Impact study of dewormers in goats and chickens in India and Tanzania

Paul Bessell | Epi Interventions Ltd | prbessell@gmail.com | Work commissioned by GALVmed

GALVmed

Protecting Livestock – Improving Human Lives

Executive summary

- The objective of this study was to evaluate the impacts on weight gain of animals following mass treatment with dewormers.

- The study was implemented in two separate study areas: Odisha state in India and the Bahi district of the Dodoma region of Tanzania.

- In India, we enrolled 234 non-pregnant adult female village goats and 1040 village chickens aged between 40 and 70 days from 18 villages. In Tanzania, we enrolled 253 non-pregnant adult female village goats and 1064 village chickens from seven villages.

- Enrolled animals were weighed and tagged with a unique identifier and randomly assigned to a non-treatment group or a treatment group. Goats in the treatment group in India were given closantel and in Tanzania goats were given albendazole. Chickens in the treatment groups in India were given fenbendazole and in Tanzania a combination of piperazine citrate and levamisole. Animals in the non-treatment groups were not given anything.

- To control for the effects of differences in exposure, flock level nutrition and genetics, analyses were conducted in a multivariable mixed model that controlled for village and flock.

- Animals were followed up after 28 and 56 days and their weights were recorded again. In India after 56 days, treated goats had gained an average of 2.85 kg and non-treated goats an average of 1.41 kg, a significant difference of an additional 25.2 g/day in the treatment group. The corresponding change in treated goats in Tanzania was also significant, gaining 9.88 g/day more than the non-treated goats. In both countries treatment resulted in an improvement in body condition score.

- In India, the difference among chickens was not as marked, but was still significant; the treatment group gained 515 g, and the non-treatment group 445 g, an additional 1.61 g/day. In Tanzania treatment resulted in no significant change in the weights of chickens.

- Therefore, goats that were treated with dewormers gained considerably more weight than those that were not treated, so it can be assumed that the treated animals will have greater value at sale or greater nutritional value. These results suggest that infestation with worms is widespread in these populations and that the treatment was effective at clearing the infection. The result of treating with closantel was considerably greater than treatment with albendazole. However, this study was not designed to compare closantel with albendazole and so the differences seen in this study could be down to a number of factors other than the dewormer.

- While there is a marked effect of treatment on the chicken populations in India and therefore we can make assumptions about the sale value and nutritional value of the treated chickens, the magnitude of the effect is not as large as in goats. There are several potential reasons for this:

  - Levels of worm infection are always lower in village chickens – usually below 50%.

  - The chickens enrolled were too young to have had exposure to worm infection.

  - There was evidence of local variations in exposure, or there could be local pockets of resistance to benzimidazoles.

  - The single dosing of fenbendazole was not totally effective in treating the animals.

- We suggest reasons for the absence of any effect of dewormers on the weight of chickens in Tanzania:

  - Infection with worms in this area has a relatively minor impact on the final weight of the animals and the final weight is determined to a much greater extent by other factors.

  - The study was conducted during a prolonged dry season when infection rates of worms are lower. This would mean that there are fewer chickens that can show an impact in terms of clearing infection and gaining weight. The lower burden also means that there is a lower possibility of reinfection.

  - The deworming agents were purchased locally but their efficacy was not tested as part of this study.

Contents

Background and aims

A literature review commissioned by GALVmed (Appendix 1) identified that a number of studies have estimated the burden of helminth infections and the specific species of helminths in different host species in different regions. Among village goats, studies of prevalence typically identify helminth prevalences that can be as high as 100% (Rupa and Portugaliza, 2016; Sharma *et al.*, 2016) but there is less evidence of the impact of the infections on weight gain. Prevalences in chickens are anywhere from 35% to 100%, depending on study and area (Kumar *et al.*, 2015; Mungube *et al.*, 2008; Nnadi and George, 2010; Permin *et al.*, 1997; Poulsen *et al.*, 2000). There have been a small number of studies in chickens that estimate 2–8 g/day of additional weight gain following treatment to clear infection (Chota *et al.*, 2010; Katoch *et al.*, 2012; Phiri *et al.*, 2007).

It is well understood that infection with helminths impacts on the growth and development of livestock. Therefore, it can be assumed that treatment with anthelminthics (if effective) will clear infection and the animal can resume the growth curve of an uninfected animal. The result will be heavier animals that are more valuable at the point of sale, or animals that reach the point of sale earlier, but quantifying this is less clear. Thus, the aims of this study were to estimate the impacts on growth rates following mass treatment of animals with anthelminthics. The study was implemented in GALVmed's core countries of Tanzania and India.

Materials and methods

Base hypothesis

The underlying premise is that there is a basic level of infection with worms in village goats and chickens. Treating a sample of the animals with dewormers will clear infections and in the period following treatment there will be a significantly greater rate of growth in the treated animals compared with the animals that were not treated. The specific hypothesis is:

- H_0 (null hypothesis): treating animals with dewormers has no significant effect on weight gain over a 56-day period.

- H_1 (alternate hypothesis): treating animals with dewormers has a significant effect on weight gain over a 56-day period.

Study design

The premise of the study design was to treat randomly selected animals with dewormers and leave other animals as untreated controls. These animals were weighed at the time of treatment and then followed up and weighed at 28 and 56 days following the baseline. These time points were selected because the literature has suggested that an effect can be detected over this time period (Chota *et al.*, 2010; Katoch *et al.*, 2012) and specifically it leaves sufficient time to clear infection and detect an effect on the animal's weight while not allowing sufficient time for reinfection. There are a number of challenges that must be addressed in this approach:

- Animal identification. It is necessary to identify each animal at the follow-up visits. This was overcome by ear-tagging goats with uniquely numbered ear tags. Each goat was double tagged in case of loss of a tag. Chickens were tagged using plastic leg bands that were labelled with a code corresponding to the flock's uniquely assigned number in that village and a number corresponding to the unique number of the bird in that flock in the form Flock#/Bird#. Subsequently each chicken was identified by Village/Flock#/Bird#.

- Controlling for exposure, husbandry, nutrition and genetic factors. Individual flocks will have different feeding regimes and different exposures to infection with worms, which will also be impacted by their different management practices and genetic factors conferring different susceptibility. Many of these factors are at the level of the flock. While it is impossible to control for all these factors, they can be controlled to some extent by enrolling birds of similar ages within an individual flock and within each flock by assigning some birds to treatment and others to the non-treatment group. These flock level effects can be controlled by analysing the data using mixed models in which the village and flock to which the birds belong is included as a random effect.

- Animal retention. There will be some loss to follow-up of animals that die, are sold, or are consumed. To minimise these losses a small financial incentive is offered for each animal present at the end of the study.

Goats included in the study were non-pregnant adult females, selected because they comprise the majority of the demographic; non-pregnant was specified because pregnancy would artificially alter the animal's weight.

In India the chickens that were included were in the age range 40–70 days. This range was selected because these birds would be showing the greatest growth rates and are less likely to be sold or consumed than adults. This was not applied in the study in Tanzania.

Goat flocks were included that had two or more eligible goats and chicken flocks that had four or more eligible chickens.

Sample size

The required sample size was 1040 chickens (allowing 520 in the treatment and 520 in the non-treatment groups) and 228 goats (117 in each group).

1. **Chickens.** The required sample size was estimated by simulating the study structure as presented above using parameters derived from published literature. The prevalence of helminth infections is sampled from a beta distribution with a mean 0.2. Given 20 flocks sampled in each village, the number of birds in each flock is sampled from a Poisson distribution with a mean of 4. The infection status of each bird is sampled from a Bernoulli distribution with a mean of the prevalence. Birds are assigned to the treatment or non-treatment groups with a probability of 0.5. Infected untreated birds are assumed to grow at a mean rate of 13.7 g/day (sampled from a log-normal distribution) and treated or non-infected birds grow at a mean rate of 18 g/day. These parameters are based on a study from India (Katoch *et al*., 2012). The number of enrolled villages was stepped from five to 20 with 10,000 iterations at each step. The sample size was taken as the first step (number of villages) at which a t-test between the treatment and non-treatment groups was significant at $P < 0.05$ on at least 90% of iterations (statistical power of 90%). An allowance of 20% was made for drop-out and non-compliance, leaving a sample size of 1040 goats.

2. **Goats.** The sample size for goats was calculated using standard online sample size calculators. Based on published parameters, we assumed that all adult animals had helminth infections. Subsequently, we assumed that the mean daily growth rate in non-treated animals was 20 g/day and was 26 g/day in treated animals (both with a standard deviation of 13 g/day). This gives a required sample size of 198, over which a 15% allowance was made for loss to follow-up and this was made up to 228 goats.

Study partners

The study was designed and managed by Epi Interventions Ltd (Edinburgh, UK).

In India, the study was managed and set up by Vet Helpline India (P) Ltd (Guwahati, Assam, India) and implemented on the ground by the Gir Odisha Foundation (Chhatia, Odisha, India). As part of a separate programme, the Gir Odisha Foundation has been developing formal qualifications for community animal health workers (CAHWs). CAHWs attached to the Gir Odisha Foundation provided field workers to implement the study, and are certified under the Agriculture Skill Council of India as per National Occupational Standards.

In Tanzania the study was managed and implemented locally by the Novel Vaccine and Biological Company Ltd (Morogoro, Tanzania), led by Professor Philemon Wambura and Dr Kichuki Mirende and locally run by Dr Godfrey Madeje.

Study areas

The study was implemented separately in India and Tanzania but due to key differences in the implementation of the two studies they cannot be regarded as replicates. In India, the project was implemented in the districts of Dhenkanal, Jajpur, Kendrapara and Cuttack in the state of Orissa (Figure 1). For administrative purposes, the study area was divided into two zones comprising villages in Jajpur and Dhenkanal districts and a second zone comprising Cuttack and Kendrapara districts; 18 villages were sampled from these four districts.

Figure 1. *The state of Odisha in India is in black and the study districts are outlined in red.*

In Tanzania the study was implemented in the Bahi district of the Dodoma region (Figure 2). This district was selected as the partners have ongoing Newcastle disease (ND) vaccination projects here. Within Bahi district, the villages of Ibihwa, Kigwe, Mayamaya, Ilindi, Makatika, Mpamantwa and Uhelela were surveyed.

Figure 2. *Map of the study area in the Bahi district of Tanzania, outlined in red.*

Timing of the study

The baseline survey in India was conducted in December 2016, shortly after the wet season when the worm burden was likely to be greatest and the villages accessible without any religious festivals. The baseline survey in Tanzania was conducted in January 2017; this was during a prolonged dry season when the animals may have been under nutritional stress.

Household enrolment: India

Households in the selected villages were surveyed to identify those that owned animals that met the eligibility criteria. Subsequently, households were selected from those surveyed until the sample sizes for that village were achieved. Households that were selected for enrolment were asked to return to a central point with their animals, where they were informed of the purpose of the study and asked to sign an informed consent form (IC). If a household declined to sign the IC then another suitable household was enlisted. At the central point, details of the household and management practices were recorded and then each animal was taken in turn and:

1. The animal was weighed. For goats, the body condition score (BCS) was assessed using the standard three metric procedure – assessing the visual aspect, spinal process and the sternal fat on a 1 to 5 scale on which 1 corresponds to highly emaciated animals with little fat and 5 corresponds to overweight animals with excess fat. The goat was assessed for each of the three metrics on a 1 to 5 scale; these were then combined to give a final score. A score of 3 corresponds to a healthy body weight. More details and a description of the process are given in Villaquiran *et al.* (2004) and are summarised in Table 1.

