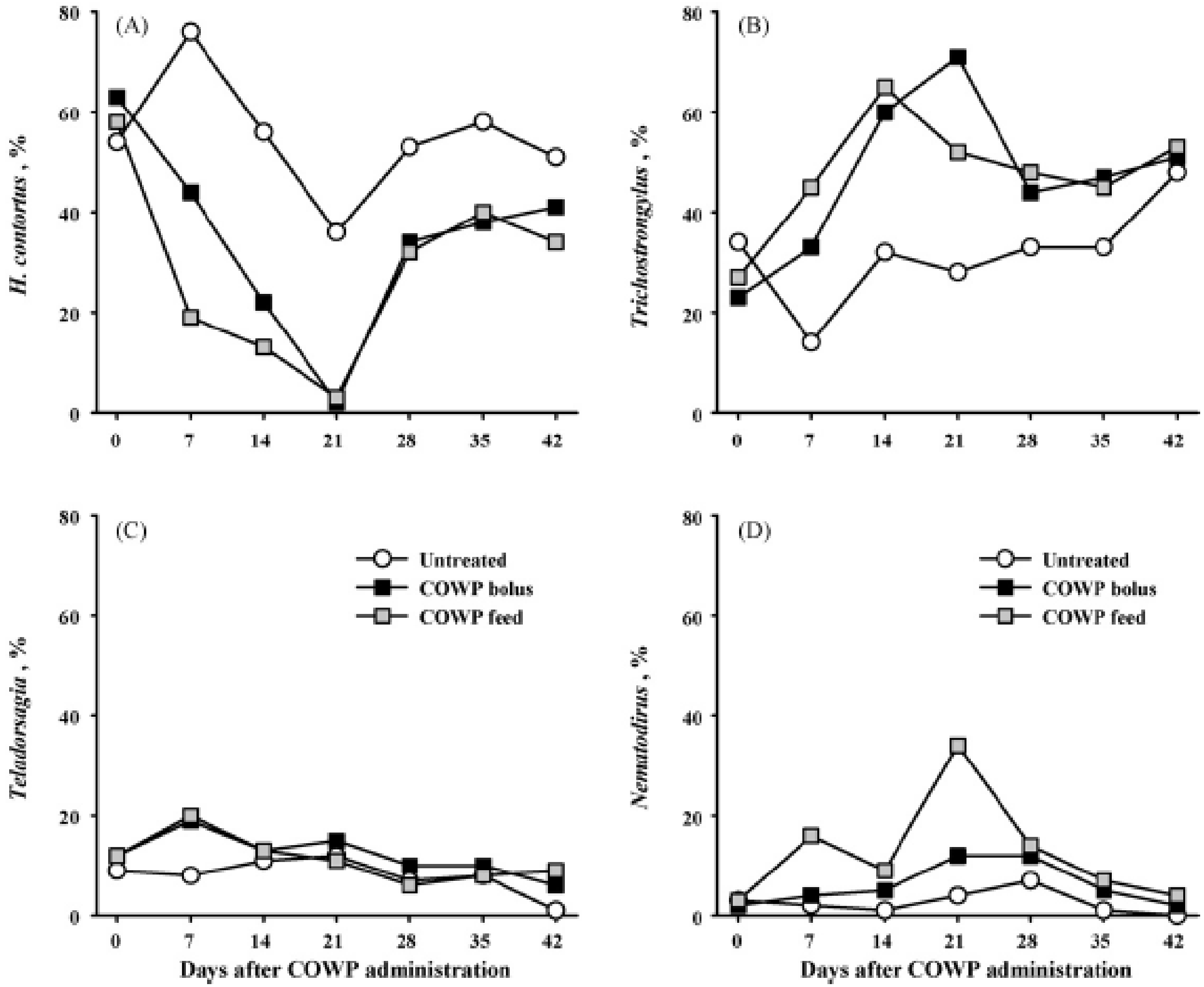


Fig. 4. Effect of administration of copper oxide wire particles (COWP) as a 2 g capsule or incorporated in the feed to deliver 2 g/goat (untreated: open circles, COWP capsule: black squares, COWP in feed: gray squares, n = 24/treatment) on percentage of *Haemonchus contortus* (A), *Trichostrongylus* spp. (B), *Teladorsagia* spp. (C), and *Nematodirus* spp. (D) from pooled feces from each treatment group of weaned kids that was cultured for 14 days (Experiment 3).

Burke JM, et al. 2010. Administration of copper oxide wire particles in a capsule or feed for gastrointestinal nematode control in goats. Vet Parasitol 168 346-350.

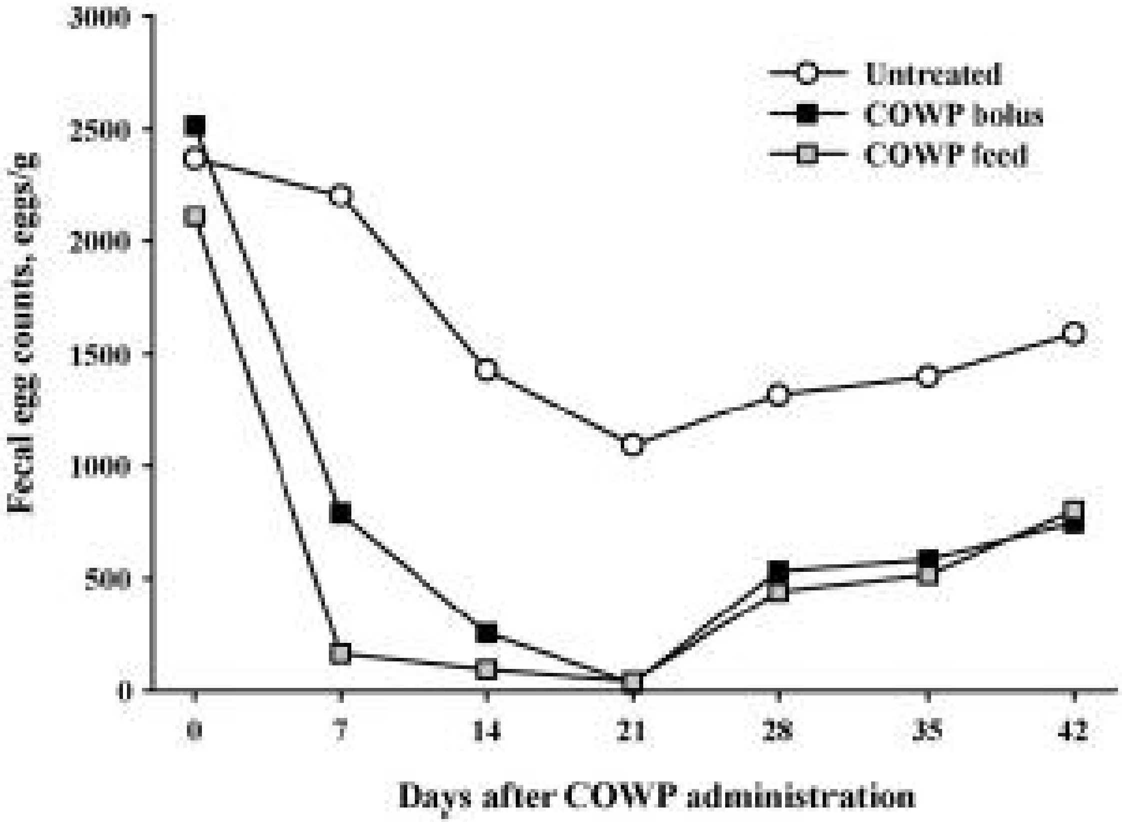


Fig. 5. Effect of administration of copper oxide wire particles (COWP) as a 2 g capsule or incorporated in the feed to deliver 2 g/goat (untreated: open circles, COWP capsule: black squares, COWP in feed: gray squares, $n = 24$/treatment) on fecal egg counts of weaned kids adjusted to percentage of *Haemonchus contortus* cultured in pooled feces between Days 0 and 42 after COWP administration (Experiment 3).