Table 1*. The scale for body condition scoring (Villaquiran et al., 2004).*

BSC	Description (Villaquiran *et al.*, 2004)
1	Visual aspect of the goat: Emaciated and weak animal, the backbone is highly visible and forms a continuous ridge. The flank is hollow. Ribs are clearly visible. There is no fat cover and fingers easily penetrate into intercostal spaces (between ribs). The spinous process of the lumbar vertebrae can be grasped easily between the thumb and forefinger; the spinous process is rough, prominent and distinct giving a saw-tooth appearance. Very little muscle and no fat can be felt between the skin and bone. There is a deep depression in the transition from the spinous to transverse process. The hand can easily grasp the transverse process of the lumbar vertebrae which is very prominent. Clearly half of the length of the transverse process is discernible. Sternal fat can be easily grasped between thumb and fingers and moved from side to side. The cartilage and joints joining ribs and sternum are easily felt.
2	Visual aspect of the goat: Slightly raw-boned, the backbone is still visible with a continuous ridge. Some ribs can be seen and there is a small amount of fat cover. Ribs are still felt. Intercostal spaces are smooth but can still be penetrated. The spinous process of the lumbar vertebrae is evident and can still be grasped between the thumb and forefinger; however, a muscle mass can be felt between the skin and bone. There is an obvious depression in the transition from the spinous to transverse process. The hand can grasp the transverse process but the outline of the transverse process is difficult to see. About one-third to one-half of the length of the transverse process is discernible. Sternal fat is wider and thicker but can still be grasped and lifted by the thumb and forefinger. The fat layer can still be moved slightly from side to side. Joints are less evident.
3	Visual aspect of the goat: The backbone is not prominent. Ribs are barely discernible; an even layer of fat covers them. Intercostal spaces are felt using pressure. The spinous process of the lumbar vertebrae cannot be easily grasped because the tissue layer covering the vertebrae is thick. When running a finger over the spinous process, a slight hollow is felt. There is a smooth slope in the transition from the spinous to transverse process. The outline of the transverse process of the lumbar vertebrae is slightly discernible. Less than one-quarter of the length of the transverse process is discernible. Sternal fat is wide and thick. It can still be grasped but has very little movement. Joints joining cartilage and ribs are barely felt.
4	Visual aspect of the goat: The backbone cannot be seen. Ribs are not seen. The side of the animal is sleek in appearance. It is impossible to grasp the spinous process of the lumbar vertebrae, which is wrapped in a thick layer of muscle and fat. The spinous process forms a continuous line. There is a rounded transition from the spinous to transverse process. The outline of the transverse process of the lumbar vertebrae is no longer discernible. The transverse process forms a smooth, rounded edge, with no individual vertebrae discernible. Sternal fat is difficult to grasp because of its width and depth. It cannot be moved from side to side.
5	Visual aspect of the goat: The backbone is buried in fat. Ribs are not visible. The rib cage is covered with excessive fat. The thickness of the muscle and fat is so great that reference marks on the spinous process are lost. The spinous process forms a depression along the backbone and there is a bulging transition from the spinous to transverse process. The thickness of the muscle and fat is so great that reference marks on the transverse process are also lost. It is impossible to grasp the transverse process. The sternal fat now extends and covers the sternum, joining fat covering cartilage and ribs. It cannot be grasped.

2. A coin was tossed to assign the animal to treatment (heads) or non-treatment.

3. If treatment then the animal was treated with a quantity of dewormer appropriate for the animal's weight. It was not logistically possible to keep the treatment or non-treatment status of the animals hidden from the farmers, but in practice it was difficult for the farmer to follow the proceedings.

4. The animal was tagged.

5. Following the final survey, compensation was paid for all tagged animals that were present at the final survey. The payment was made of 200INR (US$3) per animal by bank transfer.

Household enrolment: Tanzania

The day before a village was visited for enrolment the local animal health extension worker was informed of the study and would speak to owners of goats and chickens and ask them to keep their animals housed the following morning. The village was visited the following morning and households keeping goats or chickens were identified with the help of local animal health extension workers. The owner was informed of the purpose of the study and if they were willing to be involved they were asked to sign an IC. If a household declined to sign the IC then another suitable household was enlisted. The team would set up a weighing, tagging and treatment point and the animals would be brought to the point one at a time:

1. Non-vaccinated chickens were vaccinated using I-2 vaccines. Goats in the area are routinely vaccinated against peste des petits ruminants (PPR).

2. The animal was weighed. For goats, the BCS was assessed using the standard three metric procedure – assessing the visual aspect, spinal process and the sternal fat on a 1 to 5 scale (Table 1).

3. The ODK Collect smartphone app automatically assigned the animal to treatment or non-treatment.

4. If treatment was assigned then the animal was treated with a quantity of dewormer appropriate for the animal's weight calculated by the ODK Collect smartphone app.

5. The animal was tagged.

6. The farmer was served a questionnaire on their animal management practices.

7. Following the final survey, compensation was paid for all tagged animals that were present at the final survey. The payment was made of US$2 per animal. The householder was informed of this at the time of signing the IC.

Treatment and equipment: India

In advance of the baseline enrolment, the villages were visited and chickens vaccinated using locally available LaSota ND vaccines. Goats in the area are routinely vaccinated against PPR.

The dewormers selected were locally available and judged to be the most effective. Chickens were treated with fenbendazole 2.5% w/v (Karnataka Antibiotics Pharmaceuticals Ltd) orally with 10 mg/kg body weight (0.4 ml/kg). Goats were treated with closantel 15% oral solution (Zyclos™, Zydus AH), administered as per the manufacturer's instructions at 10 mg/kg (1 ml/15 kg). Farmers were informed of the manufacturer's withdrawal periods.

Dewormers were administered directly to the animal using a syringe. Closantel was administered as measured. Due to the small amounts and difficulty of administration, fenbendazole was administered to the beak of the bird at a calibrated number of drops of dewormer (1 ml = 20 drops), so a 1 kg chicken received eight drops of fenbendazole.

Chickens were weighed using table-top scales manufactured by Sansui Electronics (P) Ltd. The bird was placed in a box on top of the scales, which were first zeroed. Goats were weighed using a platform weighing scale manufactured by Sansui Electronics (P) Ltd. One person stands on the scale, the scale is zeroed and the person is then handed the goat (Figure 3).

***Figure 3**. Left: the chicken is in the box (centre) on the chicken scales. Right: a CAHW holding the goat for weighing.*

Treatment and equipment: Tanzania

The dewormers selected were locally available and judged to be the most effective from those available. Chickens were treated with a combination of piperazine citrate powder 100% w/w manufactured by Biotech Laboratories Ltd and Levifarm Levamisole (20%) manufactured by Farmers Centre Ltd. Levamisole was selected as it is broad spectrum and piperazine because it is very effective against ascarids. Both were powders that were reconstituted with water, piperazine at 7.5 g per 500 ml and levamisole at 5 g per 500 ml. The two powders were combined and added to a single 500 ml measure of bottled water. Chickens were treated at 4 ml/kg body weight, which delivered 60 mg/kg piperazine and 8 mg/kg levamisole as per recommendations. The appropriate volume of solution was carefully measured by a technician and was delivered directly to the beak of the chicken using a syringe to ensure that the chicken received the full dose. The treatments were tested on a pilot flock to ensure that there were no ill effects from administering the solution directly to the beak of the chicken. Following treatment, the chickens in this pilot flock were monitored for any ill effects resulting from the treatment.

Goats were treated with Tramazole 10% (Univet (Ireland) Ltd distributed by Ultravets Tanzania) abendazole solution (10%) at 7.5 mg/kg administered directly to the mouth of the animal by syringe. Dosages were calculated by the ODK Collect smartphone app.

Chickens were weighed using hanging poultry scales. Goats were weighed using a household scale, by one person standing on the scale and recording the weight; the person is then handed the goat and the second weight recorded (Figure 4). All equipment was disinfected following each farm enrolment.

Survey tools: ODK Collect

The IC was a paper form as it was necessary to obtain a signature. Data was collected using two Android OS smartphones that were purchased for each study. The models of smartphone selected were the LYF-Wind 7 in India and the Huawei Y-3 model in Tanzania. ODK Collect was installed on these two phones. Following the piloting, the form structure was slightly different for each of the two study areas, but broadly it comprised four forms:

1. **Household survey form.** This was for collecting household demographic data from the household surveys. Only households that consented to the study were loaded onto ODK Collect.

2. **Enrolment form.** This was for entering details of each animal at enrolment and was used at the time of enrolment – when animals are weighed and treated. It recorded the village, farmer name and household number and the numbers of each species that were being enrolled. Subsequently for each animal that was enrolled, it recorded the tag number, weight, whether treatment was administered, and if treatment was administered then the volume of treatment administered was automatically calculated from the animal weight. The form for the study in Tanzania randomly assigned animals to the treatment or non-treatment groups. In India this was done by toss of a coin.

3. **28-day survey form.** This was a simple follow-up for use after 28 days and recorded the village, farmer name and household number and the numbers of each species being enrolled. Subsequently, for each animal that was enrolled, it recorded the tag number and weight of the animal, and for goats the pregnancy status.

4. **56-day survey form.** This was a simple follow-up for use after 56 days and recorded the village, farmer name and household number and the numbers of each species being enrolled. Subsequently, for each animal that was enrolled, it recorded the tag number and weight of the animal, and for goats the pregnancy status. It also calculated the volume of treatment to be given to animals that were not treated at the baseline.

Statistical analysis

The outcome variable was the difference in weight of the animal between the follow-up surveys and the baseline survey. Where the timing of the follow-up surveys was not the same for all households this was expressed as the daily change in weight between baseline and follow-up. The treatment status of the animal was the key predictor in these analyses. To control for the effects of village and flock on exposure, nutrition and genetics, a generalised linear mixed model (GLMM) analysis was conducted in which the village and flock of the animal was included as nested mixed effects in a linear mixed model with treatment as the principal predictor. The weight at baseline, and for chickens their sex and age, were also included as predictors.

***Figure 4**. Left: a technician using the hanging chicken scales with a chicken in the bucket Right: a technician on the household scales weighing the goat.*

Figure 4 photo credit: Prof. Philemon Wambura.

Results

Summary of key results

The results are described in detail in subsequent sections, but Table 2 gives a brief summary of the key results. Treatment resulted in significantly greater growth rates in all species–study area combinations except for chickens in Tanzania, where there was no significant difference.

***Table 2**. Summary of the results of treatment on weight change.*

Species	Country	Number eligible at 56 days*	Mean weight at baseline (kg)	Difference in daily change in weight (g) Tx – NT**	*P-value*
Goat	India	NT 97 Tx 129	NT 13.7 Tx 12.9	25.2	<0.001
Goat	Tanzania	NT 124 Tx 120	NT 19.4 Tx 20.9	9.88	0.007
Chicken	India	NT 394 Tx 489	NT 0.391 Tx 0.358	1.61	<0.001
Chicken	Tanzania	NT 338 Tx 305	NT 1.34 Tx 1.35	0.156	0.577

* This refers to all tagged animals that were present on the farm after 56 days that were eligible for inclusion (so excluding goats that became pregnant between baseline and follow-up).

** This is the difference in daily weight change between the treatment and non-treatment groups. This is the estimate from a GLMM.

NT = non-treated. Tx = treated.

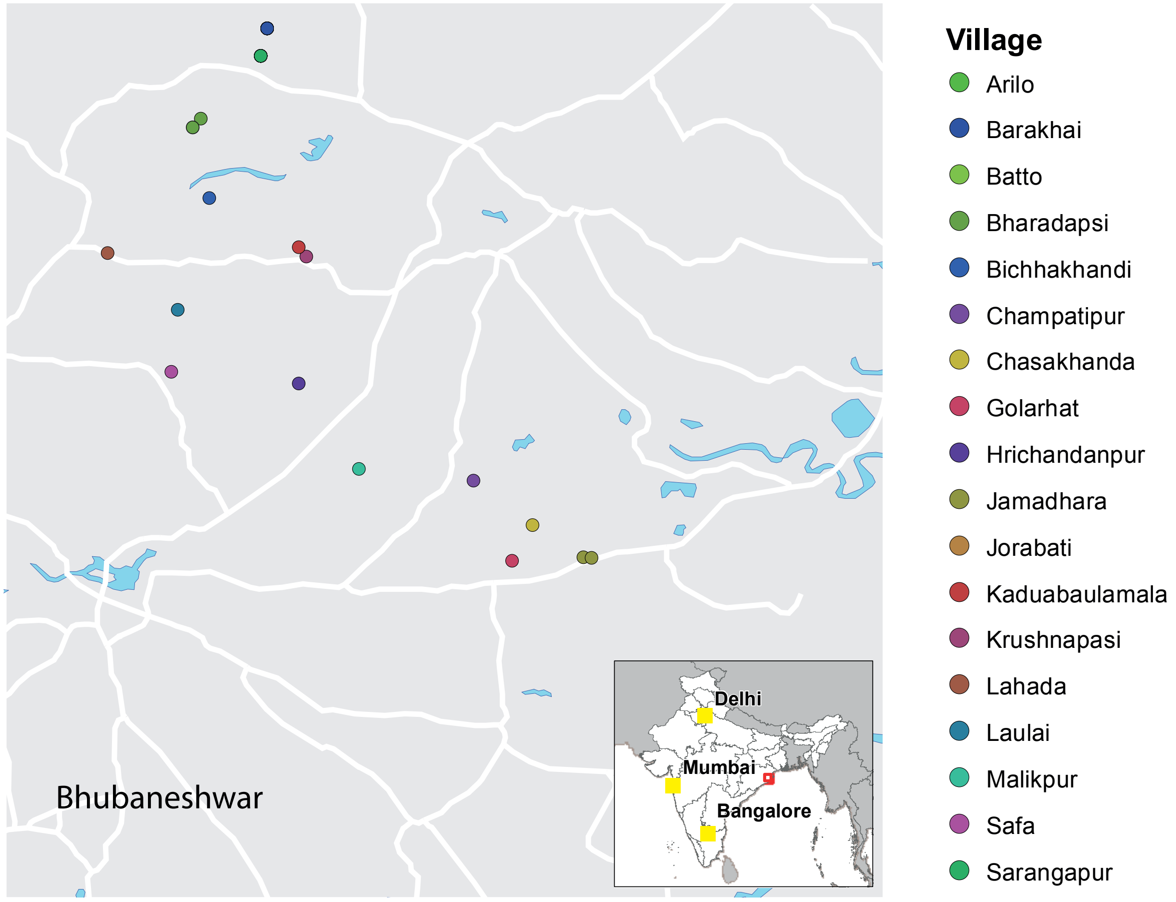
Baseline data

Animals from 223 households were enrolled from 18 villages in India (Table 3). Numbers enrolled in each village varied; it is worth noting that some villages are part of the same Gram Panchayat, such as Batto, Hrichandanpur and Jorabati, and are essentially the same village, hence they are combined as a village group (Table 3). The geographical distribution of the villages is shown in Figure 5. The 234 goats were enrolled from 92 households (2.54 goats/household; minimum 1, maximum 6), all were adult females and non-pregnant. The majority were grazed during the day but given overnight shelter, but nine flocks were tethered. Half of households gave their goats no additional nutrition. The chickens were enrolled from 168 households (6.19 chickens/household; minimum 2, maximum 17). A total of 282 (27.1%) of the chickens were males and all households provided supplementary feed and night shelter for their chickens.

***Table 3**. Summary of enrolment by village in India. Note that villages are geographically organised into these identified clusters.*

		Chickens		Goats		
Village	**Village group**	**Households**	**Chickens**	**Households**	**Goats**	**Enrolment date (DD/MM/YY)**
Batto	Jorabati	1	12	0	0	17/12/16
Hrichandanpur	Jorabati	2	12	0	0	17/12/16
Jorabati	Jorabati	8	60	8	18	17/12/16
Bharadapsi	Bharadapsi	16	90	10	18	14/12/16
Bichhakhandi	Bichhakhandi	16	101	7	18	13/12/16
Barakhai	Barakhai	11	91	7	18	15/12/16
Sarangapur	Sarangapur	14	84	5	17	16/12/16
Laulai	Laulai	16	113	7	18	14/12/16
Jamadhara	Jamadhara	15	83	7	18	18/12/16
Kaduabaulamala	Krushnapasi	2	8	5	19	12/12/16
Krushnapasi	Krushnapasi	5	20	0	0	13/12/16
Arilo	Arilo	6	19	7	18	10/12/16
Malikpur	Arilo	9	42	0	0	11/12/16
Chasakhanda	Golarhat	3	13	3	8	18/12/16
Golarhat	Golarhat	9	65	5	10	18/12/16
Champatipur	Champatipur	0	0	7	18	18/12/16
Lahada	Lahada	17	95	6	18	17/12/16
Safa	Safa	19	132	8	18	17/12/16
Total		**168**	**1040**	**92**	**234**	

__Figure 5__. Map of the villages in which animals were enrolled in India.

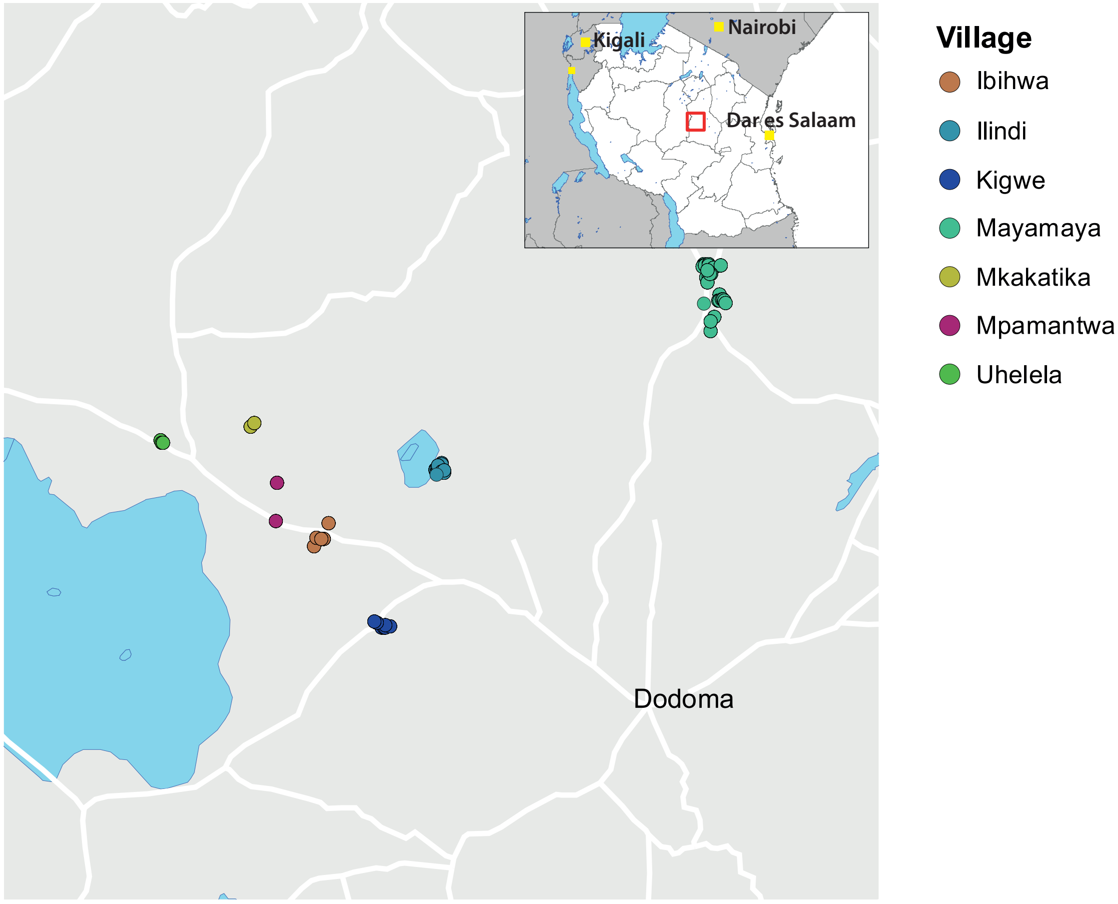


In Tanzania, animals from 61 households with chickens and 15 households with goats were enrolled from seven villages (Table 4, Figure 6). Numbers enrolled in each village varied – in the case of Makatika the chicken population is large, but the number enrolled was small due to an ongoing ND outbreak; this was compensated for by enrolling chickens elsewhere, particularly from Mayamaya. The 253 goats were enrolled from 15 households (16.9 goats/household; minimum 9, maximum 47), all were adult females and non-pregnant. All goat flocks were grazed during the day but given overnight shelter. The 1068 chickens were enrolled from 61 households (17.5 chickens/household; minimum 8, maximum 46). A total of 251 (23.5%) of the chickens were males and all households except one provided supplementary feed and all provided night shelter for their chickens.

__Table 4__. Summary of enrolment of animals by village.

	Chickens		Goats		
Village	**Households**	**Chickens**	**Households**	**Goats**	**Enrolment date (DD/MM/YY)**
Ibihwa	6	130	5	82	18/01/17
Ilindi	12	185	2	20	21/01/17
Kigwe	9	108	2	20	23/01/17
Mayamaya	27	493	1	13	22/01/17
Makatika	2	68	1	20	20/01/17
Mpamantwa	2	31	2	20	25/01/17
Uhelela	3	53	2	78	19/01/17
Total	**61**	**1068**	**15**	**253**	

Figure 6. *Map of the villages from which the households were enrolled in Tanzania.*



Treatments and weights at baseline: goats

In India, a greater number of goats were treated than not treated, but the treated goats weighed less on average (Figure 7), but this was not significant ($P = 0.198$). The BCSs of the treated goats were also lower but both were close to 2, which is a slight lack of condition (Table 5).

In Tanzania, a greater number of goats were not treated than were treated, but the mean weight of treated goats was 1.5 kg more than non-treated goats (Table 5) and this is significant ($P = 0.01$). The BCSs of the treated goats were very slightly lower (Table 5). The distributions of goat weights are illustrated by Figure 8. The goats in Tanzania were around 6 kg heavier than those from India.

Table 5. *Summary of goat treatments.*

		Not treated	Treated
India	Number	101 (43.2%)	133 (56.8%)
	Mean weight, kg (SD)	13.7 (4.9)	12.9 (4.7)
	BCS	2.15	2.02
Tanzania	Number	130 (51.4%)	123 (48.6%)
	Mean weight, kg (SD)	19.4 (4.8)	20.9 (4.6)
	BCS	2.82	2.76

Figure 7. *Density plot of the weights of all enrolled goats (top) and box plot of the weights of treated and non treated goats (bottom) in India. The 'smoothed density' indicates the relative frequency of the weights on the x-axis.*

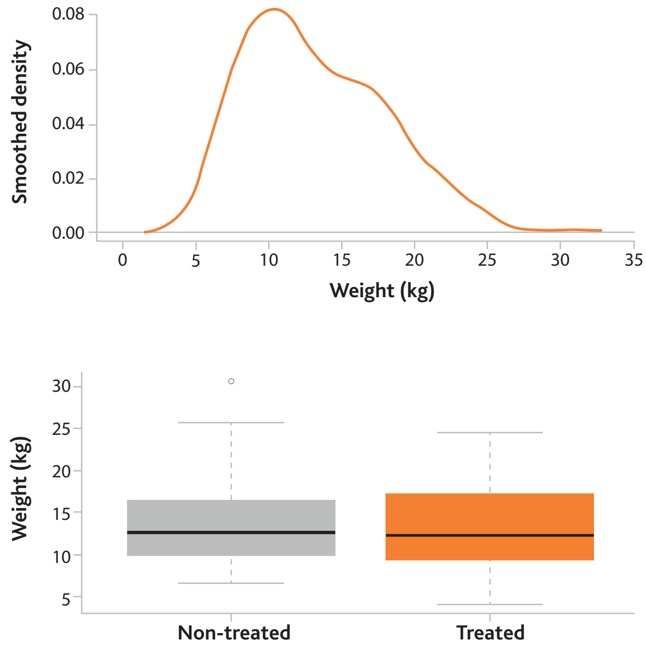
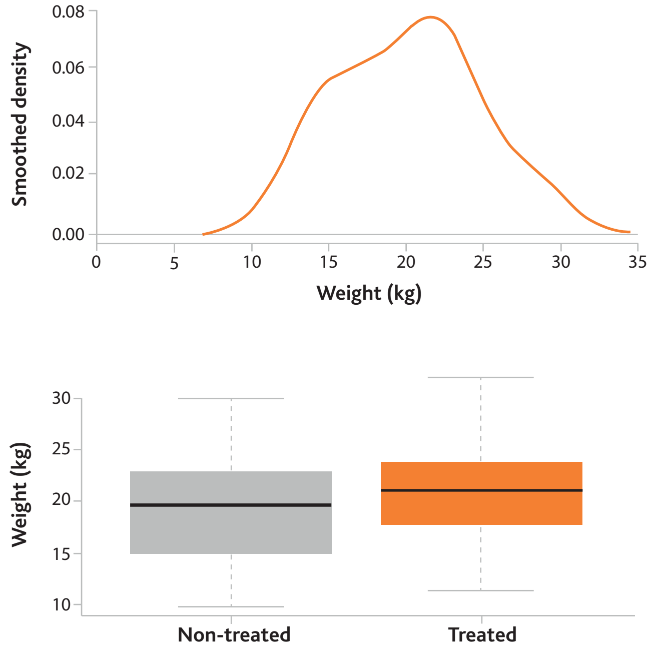


Figure 8. *Density plot of the weights of all enrolled goats (top) and box plot of the weights of treated and non-treated goats (bottom) in Tanzania. The 'smoothed density' indicates the relative frequency of the weights on the x-axis.*



Treatments and weights at baseline: chickens

In India, a greater number of chickens were treated than non-treated and the weights of treated chickens were lower, in this case significantly so ($P = 0.009$) (Table 6). In Tanzania, there were also a greater number that were non-treated but the weights of chickens in each group were similar ($P = 0.901$) (Table 6). The chickens from Tanzania were considerably heavier than those from India because there were no weight restrictions applied to those from Tanzania.