COWP in supplemented lambs

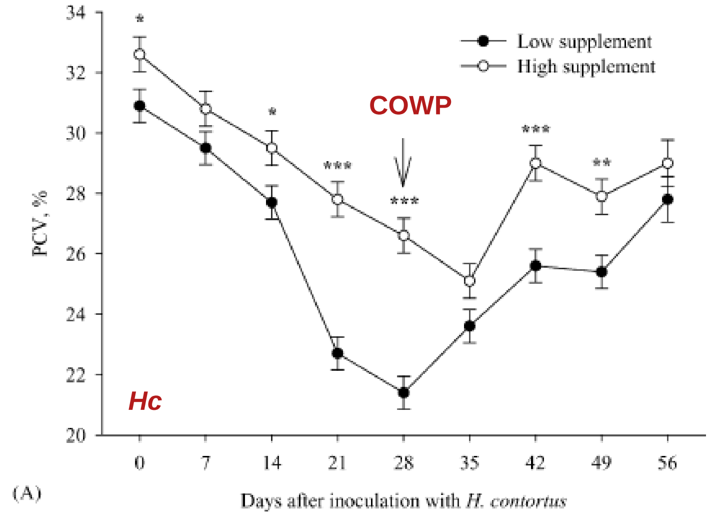
- Determining the optimal dose of COWP to reduce infection of *Haemonchus contortus* in male lambs.
  - 5-6-month-old hair breed lambs were housed on concrete and fed 450 (L; n=25) or 675 g (H; n=25) corn/soybean meal supplement and bermuda grass hay.
  - In July, lambs were inoculated with 10,000 L3 larvae (97% *H. contortus*; Day 0).
  - Lambs were administered 0, 2, 4, or 6 g COWP on Day 28.
  - Concentrations of copper in the liver were determined.
- No effects of supplement level on concentrations of copper in the liver
- Between Days 0 and 28, PCV declined and by Day 42, PCV of all COWP-treated lambs was markedly higher than control lambs and remained higher.
- By Day 21, PCV was greater in the H compared with the L group of lambs.

Burke JM, et al. 2004. Effect of copper oxide wire particles dosage and feed supplement level on Haemonchus contortus infection in lambs. Vet Parasitol 123 235-243

COWP in supplemented lambs

- Within 14 days of COWP treatment FEC declined from more than 8000 epg to less than 250 epg in all COWP-treated lambs
- The numbers of *H. contortus* in the abomasum were greatly reduced in all COWP-treated groups of lambs and remaining nematodes were predominantly males.
- FEC were greater in L versus H supplemented lambs and values decreased to a greater extent in H lambs when treated with COWP.
- The 2 g COWP was effective in alleviating *H. contortus* infection and reducing number of egg-laying nematodes in the abomasum with the lowest concentration of copper in the liver of the COWP treatment groups.
- PCV values were more favorable for lambs fed the higher level of supplement, especially when FEC were greater than 8000 epg.

Burke JM, et al. 2004. Effect of copper oxide wire particles dosage and feed supplement level on Haemonchus contortus infection in lambs. Vet Parasitol 123 235-243



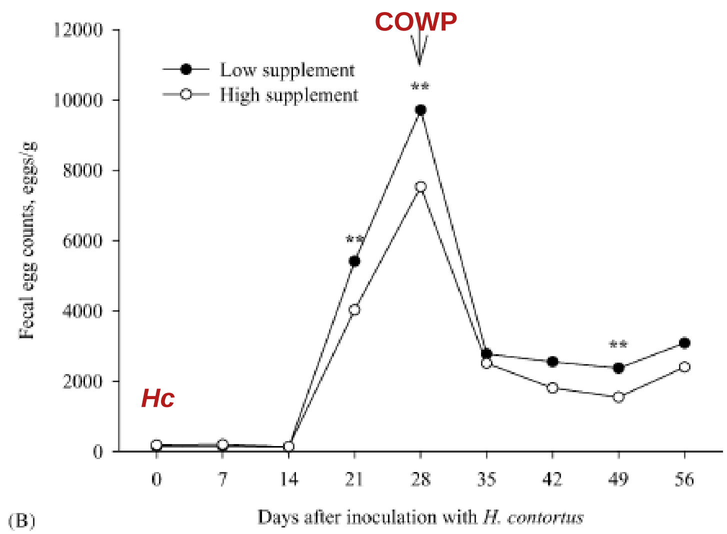


Fig. 1. Least squares means and standard errors of packed cell volume (PCV; A) and fecal egg counts (FEC; B) of lambs fed low supplement (450 g corn/soybean meal supplement per day; closed circles) or high supplement (675 g supplement per day; open circles). Arrow represents day of copper oxide wire supplement (0, 2, 4, or 6 g). Lambs were inoculated with 10,000 L_3 (97% *Haemonchus contortus*) on Day 0. Effect of dietary treatment over time was significant on PCV ($P < 0.001$) and tended to be significant on FEC ($P < 0.07$). Difference between dietary treatments for a particular time point represented by a single ($P < 0.05$), double ($P < 0.01$) or triple asterisk ($P < 0.001$).

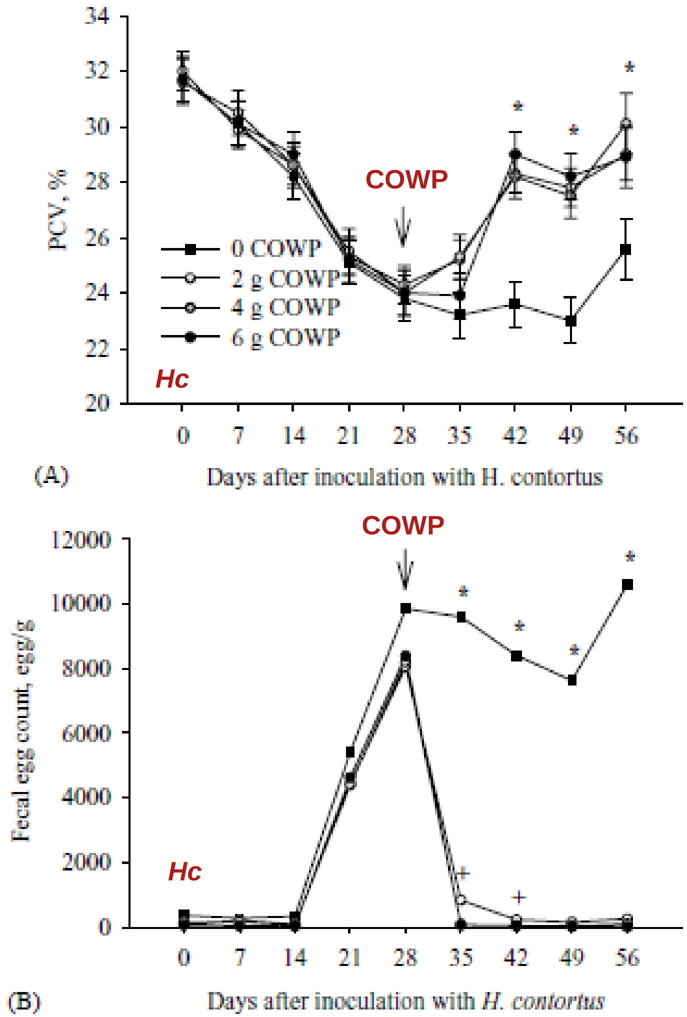


Fig. 2. Least squares means and standard errors of packed cell volume (PCV; A) and fecal egg counts (B) of lambs treated with 0 (closed squares), 2 (open circles), 4 (gray circles), and 6 (closed circles) g copper oxide wire particles (COWP) on Day 28, indicated by arrow. Lambs were inoculated with 10,000 L_3 (97% *Haemonchus contortus*) on Day 0. Arrow represents day of copper oxide wire supplement (0, 2, 4, or 6 g). There was a significant effect of COWP treatment over time ($P < 0.001$). Difference between lambs treated with 0 g compared with 2, 4, or 6 g COWP represented by an asterisk ($P < 0.001$) and difference between lambs treated with 2 g compared with 4 and 6 g COWP represented by a plus sign ($P < 0.05$).

Supplementary Feeding and COWP

- Aim to assess the benefits obtained from combining supplementary feeding and COWP, compared to the use of both approaches independently, for the control of gastrointestinal nematode infections in browsing kids.
- 44 nematode free Criollo kids were exposed to natural parasite infection.
  - Divided into six experimental groups:
    1. Not treated and Supplemented (NT-S)
    2. Not treated and not supplemented (NT-NS)
    3. Moxidectin treated, supplemented (M-S),
    4. Moxidectin treated not supplemented (M-NS)
    5. Copper treated, supplemented (COWP-S)
    6. Copper treated, non-supplemented (COWP-NS)
  - Copper treated groups received Copinox (2 g capsules) on day 0 and on day 60 of the trial.
  - Moxidectin treated groups received Cydectin (0.2 mg/kg of body weight sc) every 28 days.
  - 3 groups received individual supplementation (100 g of feed/day fresh basis; 74% sorghum: 26% soybean meal; NT-S, M-S and COWP-S)
  - 3 groups were not supplemented (NT-NS, M-NS and COWP-NS).
- Animals browsed native vegetation (6.5 h/day) during the wet season (154 days).

Ortiz de Montellano, C. M. et al., 2007. Combining the effects of supplementary feeding and copper oxide needles for the control of gastrointestinal nematodes in browsing goats. Vet Parasitol 146 66-76

Supplementary Feeding and COWP

- Kids were weighed every 14 days to determine live weight gain (LWG) and blood and faecal samples were obtained to determine packed cell volume (PCV), hemoglobin (Hb), peripheral eosinophil counts (PEC) and faecal egg counts (FEC).
- At the end of the trial, four kids of each group were euthanatized (six kids in each COWP treated group).
  - Worm burdens, female worm lengths and prolificacy were determined.
- Liver samples were used to determine copper concentration and were stained with haematoxylin-eosin to determine microscopic lesions.

Supplementary Feeding and COWP

- Animals receiving the combination of supplementary feeding and COWP improved their LWG, PCV and Hb to similar levels of animals with moxidectin treatment.
- Not the case when COWP was used without supplementation.
  - Liver copper concentration in COWP treated groups increased significantly especially in the COWP-NS kids but this was not associated with liver lesions or clinical signs.
- Post-mortem *Haemonchus contortus* and *Trichostrongylus colubriformis* worm counts had a tendency to be reduced in the different groups (66-35% reduction) compared to NT-NS group at the end of the trial (P >0.05).
  - Also, COWP treatment and/or supplementation reduced female worm length of *T. colubriformis* and prolificacy of *H. contortus* and *T. colubriformis*.
- This study, confirmed the value of nutritional supplementation in the control of gastrointestinal nematodes in growing kids.
- The use of COWP in addition to supplementation had a limited contribution on the kids' resilience against nematodes. This may be due to the reduced infection of *H. contortus* during this trial.

Ortiz de Montellano, C. M. et al., 2007. Combining the effects of supplementary feeding and copper oxide needles for the control of gastrointestinal nematodes in browsing goats. Vet Parasitol 146 66-76

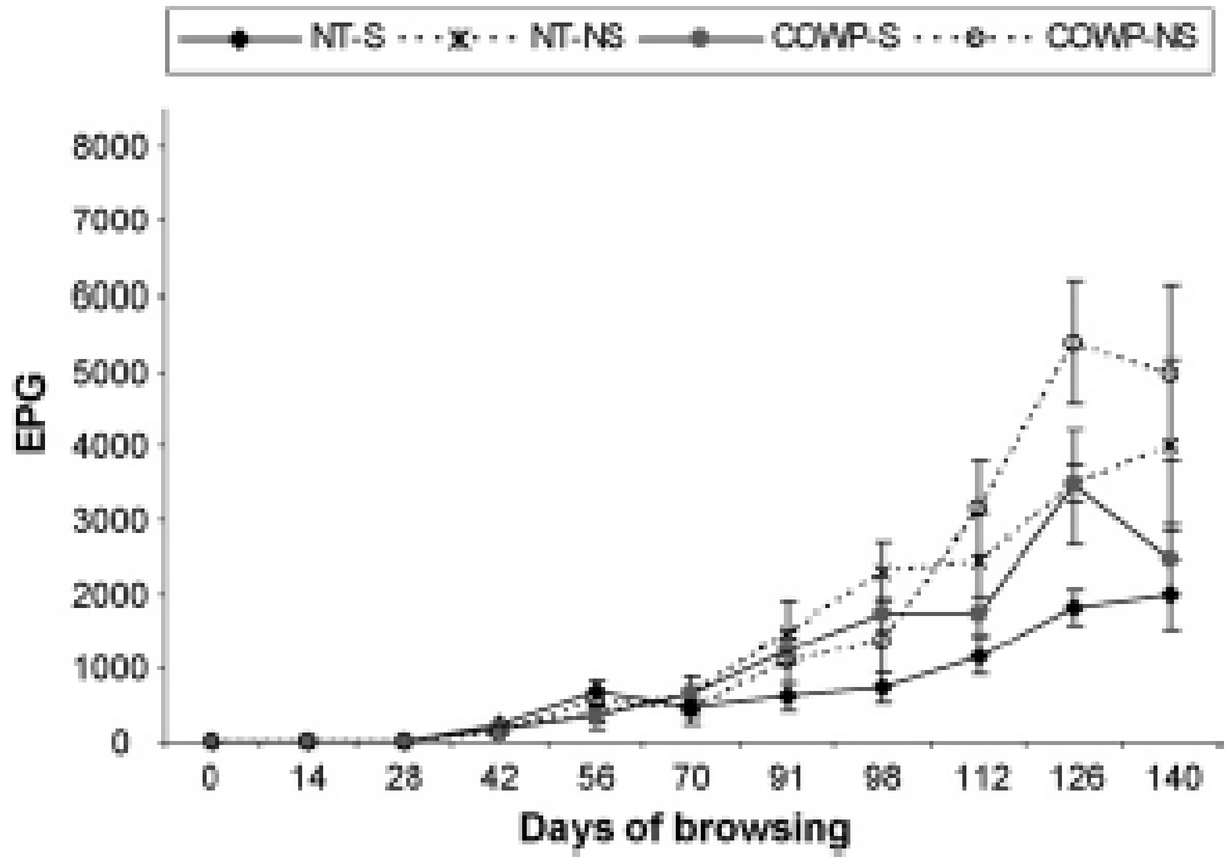


Fig. 3. Effect of supplementation (S) and copper oxide wire particles (COWP) on the nematode eggs per gram of faeces (EPG) of Criollo goats.

COWP or *S. lespedeza* and Nematodes

- 3 experiments using peri-parturient does or ewes
  1. Arkansas, meat goats were untreated (n=20) or fed copper oxide wire particles (COWP; 2 g each) in pelleted sericea lespedeza (Lespedeza cuneata; n=22) before kidding while consuming sericea lespedeza hay,
  2. Arkansas, 42 Katahdin ewes were randomly assigned to remain untreated or were fed COWP (2 g each) before lambing within groups fed bermuda grass (Cynodon dactylon) or sericea lespedeza hay in a 2*2 factorial design
  3. Louisiana, Gulf Coast Native ewes were randomly assigned to remain untreated or were fed COWP (4 g each) in a pelleted ration (n=10 each) after lambing began.
- FEC and PCV were determined weekly
- Coproculture to examine nematode species was conducted in the first two experiments.