Table 6. *Summary of chickens enrolled and treatments given.*

		Not treated	Treated
India	Number	471 (45.3%)	569 (54.7%)
	Mean weight, g (SD)	391.1 (208.0)	358.0 (198.6)
	Female	341 (32.7%)	417 (40.1%)
	Male	130 (12.5%)	152 (14.6%)
Tanzania	Number	544 (51.3%)	517 (48.7%)
	Mean weight, g (SD)	1332 (629)	1337 (608)
	Female	410 (38.6%)	406 (38.3%)
	Male	134 (12.6%)	111 (10.5%)

The distribution of weights of chickens in India is illustrated in Figure 9 and in Tanzania in Figure 10.

***Figure 9**. Density plot of the weights of all enrolled chickens (top) and box plot of the weights of treated and non-treated chickens (bottom) from India. The 'smoothed density' indicates the relative frequency of the weights on the x-axis.*

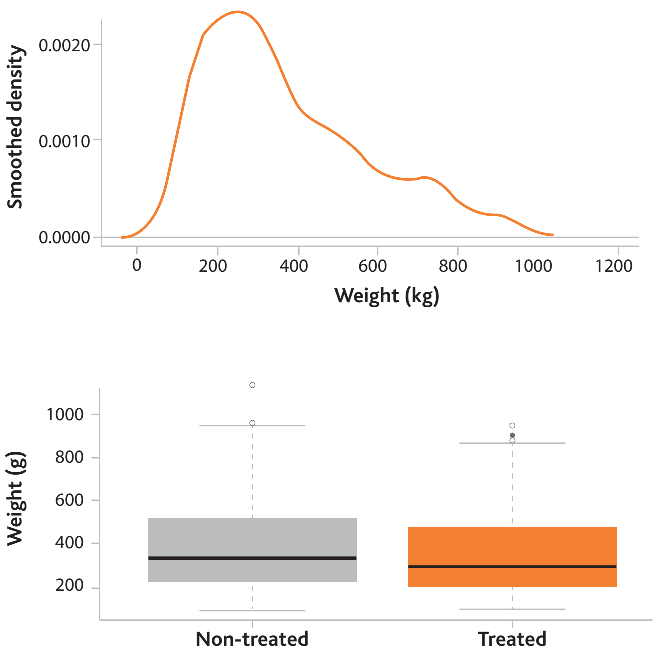
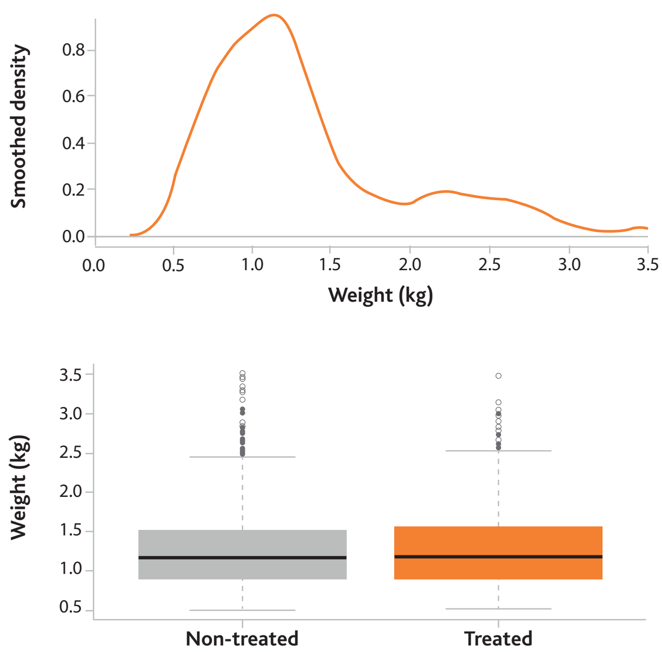


***Figure 10**. Density plot of the weights of all enrolled chickens (top) and box plot of the weights of treated and non-treated chickens (bottom) from Tanzania. The 'smoothed density' indicates the relative frequency of the weights on the x-axis.*



Follow-up surveys: goats

There was no loss to follow-up among the goats in India, but eight were excluded as they were pregnant at the final survey (Table 7). In Tanzania, nine were lost to follow-up and a further six were pregnant. In India the midpoint and endpoint surveys were carried out exactly 28 and 56 days after the baseline surveys. In Tanzania, because of logistical challenges, the final survey did not take place at exactly 56 days after the baseline survey and it was conducted between 52 and 59 days following the baseline.

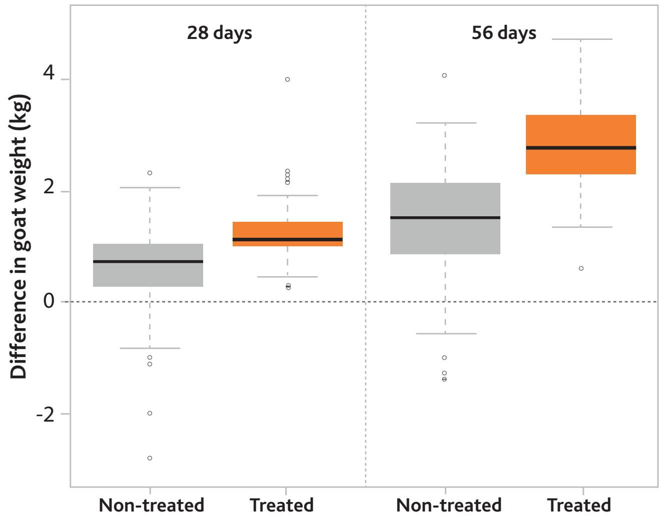
***Table 7**. Summary of follow-up enrolment in goats.*

		Baseline	Midpoint (Day 28)	Final survey (Day 56)
India	Households	92	92	92
	Enrolled (lost to follow-up)	234	234 (0%)	234 (0%)
	Pregnant (lost to follow-up)	0	0	8 (3.4%)
	Treated	133	133	129
	Non-treated	101	101	97
Tanzania	Households	15	15	15
	Enrolled (lost to follow-up)	253	248 (2.0%)	244 (3.6%)
	Pregnant (lost to follow-up)	0	0	6 (2.4%)
	Treated	123	120	120
	Non-treated	130	128	124

Change in weights: goats

In India, after 28 days the treated goats had gained 1.22 kg, compared to 0.58 kg in the non-treated goats, and this is significant ($P < 0.001$). After 56 days, the respective weight gains were 2.85 kg and 1.41 kg, also significant ($P < 0.001$). None of the treated goats lost weight (Figure 11). Thus, the treated goats gained weight at 50.8 g/day, compared to 25.2 g/day in non-treated goats.

Figure 11. *Box plot of the change in goat weight for treated and non-treated goats after 28 days (left) and after 56 days (right). Data for India.*



In Tanzania, after 28 days the treated goats had gained 1.96 kg, compared to 1.84 kg in the non-treated goats; this is not significant (univariable $P = 0.54$). After 56 days, the respective weight gains were 2.69 kg and 2.28 kg, also non-significant in univariable analysis ($P = 0.065$) (Figure 12). As the final survey was not always carried out exactly 56 days after the baseline there was a need to correct for this, so the treated goats gained weight at 49.4 g/day, compared to 42.1 g/day in non-treated goats (Figure 13), also not significant by univariable analysis ($P = 0.071$).

Figure 12. *Box plot of the change in goat weight from the baseline for treated and non-treated goats after 28 days (left) and after 56 days (right). Data for Tanzania.*

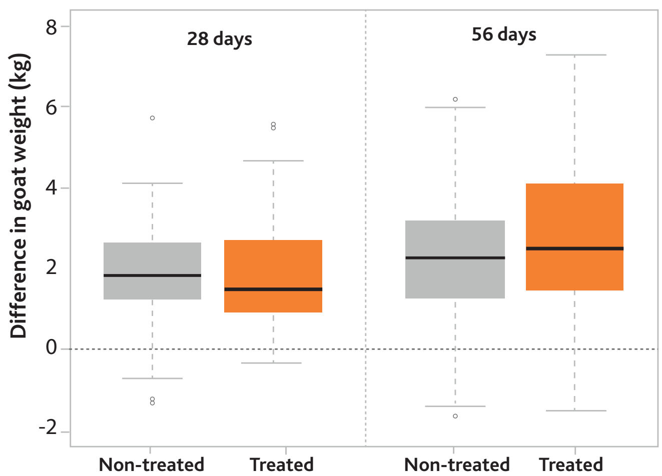
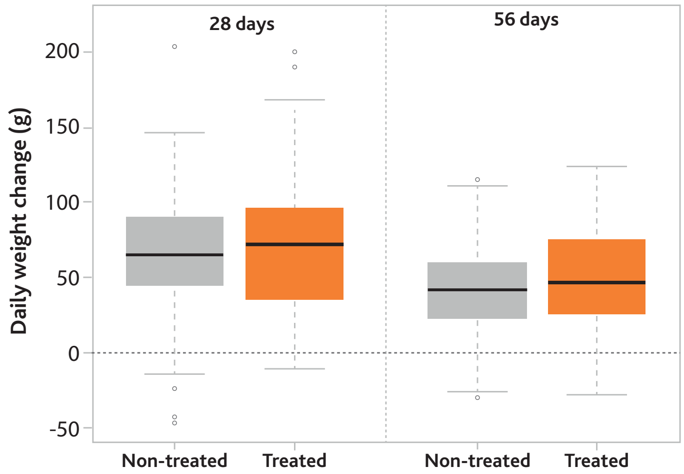


Figure 13. *Box plot of mean daily change in goat weight for treated and non-treated goats after 28 days (left) and after 56 days (right). Data for Tanzania.*



At baseline, the mean BCS was greater in Tanzania than in India, but in both areas there was a marked increase in BCS among the treated animals. However, in Tanzania there was also an increase in BCS in the non-treated animals (Table 8).

Table 8. *Mean BCS of the goats at the three time points.*

	Survey	Mean BCS (mean change)	
		Non-treated	Treated
India	Baseline	2.15	2.02
	28-day follow-up	2.11 (–0.04)	2.29 (0.27)
	56-day follow-up	2.10 (–0.03)	2.41 (0.40)
Tanzania	Baseline	2.82	2.76
	28-day follow-up	3.09 (0.25)	3.08 (0.29)
	56-day follow-up	3.18 (0.34)	3.30 (0.52)

Plotting the data for India does not show a large effect of the starting weight of the goats on the impacts of the dewormer treatment in either study area – the lines in Figure 14 show similar gradients. Analysing the Indian data in a linear model in which the difference in weight is the outcome, and random effects take account of the flock and village shows that the treatment has a significant effect, of increasing goat growth by an additional 25.2 g/day (Table 9). The weight at enrolment also has a slight significant effect on determining the weight change, heavier animals having a smaller weight change.