Burke JM, et al. 2010. Using copper oxide wire particles or sericea lespedeza to prevent peri-parturient gastrointestinal nematode infection in sheep and goats. Livestock Science 132 13-18

COWP or *S. lespedeza* and Nematodes

- *Trichostrongylus* spp. was the predominant nematode in Arkansas during these experiments.
- In all of the experiments, feeding COWP led to a reduction in FEC, but no change in PCV.
- The sericea lespedeza hay fed to ewes in Experiment 2 was associated with a reduction in FEC compared with ewes fed bermuda grass hay.
- Kids and lambs from COWP-treated dams in two experiments were lighter than those from untreated dams.
- Sericea lespedeza aided in the control of nematode infection, and while feeding COWP to peri-parturient ewes and does offered some reduction in nematode infection, body weight of offspring at birth and 60 or 90 days of age may be reduced

Burke JM, et al. 2010. Using copper oxide wire particles or sericea lespedeza to prevent peri-parturient gastrointestinal nematode infection in sheep and goats. Livestock Science 132 13-18

Tactical COWP & Levamisole

- COWP was evaluated as a tactical anthelmintic treatment in indigenous goats raised under communal farming conditions in Bergville, KwaZulu-Natal Province, South Africa.
- At the beginning of the summer rainfall season (October 2007), FEC of 172 female goats belonging to 15 farmers were determined every four weeks until the second week of January 2008.
  - Goats within each of the 15 herds were ranked according to their faecal egg counts for this week. The goats were sequentially paired off within each ranking starting with those goats with the highest counts.
  - One goat from each pair was randomly allocated to a treated or control group.
  - Two weeks later, a 4 g COWP bolus was randomly administered to each goat in the treated group.
- the goats were examined according to the FAMACHA system and symptomatically treated with 12 mg/kg levamisole when anaemic.
- The percentage reduction EPG due to the COWP treatment was 89.0%.
- Mean pre- and post-treatment faecal egg counts for the COWP-treated group (n=73) were 2347 eggs per gram of faeces (epg) and 264 epg, respectively.
- The corresponding values for the untreated controls (n=66) were 2652 epg and 2709 epg.
- The prevalence of *Haemonchus* spp. larvae in pre- and post-treatment faecal cultures was 72% and 46%, respectively.
- Symptomatic anthelmintic treatments in combination with mid-summer tactical treatments with COWP appear to be useful strategies for the control of *Haemonchus contortus* in indigenous goats in this farming system and this approach could have application in other similar agro-ecological zones.

Spickett A, et al. 2012. Tactical treatment with copper oxide wire particles and symptomatic levamisole treatment using the FAMACHA system in indigenous goats in South Africa. Vet Parasitol 184: 48-58.

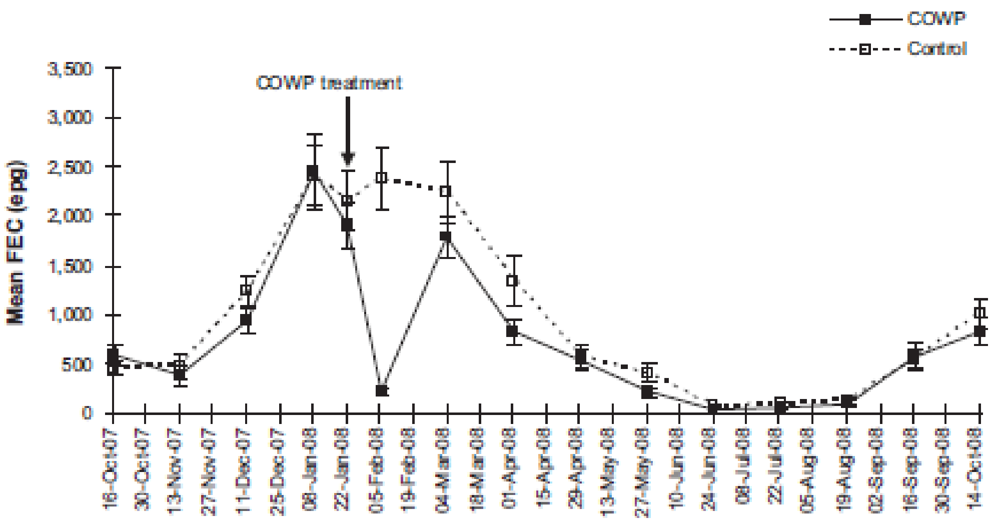


Fig. 3. Mean faecal egg counts (FECs) for the control and COWP-treated goats combined for all three trial areas. The error bars indicate the standard error.

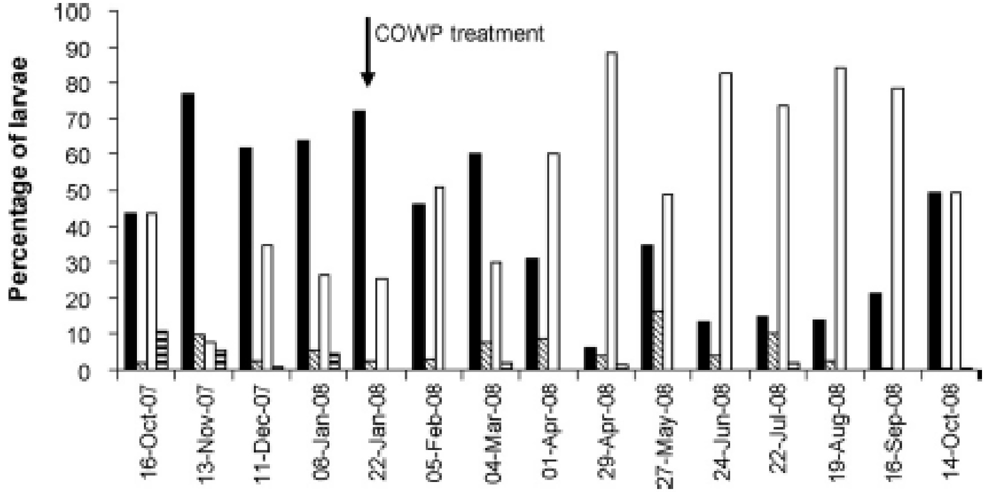


Fig. 4. Percentage of nematode larvae recovered from faecal cultures, averaged for all three trial areas, identified as *Haemonchus* (solid black columns), *Oesophagostomum* (diagonally striped columns), *Teladorsagia/Trichostrongylus* (white columns) and *Strongyloides* (horizontally striped columns) for each sampling occasion of the trial period.

Sericea lespedeza vs Grass

- Examined the effectiveness of grazing sericea lespedeza (SL) compared with grass pastures for control of nematodes in lambs.
  1. In Experiment 1, Katahdin lambs grazed bermuda grass (BG; n=14), tall fescue (TF; n=7), or SL (n=19) pastures during early summer.
  2. In Experiment 2, lambs grazed TF (n=15) or SL (n=13) pastures during late summer.
- Stocking rate of pastures was based on forage availability; additional lambs grazed pastures in Experiment 2, but were not sampled.
- Lambs were dewormed with 0.5 g COWP if FAMACHA score was >3.

Burke JM, et al. 2012. Grazing sericea lespedeza for control of gastrointestinal nematodes in lambs. Vet Parasitol 186 507-512.

Sericea lespedeza vs Grass

- In Experiment 1, FEC were reduced within 35 days in SL compared with BG lambs
  - The PCV was more resilient to changes over time in SL compared with other groups of lambs (forage by time, P=0.001).
- In Experiment 2, FEC were lower and PCV tended to be higher in lambs grazing SL compared with TF forage.
- Incidence of deworming was similar among forage groups in both experiments.
- Grazing SL reduced FEC in lambs in early and late summer, despite reluctance by lambs to graze.
- Grazing forage and selective deworming using COWP was effective in lambs.

Burke JM, et al. 2012. Grazing sericea lespedeza for control of gastrointestinal nematodes in lambs. Vet Parasitol 186 507-512.

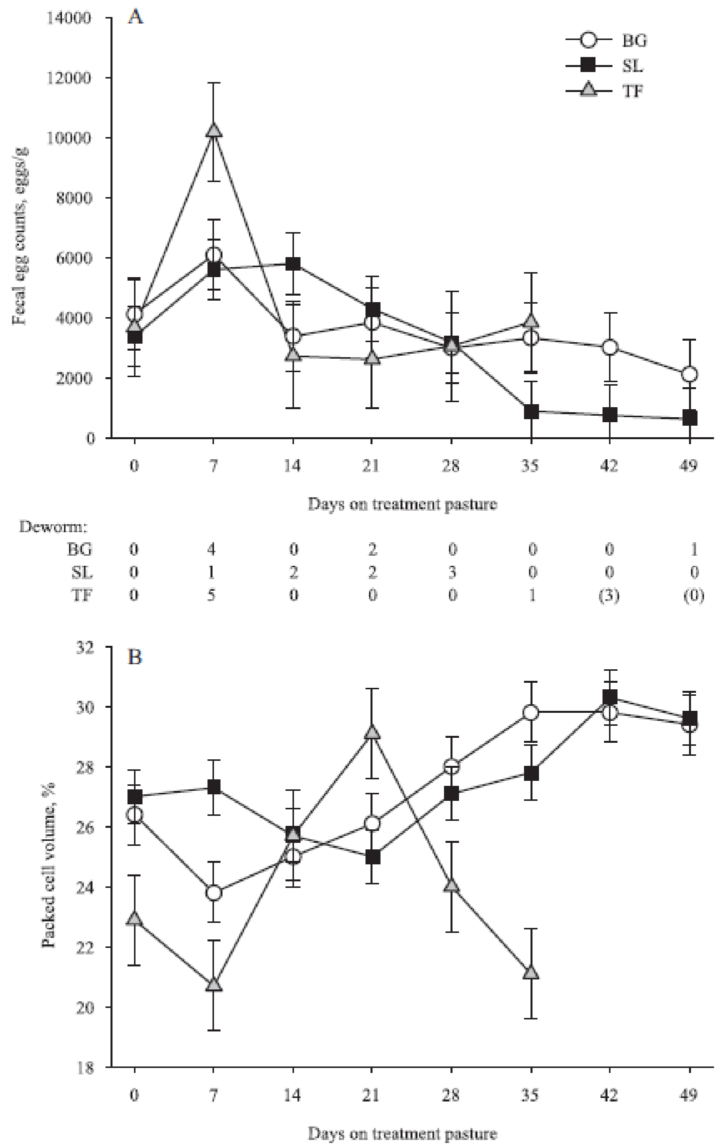


Fig. 1. Effect of grazing bermudagrass (BG; open circles, $n = 14$), sericea lespedeza (SL; closed squares, $n = 19$), or tall fescue (TF; gray triangles, $n = 7$) on fecal egg counts (FEC; Panel A) and blood packed cell volume (PCV; Panel B) in lambs (Experiment 1). Least squares means and standard errors are presented; statistical analysis of FEC was performed on log transformed values. Number of lambs that required deworming within each grazing treatment group on day of sampling is indicated below Panel (A).

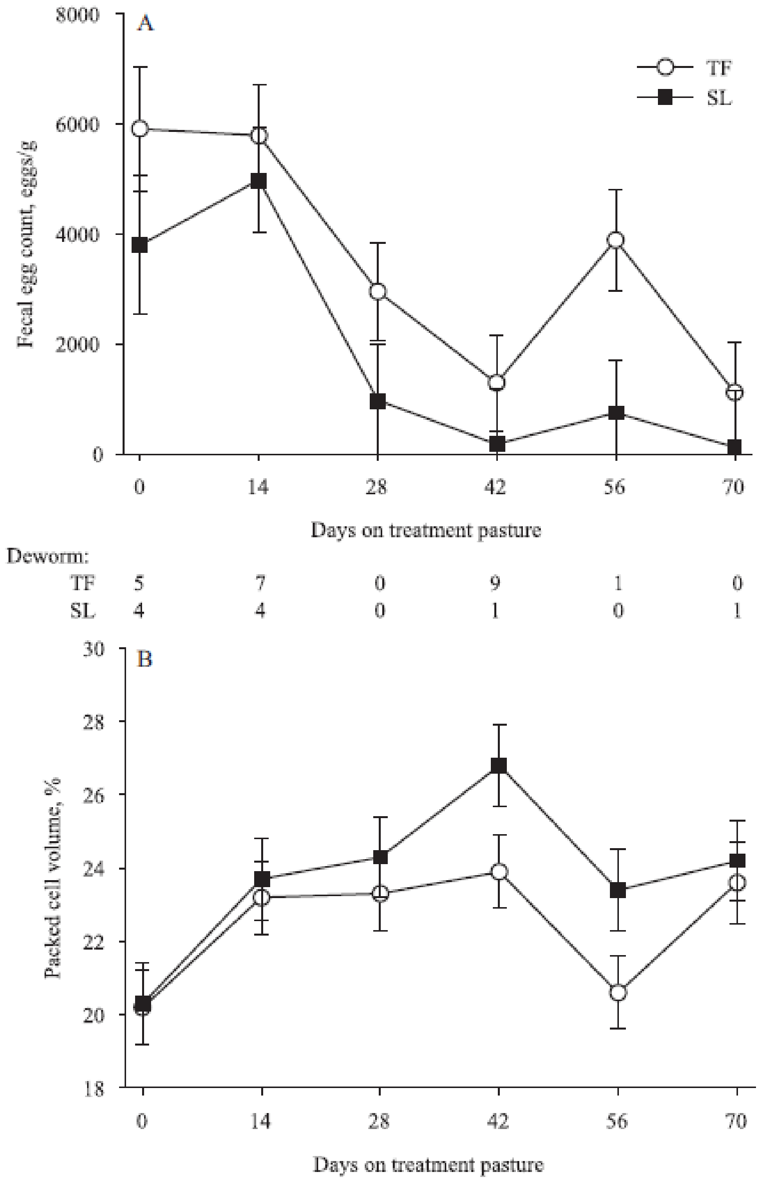


Fig. 2. Effect of grazing tall fescue (open circles, $n = 15$) or sericea lespedeza (black squares, $n = 13$) on fecal egg counts (FEC; Panel A) and blood packed cell volume (PCV; Panel B) in lambs (Experiment 2). Least squares means and standard errors are presented and statistical analysis of FEC was performed on log transformed values. Number of lambs that required deworming within each grazing treatment group on day of sampling is indicated below Panel (A).

SL, COWP, and FAMACHA

1. In Experiment 1, lambs co-grazed bermudagrass (BG; n=21) or SL in a mixed grass pasture (SLM; n=22) with dams for 14 days.
2. In Experiment 2, lambs grazed BG (n=14), SLM (n=13), or pure SL (SLP; n=13) pastures for 56 days.
3. In Experiment 3, doe kids grazed BG (n=12), SLM (n=13), or SLP (n=13) for 84 days.

- Animals were fed a 16% crude protein supplement based on NRC requirements and estimated forage quality of pastures, so that 454, 389, and 200 g/lamb (Experiment 2), or 454, 300, and 150 g of supplement/goat (Experiment 3) was fed to BG, SLM, and SLP, respectively.
- Animals were dewormed with COWP if FAMACHA was >3.
- Coprocultures were conducted to identify GIN genus

Burke JM, et al. 2012. Use of a mixed sericea lespedeza and grass pasture system for control of gastrointestinal nematodes in lambs and kids. Vet Parasitol 186: 328-336.

SL, COWP, and FAMACHA

- In Experiment 1, FEC were reduced in lambs grazing SLM compared with BG pastures.
- In Experiment 2, FEC were reduced in SLP compared with BG lambs on all days, and reduced in SLM compared with BG lambs on day 56.
- Initially, *Haemonchus contortus* was the predominant nematode, but the population shifted to other species in the SL groups by the end of the study.
- The mean number of dewormings/lamb was 0.71, 0.20, and 0.210.13 for BG, SLM, and SLP groups, respectively.
- In goats in Experiment 3, *Trichostrongylus* spp. was the predominant nematode in May and June and *H. contortus* in July.
  - There was little meaningful effect of forage treatments on nematodes in kids.
  - Because *H. contortus* was not the predominant nematode in kids, the integrated approaches used may not have been effective in controlling nematodes.
- Grazing SL was effective for nematodes control in lambs in early summer, but the effect was delayed in lambs grazing a mixed SL/grass pasture unless lambs initially grazed with dams.
- An integrated approach used that included SL grazing and COWP for deworming was effective in lambs.

Burke JM, et al. 2012. Use of a mixed sericea lespedeza and grass pasture system for control of gastrointestinal nematodes in lambs and kids. Vet Parasitol 186: 328-336.