Figure 14. *Scatter plot of goat weights by treatment group. Solid lines represent the trend lines – the outputs of linear models. India (left), Tanzania (right).*

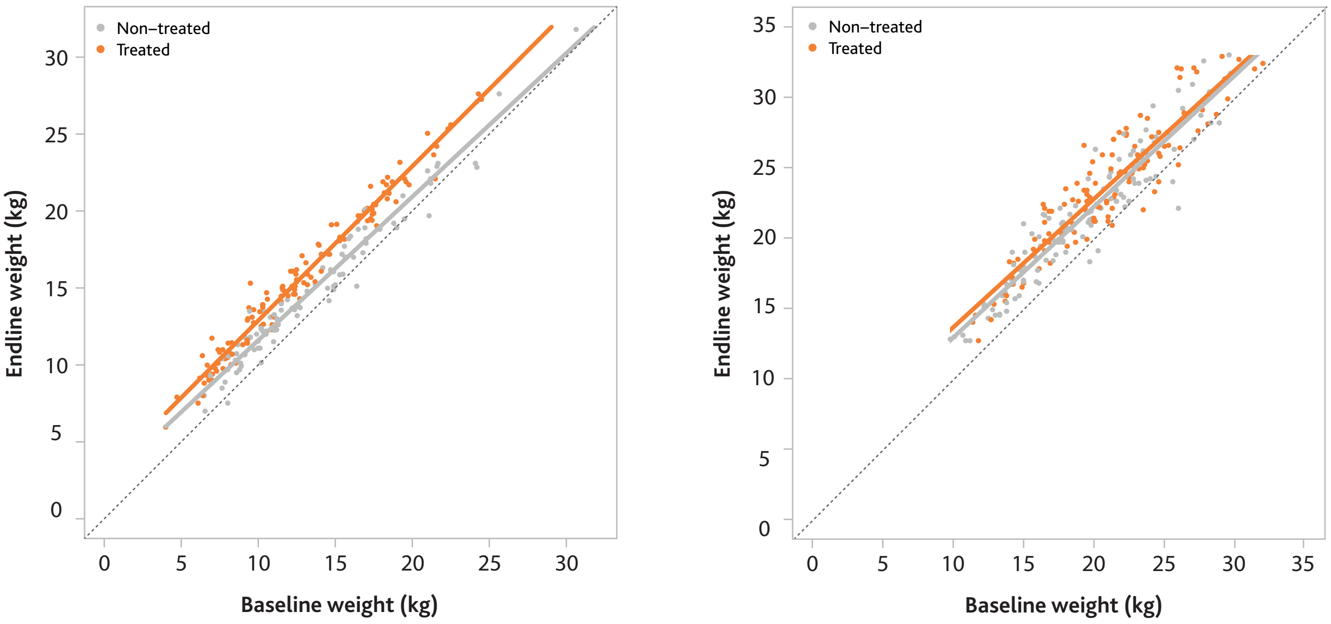


Table 9. *Output of a multivariable GLMM of the effect of treatment on the daily weight change in goats. Data for India.*

Variable	Units	Estimate	SE	t-value	*P*-value
Intercept		31.9	3.95	8.08	<0.001
Weight at enrolment	kg	–0.450	0.204	–2.21	0.027
Treatment (difference in daily change in weight (g))	Non-treated Treated	– 25.2	1.84	13.6	<0.001

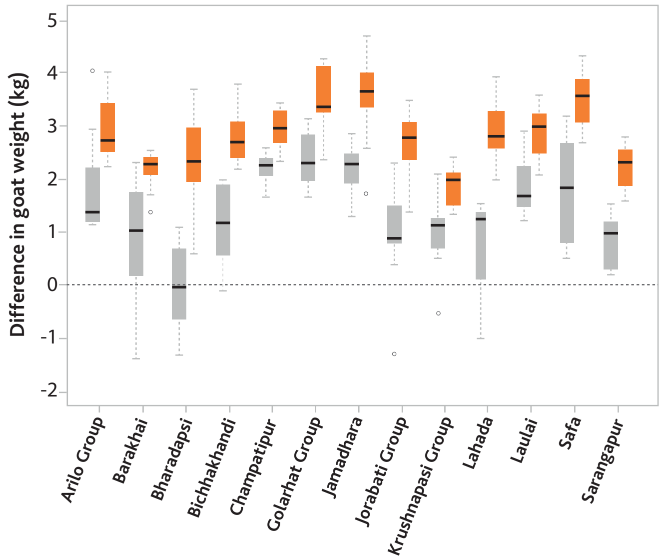
The same analysis of the data from Tanzania in a GLMM in which the change in the daily change in weight is the outcome shows that the treatment has a significant effect, increasing goat growth by an additional 9.878 g/day. There is also a residual effect of the starting weight, so goats that were heavier at baseline gained less weight than lighter goats (Table 10).

Table 10. *Output of a multivariable GLMM of the effect of treatment on the daily weight change in goats. Data for Tanzania.*

Variable	Units	Estimate	SE	t-value	*P*-value
Intercept		66.0	9.34	7.07	<0.001
Weight at enrolment	kg	–1.34	0.409	–3.29	0.001
Treatment (difference in daily change in weight (g))	Non-treated Treated	– 9.88	3.69	2.68	0.007

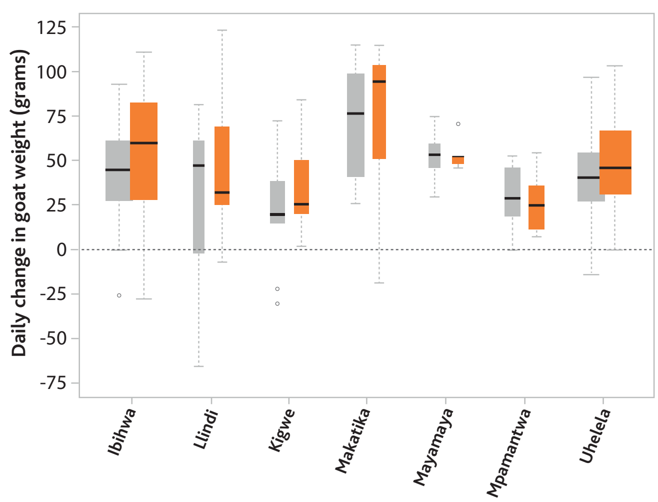
In India the differences between treated and non-treated goats were pretty consistent across the study villages (Figure 15).

Figure 15. *Box plot of the change in goat weight by village in India. Grey boxes represent the non-treated goats, and orange boxes the treated goats. The widths of each box correspond to the number in the group.*



In Tanzania, analysis by village shows that there is some variation between villages, with a mean difference of 9 g in Ibihwa, 11 g in Uhelela, but a decline in weight in Mpamantwa, suggesting that there are different exposures in the different villages (Figure 16).

Figure 16. *Box plot of the change in goat weight by village for Tanzania. Grey boxes represent the non-treated goats, and orange boxes the treated goats. The widths of each box correspond to the number in the group.*



Follow-up surveys: chickens

In India, 157 (15.1%) chickens were lost to follow-up, with 'death' being cited as the principal reason for loss, but there was also the loss of a flock due to a disagreement among the family over involvement in the study. Among these there were seven households that were lost to follow-up, either because they dropped out or because they lost all their animals (Table 11).

Table 11. *Summary of follow-up enrolment of chickens in India.*

	Baseline	Midpoint (Day 28)	Final survey (Day 56)
Households	168	167	161
Chickens enrolled (lost to follow-up)	1040	969 (6.8%)	883 (15.1%)
Chickens treated	569	531	489
Chickens not treated	471	438	394

In Tanzania, among the chickens there was a loss of follow-up due to a failing in the study design such that the markings on the chicken leg bands did not remain permanent and so were lost. It was possible to recover much of the data using records of the ten different colours that the leg bands were divided into; these colours had been recorded. These rules used the unique flock number, leg band colour and the gender of the chicken as recorded at baseline compared to follow-up surveys:

1. Flock number, leg band colour and the sex of the chicken were combined to create an identifier. For a proportion of chickens this was unique and could be used to match between surveys.
2. Where possible, flock number, leg band colour, sex and weight were used to match, so if at baseline a flock had two chickens with pink leg bands, one weighing 1000 g and the second 2000 g, and at follow-up there were also two with pink leg bands weighing 1100 g and 2200 g, then they were matched. If on the other hand the two chickens weighed 1000 g and 1100 g at baseline and 1050 g and 1150 g at follow-up then they could not be matched with confidence owing to the similar weights.

A total of 950 chickens were followed up after 28 days and 727 of these were matched; 833 were followed up after 56 days and 643 were matched; this represented a loss of 190 chickens. Around half were matched directly, using the leg band colour and the chicken's weight, and the other half required the weight of the chicken to inform this (Table 12).

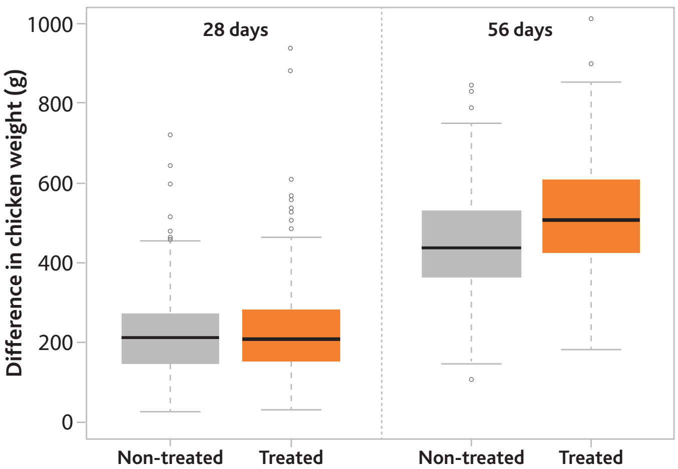
Table 12. *Summary of follow-up of the chickens at 28 days and 56 days.*

		Chickens	Treated	Not treated
Baseline	**Enrolled**	**1068**	**521**	**547**
28-day follow-up	Surveyed	950	–	–
	Matched – uniquely	371	179	192
	Matched – on weight	356	179	177
	Not matched	223 (23.5%)	–	–
	Total matched	**727**	**358**	**369**
56-day follow-up	Surveyed	833	–	–
	Matched – uniquely	332	151	181
	Matched – on weight	311	154	157
	Not matched	190 (22.8%)	–	–
	Total matched	**643**	**305**	**338**

Change in weight: chickens

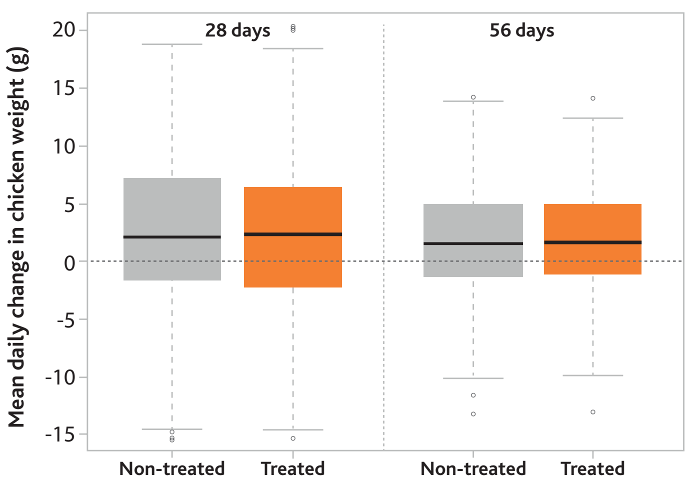
After 28 days, there was no significant difference between the treated and non-treated chickens in India; treated chickens had gained a mean of 224 g, compared to 217 g for the non-treated chickens. However, after 56 days the change in weight was 515 g compared to 445 g, and this was significant ($P < 0.001$), being a change in weight of 9.20 g/day for the treated and 7.95 g/day in the non-treated chickens (Figure 17).