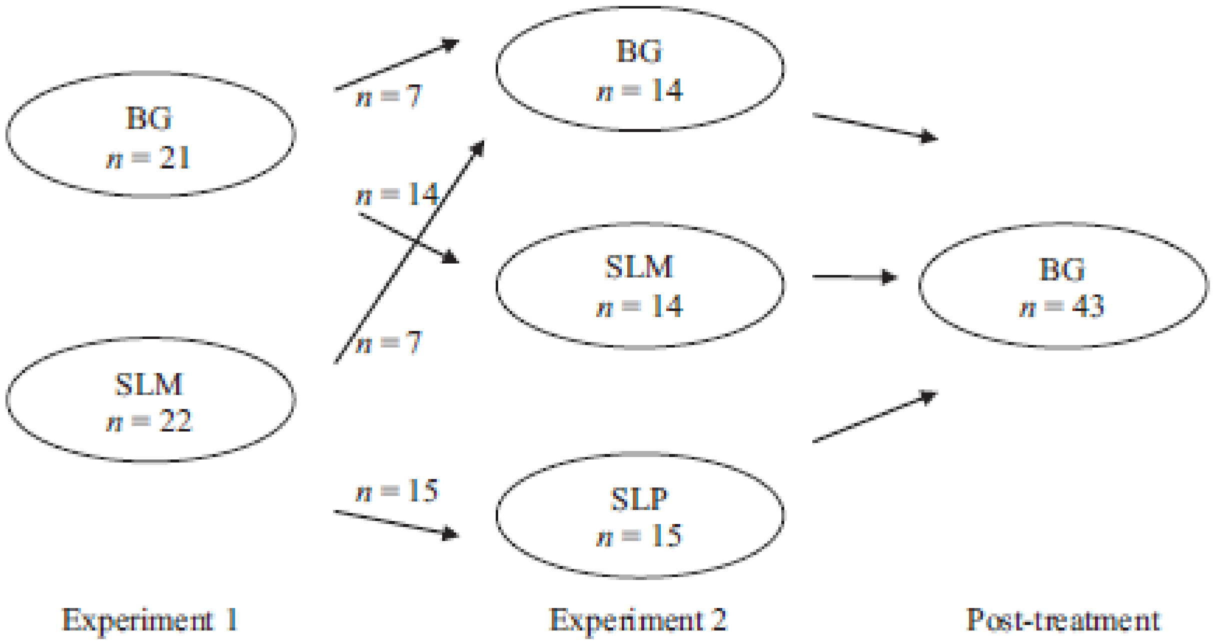


Fig. 1. Diagram of lambs in each treatment in Experiments 1 and 2. In Experiment 1, lambs grazed bermudagrass (BG) or sericea lespedeza in a mixed pasture (SLM) with their dams for 14 days. In Experiment 2, lambs were reassigned to graze BG, SLM, or a pure SL (SLP) pasture as indicated for 56 days. During a post-treatment period, all lambs grazed BG pastures for 14 days.

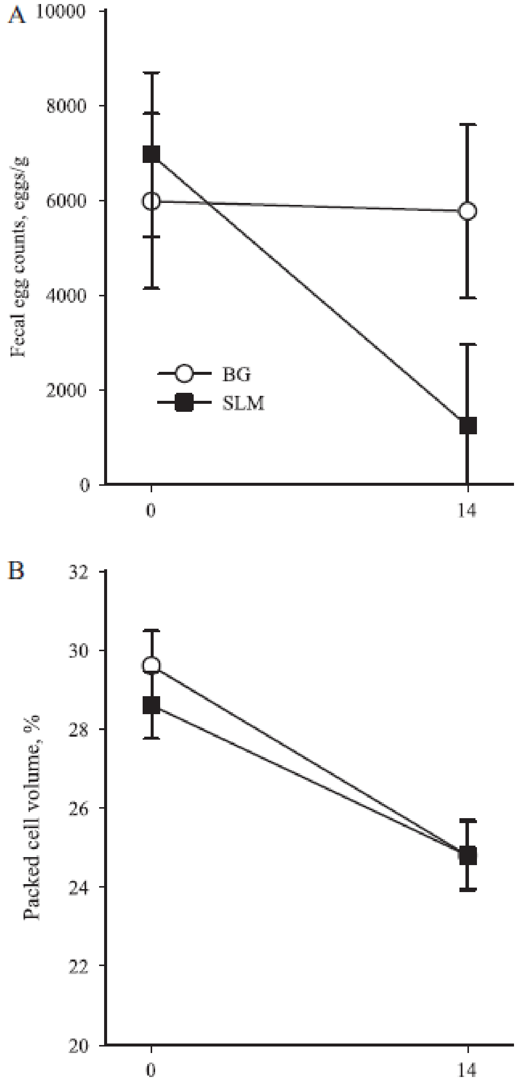


Fig. 2. Effect of lambs grazing bermudagrass (BG; open circles, $n = 21$) or sericea lespedeza as mixed pasture (SLM; closed squares, $n = 22$) with their dams in Experiment 1 on fecal egg counts (FEC; Panel A) and blood packed cell volume (PCV; Panel B). Least squares means and standard errors are presented and statistical analysis of FEC was performed on log transformed values. There were 2 and 6 BG, and 3 and 1 SLM lambs that required deworming on days 0 and 14, respectively.

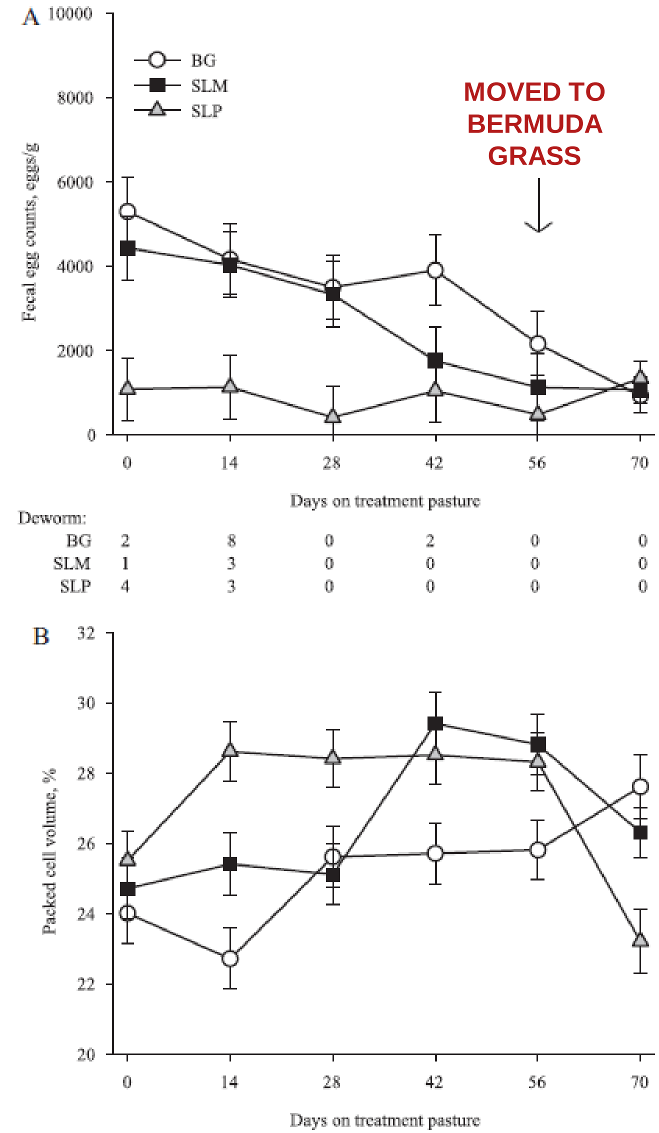


Fig. 3. Effect of weaned lambs grazing BG (open circles, $n = 14$), SLM (closed squares, $n = 14$), or a pure stand of sericea lespedeza (SLP; gray triangles, $n = 15$) on FEC (Panel A) and PCV (Panel B) in Experiment 2. Least squares means and standard errors are presented and statistical analysis of FEC was performed on log transformed values. Arrow represents day that pasture treatments ended and all lambs grazed BG pasture for 14 days. Number of lambs that required deworming within each grazing treatment group on day of sampling is indicated below Panel A.

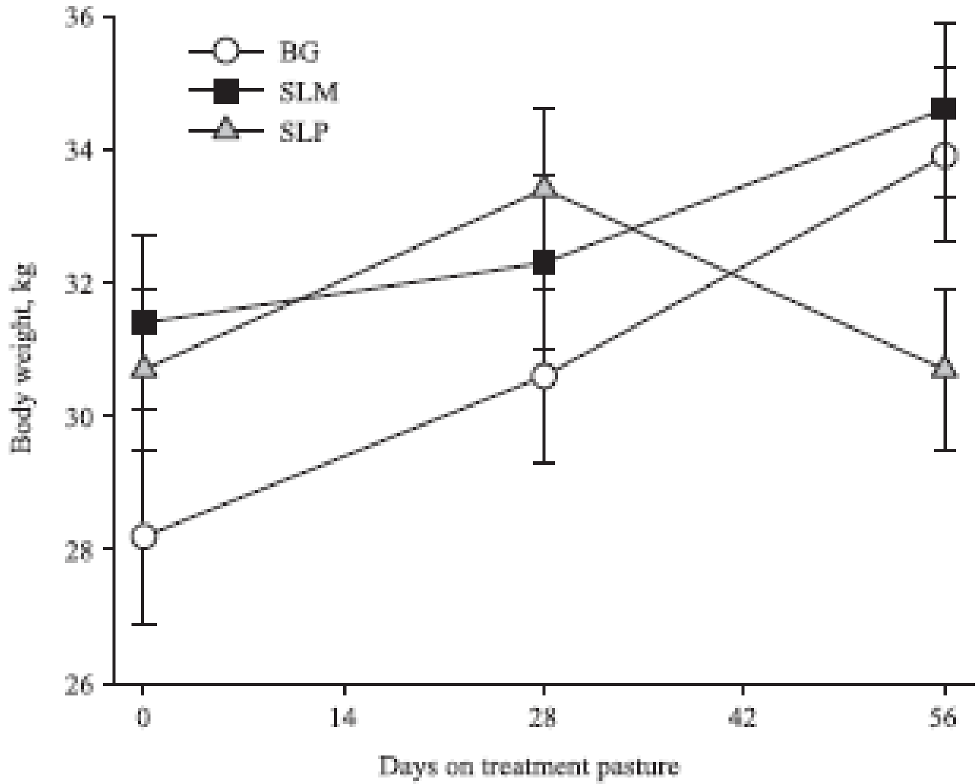


Fig. 4. Effect of grazing lambs on bermudagrass (BG; open circles; $n = 14$), sericea lespedeza and mixed grasses (SLM; closed squares; $n = 14$), or a pure stand of sericea lespedeza (SLP; gray triangles; $n = 15$) on body weight in Experiment 2.

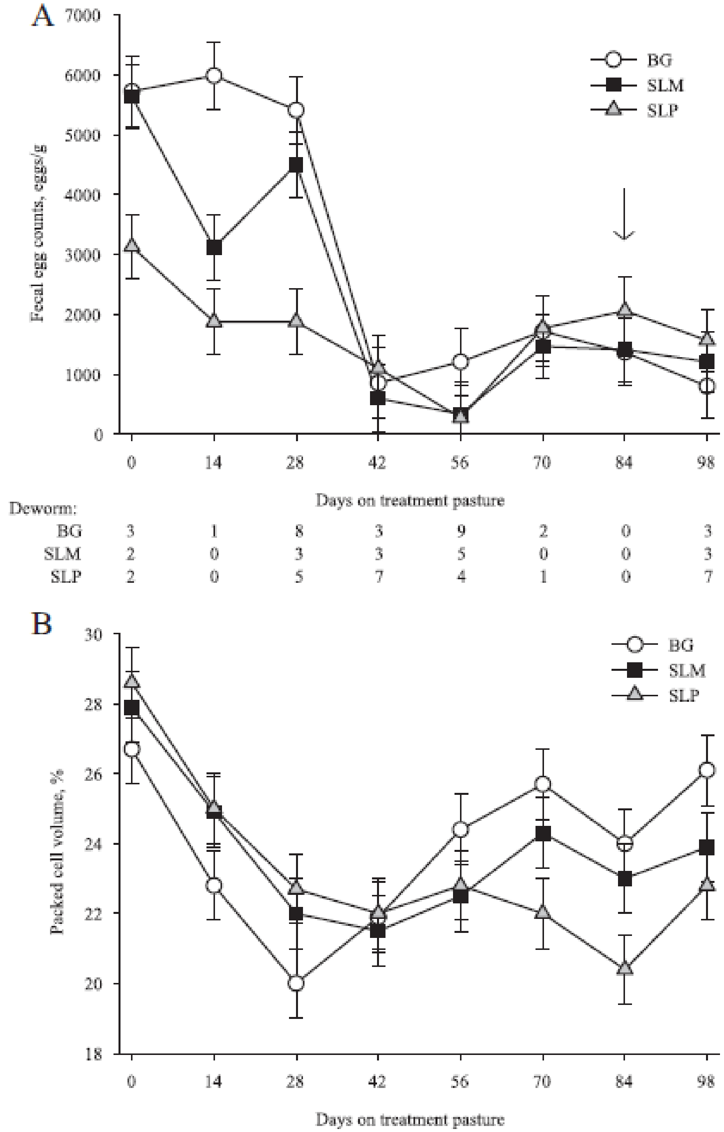


Fig. 5. Effect of grazing bermudagrass (BG; open circles, $n = 12$), sericea lespedeza and mixed grasses (SLM; closed squares, $n = 13$), or a pure stand of sericea lespedeza (SLP; gray triangles, $n = 13$) on fecal egg counts (FEC; Panel A) and blood packed cell volume (PCV; Panel B) in weaned Spanish doe kids (Experiment 3). Least squares means and standard errors are presented and statistical analysis of FEC was performed on log transformed values. Arrow represents day that pasture treatments ended and all goats grazed BG pasture for 14 days. Number of kids that required deworming within each grazing treatment group on day of sampling is indicated below Panel A.

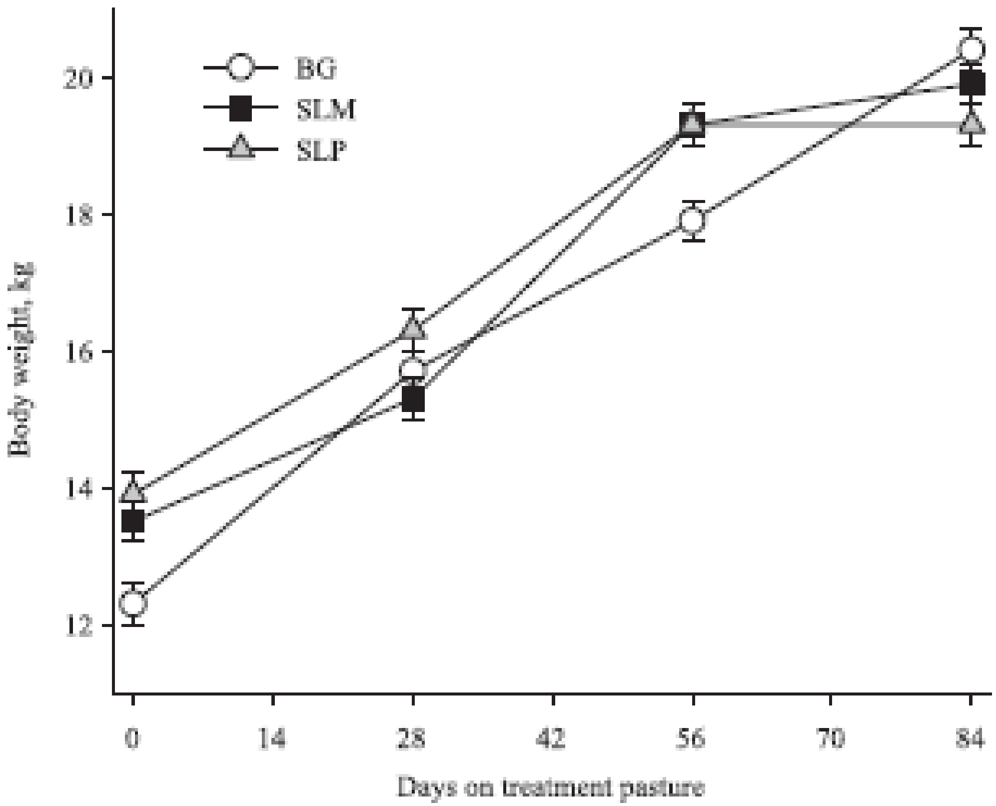


Fig. 6. Effect of grazing kids on bermudagrass (BG; open circles; *n* = 12), sericea lespedeza and mixed grasses (SLM; closed squares; *n* = 13), or a pure stand of sericea lespedeza (SLP; gray triangles; *n* = 13) on body weight (Experiment 3).