Figure 17. *Box plot of the change in goat weight for treated and non-treated chickens after 28 days (left) and after 56 days (right). Data for India.*



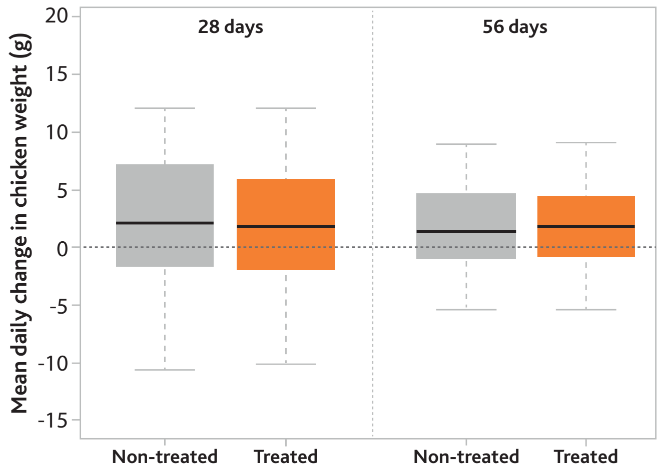
In Tanzania after 28 days, there was no significant difference between the treated and non-treated chickens. Treated chickens had gained a mean of 52.7 g, compared to 52.3 g for the non-treated chickens. After 56 days the change in weight was 86.9 g compared to 91.5 g, and this was also not significant ($P = 0.816$). This translated to a mean daily change in weight of 1.61 g/day for the treated and 1.68 g/day for the non-treated chickens (Figure 18).

Figure 18. *Box plots of the difference after 28 days (left) and after 56 days (right) for Tanzania.*



Rerunning the analysis on a 'completely clean' subset of data leaves 294 chickens (160 not treated and 134 treated at the endline survey). The clean dataset is created by excluding the 5% that lost the greatest amount of weight and the 5% that gained the greatest amount of weight and only using those that were matched directly from baseline to follow-up surveys. Analysing these, there remains no significant difference between baseline and follow-up surveys ($P = 0.972$) (Figure 19).

Figure 19. *Box plot for a subset of 'clean' data – box plots of the mean daily difference in weight after 28 days (left) and after 56 days (right) for Tanzania.*



Analysis of scatter plots for chickens show similar trends to the data for goats, although note that there is a less clear trend in Tanzania (Figure 20). Analysing the data in a linear mixed model in which the change in weight is the outcome, and random effects take account of the flock and village shows that the treatment still has a strong, significant effect on final chicken weight in India (Table 13), but not in Tanzania (Table 14). There is also a small residual effect of the starting weight, but in the opposite direction to goats – heavier chickens at baseline put on more weight after treatment is taken into account.

Figure 20. Scatter plot of chicken weights by treatment group. Solid lines represent the trend lines – the outputs of linear models. Left, data for India. Right, data for Tanzania.

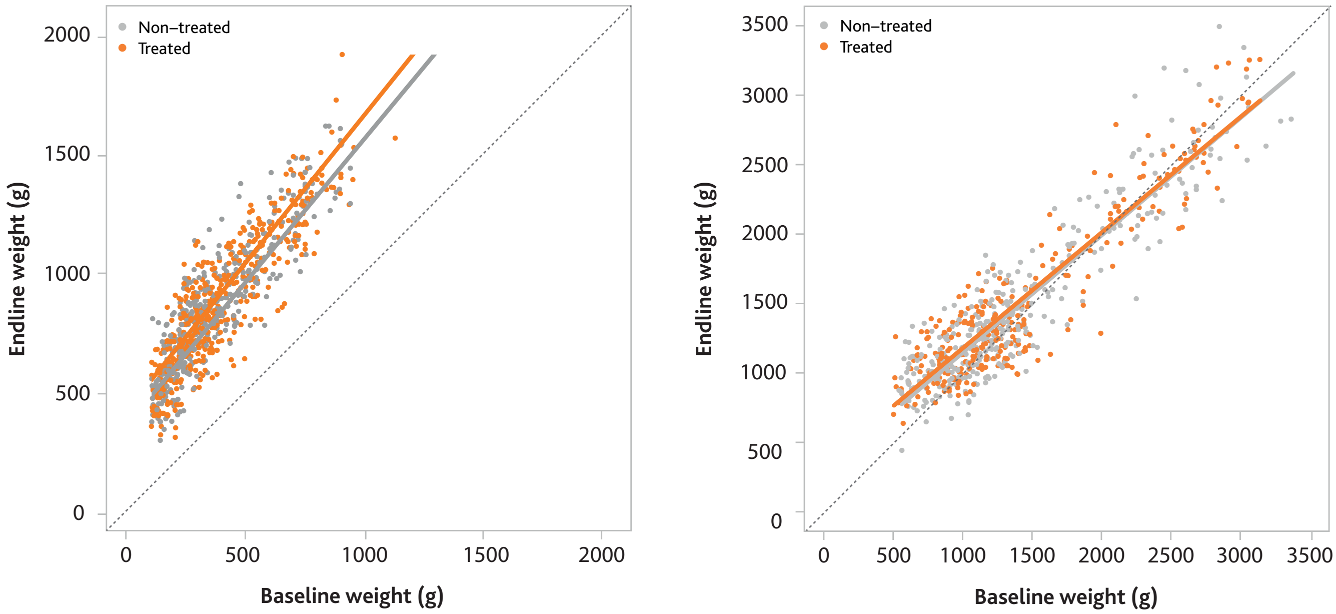


Table 13. Output of a multivariable GLMM of the effect of treatment on the daily weight change in chickens. Data for India.

Variable	Units	Estimate	SE	t-value	*P*-value
Intercept		6.61	0.338	19.6	<0.001
Weight at enrolment	g	0.0036	0.00034	10.49	<0.001
Treatment (difference in daily change in weight (g))	Non-treated Treated	– 1.61	0.107	14.95	<0.001

Table 14. Output of a multivariable GLMM of the effect of treatment on the daily weight change in chickens. Data for Tanzania.

Variable	Units	Estimate	SE	t-value	*P*-value
Intercept		5.76	0.499	11.54	<0.001
Weight at enrolment	kg	–3.553	0.254	–14.01	<0.001
Sex	Female Male	– 2.871	0.344	8.342	<0.001
Treatment (difference in daily change in weight (g))	Non-treated Treated	– 0.156	0.279	0.557	0.577

In India, there were some differences between villages – with many villages showing a marked effect, but others such as Arilo, Bharadapsi and Lahada showing no effect (Figure 21). In Tanzania there were few differences between villages (Figure 22).

Figure 21. *Box plot of the change in chicken weight by village. Grey boxes represent the non-treated chickens, and orange boxes the treated chickens. The widths of each box correspond to the number in the group. Data for India.*

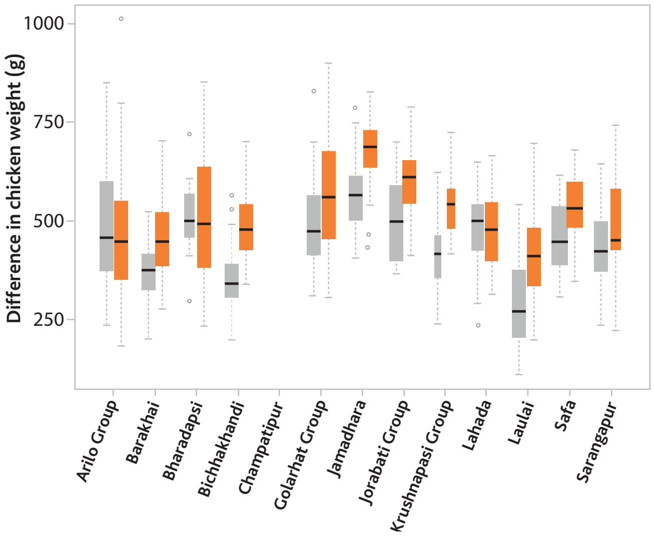
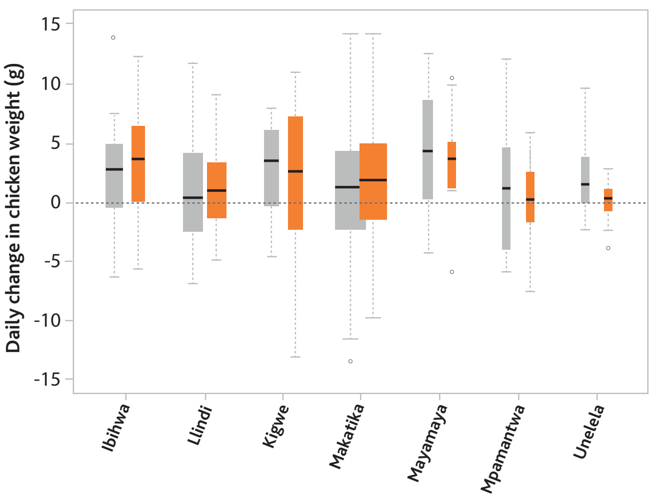


Figure 22. *Box plot of the change in chicken weight by village. Grey boxes represent the non-treated chickens, and orange boxes the treated chickens. The widths of each box correspond to the number in the group. Data for Tanzania.*



Conclusions

Mass treatment of animals with anthelminthics has a clear beneficial effect on the development of goats, with the beneficial impacts being seen in both study areas. In chickens, there was a smaller overall effect and this was only seen in India.

In goats, the beneficial effect was an additional 9.88 g in weight gain per day in Tanzania compared to India where the difference was an additional 25.6 g/day, but the weight change observed in Tanzania is still a considerable improvement if sustained over a long period of time. This is supported by a change in BCS, which is often key in determining the value of an animal at market. Some aspects that may have influenced the observed difference between the Indian and Tanzanian studies include:

1. The deworming agent in India was closantel, which was not available in Tanzania. Closantel has the advantage of not being a benzimidazole (as albendazole is) and the prevalence of helminths that are resistant to benzimidazoles is high (Bjørn *et al.*, 1990; Chandra *et al.*, 2015).

2. Goats in India were typically tethered or grazed in a small area during the day which could lead to a greater likelihood of consumption of worm eggs and a higher parasite burden and therefore treatment with dewormers is more likely to produce a response.

3. The goats in Tanzania were typically kept in larger flocks in more professional set-ups, and their body condition was generally better. This is more of an observation than a detail that can immediately explain the difference in impact of dewormers in India compared to Tanzania.

Treating chickens with dewormers had a detectable effect in India but did not have a detectable effect in Tanzania. Part of this may be due to the difference in ages of the chickens, which were between 40 and 70 days in India, or the choice of anthelminthic. Various other reasons could explain the lack of significant effect in Tanzania:

1. Infection with worms in this area has a relatively minor impact on the final weight of the animals and the final weight is determined to a much greater extent by other factors such as nutrition and disease, which vary between settings, or the age at which the chickens are treated with dewormers.

2. A period of 56 days was insufficient time to detect a large impact on growth (the impact in India was relatively small). Literature suggests that this is not the case.

3. There was a loss of data owing to the failure of the markings in Tanzania, but this is unlikely to have influenced the overall results given the small magnitude of effect. There were no such problems in India.

4. It is possible there could have been some swapping of leg bands between chickens on farms in Tanzania. However, there should be some detectable effect of this in the chicken's weights which was not present.

5. It is possible there is a very low burden of worms in the study area of Tanzania. This seems unlikely and anecdotally, the chickens are known to have worms. Furthermore, the field team reported seeing worms in the faeces of treated chickens in the days following the treatment.

6. For logistical reasons it was necessary to conduct the study at the end of a protracted dry season. Infection rates of worms are known to be lower during the dry season, so it is possible that the prevalence of infection was low.

7. The dewormers that are intended to be administered through drinking water were administered directly to the beak of the chickens after being reconstituted with drinking water. This should not have affected the efficacy of the dewormers.

8.The combination of dewormers of levamisole and piperazine were purchased locally and are in common use (administered individually) in Tanzania and have been sold by GALVmed village vaccinators. It is possible that the locally purchased dewormers were not effective. The efficacy of the specific products that were used in the study was not verified independently.

9. There could have been treatment with dewormers instigated by the farmer in between surveys. This was a risk in this study design that could not be controlled.

Further work is required to understand the impact of the greater weight gain on smallholder economics. This could consider the greater economic value of the additional weight gain, impacts on fertility and milk production and the nutritional benefits from consuming the larger animals. Further work should also be conducted to understand the impacts of these treatments at different times of year and different seasons. In this study, animals were treated towards the end of the dry season, but typically worm burdens are higher during the wet season, so treatment in a wet season is more likely to have an impact, but there is greater risk of reinfection. However, logistics are a core consideration of this study and when the rains started at the end of this study access to villages became very difficult.