COWP persistency in goats

- 48 indigenous male goats were infected naturally by grazing them on *Haemonchus contortus-infected* pasture.
- When the faecal egg count (FEC) in the goats was 3179 eggs per gram of faeces, half the animals were treated with 4 g COWP (day 0; mean live weight=25.50.8 kg).
  - 8 treated (COWP) and 8 non-treated (CONTROL) goats were removed from the pasture on each of days 7, 28 and 56, maintained for 27 or 29 days in concrete pens and then humanely slaughtered for nematode recovery.
- Mean liver copper levels were in the high range in the goats removed from pasture at day 7 (treated: 191 ppm; untreated: 120 ppm; P=0.022), but had dropped to normal levels at days 28 and 56.
- The mean *H. contortus* burdens of the treated versus the non-treated goats were, respectively, 184 and 645 for the goats removed from pasture at day 7 (71% reduction; P=0.004), 207 and 331 at day 28 (37% reduction; P=0.945) and 336 and 225 at day 56 (-49% reduction; P=0.665).
- Weekly monitoring of FECs after treatment until slaughter indicated that the COWP-treated goats had lower FECs than the controls, the treatment main effect being significant at days 7, 28 and 56 (P<0.01).
  - The day main effect and the treatment * day interaction were only significant for the goats removed from pasture at day 28 (P≤0.001).
  - Packed cell volumes increased during the course of the experiment (day, P <0.001), but the treatment main effect was significant only for the goats removed from pasture at day 28 (CONTROL 28 d, 28.650.52% < COWP 28 d, 31.310.52%; P<0.001).
  - No differences in live weight between groups were considered to be of any practical significance.
- The study indicated that persistence of efficacy of COWP is limited in goats, extending at most to 28 days after treatment.
- However, repeated COWP administration at three-month intervals may be safe, given that liver copper levels return to normal two to three months after COWP treatment.

Vatta AF, et al. 2012. Persistence of the efficacy of copper oxide wire particles against Haemonchus contortus in grazing South African goats. Vet Parasitol 190: 159-166.

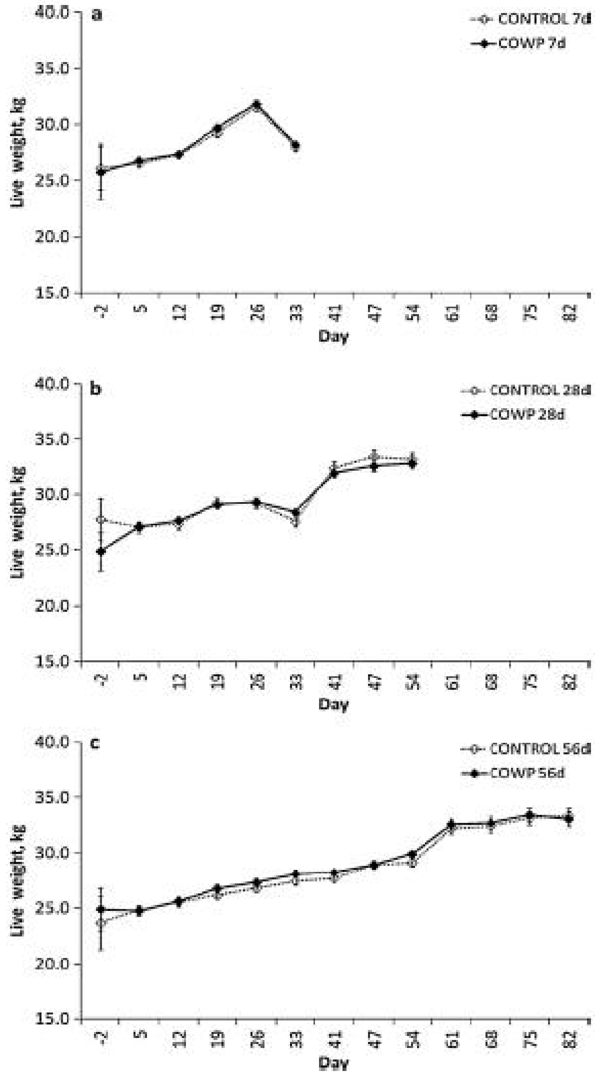


Fig. 2. Live weights in kilograms for groups of goats ($n = 8$) treated with 4 g copper oxide wire particles (♦, COWP) on day 0 and removed from *Haemonchus contortus*-seeded pasture on day 7 (a), day 28 (b) or day 56 (c) post treatment and the respective control groups (◇, CONTROL). Adjusted means ± standard errors of the means for day 5 onwards are presented. Day 2 means ± standard errors represent the unadjusted values used as covariates in the analysis.

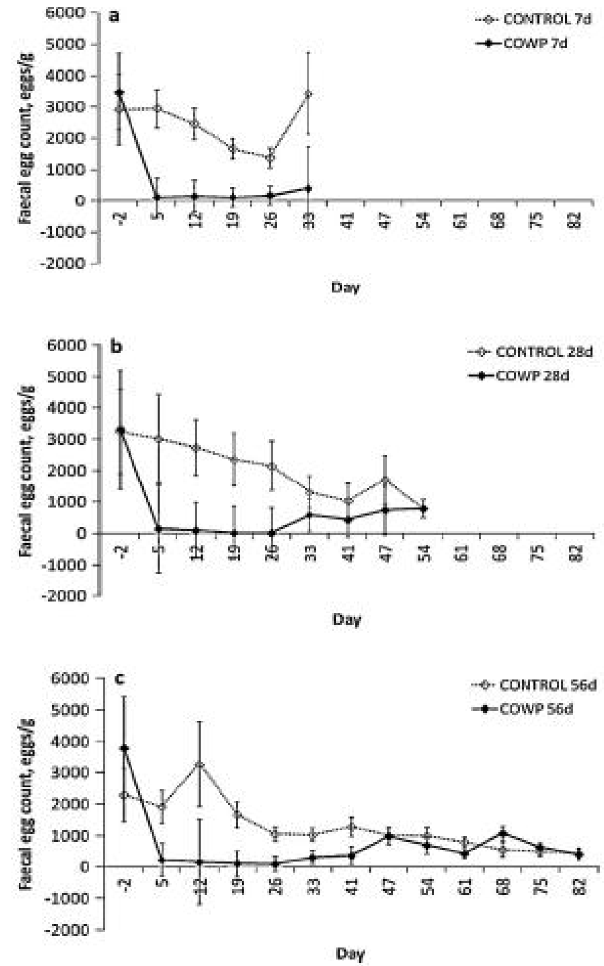


Fig. 3. Faecal egg counts in eggs per gram of faeces for groups of goats ($n = 8$) treated with 4 g copper oxide wire particles (♦, COWP) on day 0 and removed from *Haemonchus contortus*-seeded pasture on day 7 (a), day 28 (b) or day 56 (c) post treatment and the respective control groups (◇, CONTROL). Adjusted means ± standard errors of the means for the untransformed data for day 5 onwards are presented in the figure, but statistical inferences in the text are based upon log_{10} transformed data. Day 2 means ± standard errors represent the unadjusted values used as covariates in the analysis.

the COWP-treated goats for the groups removed from pas-

Thanks!