Lessons learned

Some observations from conducting this study:

- The choice of anthelminthic is important. It must be effective against the local worm populations, but if dewormers are used then they should be suitable for single-dose application. In this study, repeat dosing was not logistically feasible, and in reality it may be logistically difficult to repeat dose as part of mass treatment.

- Despite communicating the objectives of the study and that animals would be treated with dewormers, there was little interest in participating in the study among the population in India and the financial incentives were the major motivating factor. In Tanzania the smallholders were motivated to be involved because they were aware of the detrimental effects of worms and were enthusiastic to have their animals treated.

- In India, the CAHWs had little awareness of chicken disease and handling chickens before the study. CAHWs in this area act as independent businesses and most of their day-to-day income comes from cattle farmers. The economics may make it a challenge to ensure that CAHWs include poultry smallholders as part of their day-to-day business.

- The chickens enrolled in this study may have been too young to see a large effect on weight gain and if older chickens had been selected there may have been a greater effect. The age range was defined as it is an age range where the chickens will be growing and are less likely to be sold. However, a downside of this is that the chickens had less exposure to infection with worms.

- In India, random allocation to treatment or control in this study was by toss of a coin with the 'heads' side defined as the treatment side. In both chickens and goats, a greater number (around 55%) were treated than not, suggesting that the coins used were not entirely 50/50. In the subsequent study in Tanzania we used the mobile app to allocate animals to the groups.

- For future similar studies it will be necessary to find a robust method for tagging chickens in such a way that the tags cannot be removed and the markings are indelible. The solution used here was a compromise and caused some problems.

Acknowledgements

The work in India was implemented by Vet Helpline India (P) Ltd, the Gir Odisha Foundation and the CAHWs who implemented the study. The work in Tanzania was implemented by the Novel Vaccine and Biological Company Ltd, its field team and the local animal health extension workers who helped in the study.

This is based on work funded in part by the Bill & Melinda Gates Foundation and with UK Aid from the UK Government through GALVmed. The findings and conclusions contained within are those of the authors and do not necessarily reflect positions or policies of the Bill & Melinda Gates Foundation or the UK Government.

References

Bjørn, H., Monrad, J., Kassuku, A.A., Nansen, P., 1990. Resistance to benzimidazoles in Haemonchus contortus of sheep in Tanzania. Acta Trop. 48, 59–67.

Chandra, S., Prasad, A., Yadav, N., Latchumikanthan, A., Rakesh, R.L., Praveen, K., Khobra, V., Subramani, K.V., Misri, J., Sankar, M., 2015. Status of benzimidazole resistance in Haemonchus contortus of goats from different geographic regions of Uttar Pradesh, India. Vet. Parasitol. 208, 263–7. doi:10.1016/j.vetpar.2015.01.005

Chota, A., Sikasunge, C.S., Phiri, A.M., Musukwa, M.N., Haazele, F., Phiri, I.K., 2010. A comparative study of the efficacy of piperazine and Carica papaya for the control of helminth parasites in village chickens in Zambia. Trop. Anim. Health Prod. 42, 315–18. doi:10.1007/s11250-009-9432-6

Katoch, R., Yadav, A., Godara, R., Khajuria, J.K., Borkataki, S., Sodhi, S.S., 2012. Prevalence and impact of gastrointestinal helminths on body weight gain in backyard chickens in subtropical and humid zone of Jammu, India. J. Parasit. Dis. 36, 49–52. doi:10.1007/s12639-011-0090-z

Kumar, S., Garg, R., Ram, H., Maurya, P.S., Banerjee, P.S., 2015. Gastrointestinal parasitic infections in chickens of upper gangetic plains of India with special reference to poultry coccidiosis. J. Parasit. Dis. 39, 22–6. doi:10.1007/s12639-013-0273-x

Mungube, E.O., Bauni, S.M., Tenhagen, B.-A., Wamae, L.W., Nzioka, S.M., Muhammed, L., Nginyi, J.M., 2008. Prevalence of parasites of the local scavenging chickens in a selected semi-arid zone of Eastern Kenya. Trop. Anim. Health Prod. 40, 101–9.

Nnadi, P.A., George, S.O., 2010. A cross-sectional survey on parasites of chickens in selected villages in the subhumid zones of South-eastern Nigeria. J. Parasitol. Res. 2010. doi:10.1155/2010/141824

Permin, A., Magwisha, H., Kassuku, A.A., Nansen, P., Bisgaard, M., Frandsen, F., Gibbons, L., 1997. A cross-sectional study of helminths in rural scavenging poultry in Tanzania in relation to season and climate. J. Helminthol. 71, 233–40.

Phiri, I.K., Phiri, A.M., Ziela, M., Chota, A., Masuku, M., Monrad, J., 2007. Prevalence and distribution of gastrointestinal helminths and their effects on weight gain in free-range chickens in Central Zambia. Trop. Anim. Health Prod. 39, 309–15. doi:10.1007/s11250-007-9021-5

Poulsen, J., Permin, A., Hindsbo, O., Yelifari, L., Nansen, P., Bloch, P., 2000. Prevalence and distribution of gastro-intestinal helminths and haemoparasites in young scavenging chickens in upper eastern region of Ghana, West Africa. Prev. Vet. Med. 45, 237–45. doi:10.1016/S0167-5877(00)00125-2

Rupa, A.P.M., Portugaliza, H.P., 2016. Prevalence and risk factors associated with gastrointestinal nematode infection in goats raised in Baybay City, Leyte, Philippines. Vet. World 9, 728–34. doi:10.14202/vetworld.2016.728-734

Sharma, D., Vatsya, S., Kumar, R.R., 2016. Impact of treatment of gastrointestinal nemathelminths on body weight of sheep and goats. J. Parasit. Dis. 40, 801–4. doi:10.1007/s12639-014-0581-9

Villaquiran, M., Gipson, T.A., Merkel, R.C., Goetsch, A.L., Sahlu, T. 2004. Body Condition Scores in Goats. Langston University, Langston, OK, USA. Available at: http://www2.luresext.edu/goats/research/BCS_factsheet.pdf (accessed 28 July 2017).

Appendix 1

Literature review on studies of dewormers in village livestock

Paul Bessell, Report to GALVmed , 22 February 2016

Summary

- A review of the literature on gastrointestinal worms (helminths) in village livestock found prevalences of up to 100%, with a wide range of helminth species identified.
- In village cattle and poultry populations, dewormers (anthelminthics) have been shown to result in substantial increases in weight gain, of 30–80% in chickens and between 8 and 37% in cattle. Economic analysis has shown a positive cost–benefit ratio for the use of anthelminthic treatments in cattle. No similar studies for small ruminants were found.
- Important concerns regarding anthelminthic resistance were raised, with one study in small ruminants identifying treatment failure resulting from overtreatment.

Scope of the analysis

A brief literature review on helminths and anthelminthic interventions in poultry, small ruminants and cattle in backyard / traditional / village / small production systems (terms that are used somewhat interchangeably) in developing countries, specifically in Asia and Africa. The review covers baseline studies of helminth infection burdens and studies that estimate the impacts of anthelminthic interventions. The literature review is to include published literature and non-published reports and material.

Literature

Both the PubMed database and Google were searched using the search terms in Table A1. Google searches did not yield any material additional to that on PubMed.

Table A1. *Results of PubMed searches.*

Search term	Number of hits	Relevant hits
(helminth OR anthelminthic) AND (poultry OR chicken) AND (backyard OR village OR scavenging)	21	7 (1 unavailable)
(helminth OR anthelminthic OR worm) AND (sheep OR goat OR small ruminant) AND (smallholder OR village)	40	12 (2 unavailable)
(helminth OR anthelminthic OR worm) AND cattle AND (smallholder OR village OR traditional)	92	7

Material that was referenced through the publications in Table A1 but was not identified in the initial search was followed.

Poultry diseases

Helminths are recognised as a major constraint to village poultry production. Two studies found that farmers rated helminth infections as the most serious constraint to poultry production (Gondwe and Wollny, 2007; Nnadi and George, 2010). Five studies investigated the baseline prevalence of helminth infections in village poultry systems (all studies were of chickens), summarised by Table A2. In some countries prevalence reached 100%, with a wide range of helminth species found. Some species, such as *Ascaridia galli*, are found widely, other species are more localised in their distribution.

Table A2. *Studies of the baseline incidence of helminth infections.*

Study	Location	Sample size	Prevalence – helminth infections	Helminth species found (prevalence)
Kumar *et al*., 2015	India – Upper Ganges	10 backyard flocks	36.4%	*Ascaridia galli* (15.5%), *Capillaria* spp. (5.2%) *Hetarakis gallinarum* (3.5%), 5 other species < 2%
Nnadi and George, 2010	Nigeria – Enugu state	261 birds sampled; 90 households; 9 villages	35.5%	*Ascaridia galli* (17.2%), *Hetarakis gallinarum* (12.6%) *Capillaria* spp. (5.7%), *Raillietina* spp. (5.7%), 4 species < 5%
Mungube *et al*., 2008	Kenya – Machakos	360 birds sampled	93.3% helminths 74.4% nematodes 68.1% cestodes	*Tetrameres americana* (37.7%), *A. galli* (33.3%) *R. echinobothrida* (33.3%), *H. gallinarum* (22.8%) 12 species < 20%
Poulsen *et al*., 2000	Ghana – upper eastern region	100 birds – two villages	100%	*Raillietina echinobothrida* (81%), *Hymenolepis* spp. (66%) *Gongylonema ingluvicola* (62%), *Capillaria* spp. (60%) *R. tetragona* (59%), *T. fissipina* (58%), 12 species < 50%
Permin *et al*., 1997	Tanzania – Morogoro region	600 chickens – three villages – two seasons	100% Mean 4.8 helminths per bird (wet season); 5.1 (dry season)	*H. gallinarum* (74.0–78.7%) *T. americana* (54.3–60.3%) *Allodapa sutoria* (40.0–52.0%) *R. echinobothrida* (41.3–46.3%) *H. cantaniana* (43.0–48.0%), 24 species < 40%

There have been no studies of long-term mass administration of anthelminthics, but three small-scale studies (100 birds or fewer) examined the impacts on growth rates of treated and untreated chickens with greater growth rates in the treatment compared to untreated groups (Table A2); this is coupled with a corresponding decrease in parasite burden. No studies considered economics in terms of the cost–benefit of interventions.

***Table A3**. The impact of interventions on helminth infections.*

Study	Location (baseline prevalence)	Treatment / control groups	Age at start / duration of study	Anthelminthic treatment	Impact on weight gain	Impact on parasite burden
Katoch *et al.*, 2012	Jammu – India (72%)	50 untreated (UT) 50 treated (T)	40 days / 90 days	Fenbendazole (7.5 mg/kg)	13.7 g/day (UT) 18.0 g/day (T)	32.9 worms (UT) 2.5 worms (T)
Chota *et al.*, 2010	Zambia	10 untreated (UT) 10 treated (T)	5–6 months / 2 weeks	Piperazine	9.3 g/day (UT) 17.1 g/day (T)	62.4 worms (UT) 30.8 worms (T)
Phiri *et al.*, 2007	Central province – Zambia	50 untreated (UT) 50 treated (T)	Growers / 12 weeks	Levamisole 25%	5.9 g/day (UT) 7.7 g/day (T)	96.3 worms (UT) 22.1 worms (T)

Further studies have demonstrated that helminth infections can result in a lower antibody titre following vaccination and challenge with Newcastle disease (ND), making it possible that birds with a lower helminth burden will be better protected against ND (Hørning *et al.*, 2003). Due to concerns regarding anthelminthic resistance and difficulties in the application of treatments, there are a number of studies investigating the potential to use plant derivatives such as papaya as anthelminthics (Chota *et al.*, 2010; Mwale and Masika, 2009).

Small ruminants

Many studies report high levels of nematode infections in sheep and goat populations, although few estimate prevalences. An exception to this was Odoi *et al.* (2007), who found faecal egg counts (FEC) greater than zero in 50% of animals in Kenya with seasonal variations in burdens. In South Africa, 87% of smallholders that were surveyed reported worms (Tsotetsi and Mbati, 2003). Studies of treatments found good efficacy in terms of FEC in South Africa (Bakunzi, 2008), Kenya (Odoi *et al.*, 2007, 2008), Ethiopia (Sissay *et al.*, 2006) and Burkina Faso (Tamboura *et al.*, 1998). Only one study identified an impact of helminths on weight gain with negative correlation between FEC and weight gain. This study estimates that a difference in FEC of 100 in kids and lambs results in a difference in productivity of 41 g/day (Odoi *et al.*, 2008). There is concern about the overuse of anthelminthics and development of resistance in parasites (Gray *et al.*, 2012), and one study in Malaysia where treatments had been applied heavily (8–10 times per year for a number of years) found low efficacy in terms of FEC reductions (Chandrawathani *et al.*, 2004).

Cattle

Rast *et al.* (2013) identified a baseline prevalence of *Toxocara vitulorium* of 22.6% among calves aged 1–120 days (the principal risk period for T. *vitulorium*) from a cross-sectional survey of 899 calves in 69 villages in Lao PDR. The study found 76.8% of villages with at least one positive calf, but in spite of the availability of treatment, very few animals were treated (Rast *et al.*, 2013). A subsequent questionnaire survey of 273 smallholders in the same area identified annual morbidity rates of 46% and mortality of 37% among cattle aged under 12 months. However, despite the T. *vitulorium* prevalence of 22.6%, it is unclear what proportion of the morbidity and mortality is due to T. *vitulorium* (Rast *et al.*, 2014). Using this information, the authors conduct partial budget analysis of financial benefits of treating calves aged between 1 and 21 days with pyrantel. If 25% of morbidity and mortality is due to T. *vitulorium* they estimate a mean net profit of US$3.69 per calf, rising to US$14.86 with 100% morbidity and mortality attributed to T. *vitulorium*.

In the Iringa district of Tanzania, a cross-sectional survey of 236 animals on large dairy farms, 102 on small dairy farms and 144 on traditional farms found an overall prevalence of *Fasciola gigantica*, amphistomes (trematodes) and gastrointestinal nematodes of 46.1%, 62.6% and 50%, respectively (slightly different sample sizes for different parasites) (Keyyu *et al.*, 2006). Prevalences of all three parasite groups were highest on traditional farms at 63.8% for F. *gigantica*, 81.9% for *amphistomes* and 67% for nematodes (*Trichurius* spp., *Capillaria* spp., *Strongyloides* spp. and *Oesophagostomum* spp. being principal nematode genera). Significant co-infection with F. *gigantica* and *amphistomes* were found on cattle from traditional farms. The majority of farmers, including traditional farmers, reported using anthelminthics (87.7%), but other helminth controls such as isolating infected animals were not employed (Keyyu *et al.*, 2003). In a study of 167 animals (6–18 months) managed under these three farming systems, 55 animals were treated with albendazole four times in one year, 55 treated twice in that year and 57 were untreated (Keyyu *et al.*, 2009b). Twice-yearly treatments reduced FECs by 49.5% and 4-yearly treatments by 62.3%; corresponding weight gains were 62.6 kg and 65.5 kg, compared to 47.8 kg in the untreated group. In a study looking only at traditional farms, a community-based worm control programme (CBWC) was implemented in a village with 55 farms. Sixty cattle in this village (aged 6–18 months) were selected for monitoring. In the non-CBWC village, 68 cattle were selected from the 47 farms (Keyyu *et al.*, 2009a). All cattle in the CBWC village were treated four times per year with albendazole, and the resulting increase in cattle weight after 1 year was 68.1 kg in the CBWC village compared to 54.2 kg in the non-CBWC village.

A wide range of helminth species have been identified in the Gambia, with 97% of 175 animals infected with at least one nematode with important seasonal differences depending on the species (Kaufmann and Pfister, 1990). In a subsequent long-term study between October 1989 and December 1994, one group of 250 animals was treated twice with fenbendazole in each rainy season, with 277 animals untreated. Herds were age-stratified and treatment and non-treatment allocated such that each herd included some treated and untreated animals (Zinsstag *et al.*, 2000). Treatment reduced the FECs by 31% in the dry season, compared to 57% in the rainy season. Mean live weights of 3-year-old animals among treated animals were 13.1% higher than controls, and 8.2% higher in 4-year-old animals (Zinsstag *et al.*, 1997a), and annual calving rates of the twice-treated animals were 52.2% compared to 43.6% in control animals (Zinsstag *et al.*, 1997b). In a cost–benefit analysis, the cost–benefit ratio of twice-yearly treatment was 1.14, but this was dependent on the specific herd, and some herd costs outweighed financial benefits (Itty *et al.*, 1997).

References

Bakunzi, F.R., 2008. Efficacy of 3 anthelmintics in communally grazed sheep as reflected by faecal egg count reduction tests in a semi-arid area of South Africa. J. S. Afr. Vet. Assoc. 79, 54–5.

Chandrawathani, P., Yusoff, N., Wan, L.C., Ham, A., Waller, P.J., 2004. Total anthelmintic failure to control nematode parasites of small ruminants on government breeding farms in Sabah, East Malaysia. Vet. Res. Commun. 28, 479–89.

Chota, A., Sikasunge, C.S., Phiri, A.M., Musukwa, M.N., Haazele, F., Phiri, I.K., 2010. A comparative study of the efficacy of piperazine and Carica papaya for the control of helminth parasites in village chickens in Zambia. Trop. Anim. Health Prod. 42, 315–18. doi:10.1007/s11250-009-9432-6

Gondwe, T.N., Wollny, C.B.A., 2007. Local chicken production system in Malawi: household flock structure, dynamics, management and health. Trop. Anim. Health Prod. 39, 103–13. doi:10.1007/s11250-006-4293-8

Gray, G.D., Connell, J.G., Phimphachanhvongsod, V., 2012. Worms in smallholder livestock systems: technologies and practices that make a difference. Vet. Parasitol. 186, 124–31. doi:10.1016/j.vetpar.2011.11.056

Hørning, G., Rasmussen, S., Permin, A., Bisgaard, M., 2003. Investigations on the influence of helminth parasites on vaccination of chickens against Newcastle disease virus under village conditions. Trop. Anim. Health Prod. 35, 415–24.

Itty, P., Zinsstag, J., Ankers, P., Njie, M., Pfister, K., 1997. Returns from strategic anthelmintic treatments in village cattle in the Gambia. Prev. Vet. Med. 32, 299–310. doi:10.1016/S0167-5877(97)00033-0

Katoch, R., Yadav, A., Godara, R., Khajuria, J.K., Borkataki, S., Sodhi, S.S., 2012. Prevalence and impact of gastrointestinal helminths on body weight gain in backyard chickens in subtropical and humid zone of Jammu, India. J. Parasit. Dis. 36, 49–52. doi:10.1007/s12639-011-0090-z

Kaufmann, J., Pfister, K., 1990. The seasonal epidemiology of gastrointestinal nematodes in N'Dama cattle in The Gambia. Vet. Parasitol. 37, 45–54.

Keyyu, J.D., Kassuku, A.A., Kyvsgaard, N.C., Monrad, J., 2009a. Effectiveness of a community-based strategic anthelmintic treatment programme in the control of gastrointestinal nematodes and Fasciola gigantica in cattle in Kilolo district, Tanzania. Vet. Res. Commun. 33, 555–65. doi:10.1007/s11259-009-9204-9

Keyyu, J.D., Kassuku, A.A., Msalilwa, L.P., Monrad, J., Kyvsgaard, N.C., 2006. Cross-sectional prevalence of helminth infections in cattle on traditional, small-scale and large-scale dairy farms in Iringa district, Tanzania. Vet. Res. Commun. 30, 45–55. doi:10.1007/s11259-005-3176-1

Keyyu, J.D., Kyvsgaard, N.C., Kassuku, A.A., Willingham, A.L., 2003. Worm control practices and anthelmintic usage in traditional and dairy cattle farms in the southern highlands of Tanzania. Vet. Parasitol. 114, 51–61.

Keyyu, J.D., Kyvsgaard, N.C., Monrad, J., Kassuku, A.A., 2009b. Effectiveness of strategic anthelmintic treatments in the control of gastrointestinal nematodes and Fasciola gigantica in cattle in Iringa region, Tanzania. Trop. Anim. Health Prod. 41, 25–33. doi:10.1007/s11250-008-9150-5

Kumar, S., Garg, R., Ram, H., Maurya, P.S., Banerjee, P.S., 2015. Gastrointestinal parasitic infections in chickens of upper gangetic plains of India with special reference to poultry coccidiosis. J. Parasit. Dis. 39, 22–6. doi:10.1007/s12639-013-0273-x

Mungube, E.O., Bauni, S.M., Tenhagen, B.-A., Wamae, L.W., Nzioka, S.M., Muhammed, L., Nginyi, J.M., 2008. Prevalence of parasites of the local scavenging chickens in a selected semi-arid zone of Eastern Kenya. Trop. Anim. Health Prod. 40, 101–9.

Mwale, M., Masika, P.J., 2009. Ethno-veterinary control of parasites, management and role of village chickens in rural households of Centane district in the Eastern Cape, South Africa. Trop. Anim. Health Prod. 41, 1685–93. doi:10.1007/s11250-009-9366-z

Nnadi, P.A., George, S.O., 2010. A cross-sectional survey on parasites of chickens in selected villages in the subhumid zones of South-eastern Nigeria. J. Parasitol. Res. 2010. doi:10.1155/2010/141824

Odoi, A., Gathuma, J.M., Gachuiri, C.K., Omore, A., 2007. Risk factors of gastrointestinal nematode parasite infections in small ruminants kept in smallholder mixed farms in Kenya. BMC Vet. Res. 3, 6. doi:10.1186/1746-6148-3-6

Odoi, A., Gathuma, J.M., Gachuiri, C.K., Omore, A., 2008. Feeding practices and effects of gastrointestinal parasite infections on live weight gain of small ruminants in smallholder mixed farms in Kenya. Res. Vet. Sci. 84, 185–93. doi:10.1016/j.rvsc.2007.04.013

Permin, A., Magwisha, H., Kassuku, A.A., Nansen, P., Bisgaard, M., Frandsen, F., Gibbons, L., 1997. A cross-sectional study of helminths in rural scavenging poultry in Tanzania in relation to season and climate. J. Helminthol. 71, 233–40.

Phiri, I.K., Phiri, A.M., Ziela, M., Chota, A., Masuku, M., Monrad, J., 2007. Prevalence and distribution of gastrointestinal helminths and their effects on weight gain in free-range chickens in Central Zambia. Trop. Anim. Health Prod. 39, 309–15. doi:10.1007/s11250-007-9021-5

Poulsen, J., Permin, A., Hindsbo, O., Yelifari, L., Nansen, P., Bloch, P., 2000. Prevalence and distribution of gastro-intestinal helminths and haemoparasites in young scavenging chickens in upper eastern region of Ghana, West Africa. Prev. Vet. Med. 45, 237–45. doi:10.1016/S0167-5877(00)00125-2

Rast, L., Lee, S., Nampanya, S., Toribio, J.A., Khounsy, S., Windsor, P.A., 2013. Prevalence and clinical impact of Toxocara vitulorum in cattle and buffalo calves in northern Lao PDR. Trop. Anim. Health Prod. 45, 539–46. doi:10.1007/s11250-012-0256-4

Rast, L., Toribio, J.A., Dhand, N.K., Khounsy, S., Windsor, P.A., 2014. Why are simple control options for Toxocara vitulorum not being implemented by cattle and buffalo smallholder farmers in South-East Asia? Prev. Vet. Med. 113, 211–18. doi:10.1016/j.prevetmed.2013.10.021

Sissay, M.M., Asefa, A., Uggla, A., Waller, P.J., 2006. Assessment of anthelmintic resistance in nematode parasites of sheep and goats owned by smallholder farmers in eastern Ethiopia. Trop. Anim. Health Prod. 38, 215–22.

Tamboura, H.H., Kabore, H., Nikiema, L., 1998. Etiology and prophylaxis of helminthiasis in sheep in Burkina Faso. Ann. N. Y. Acad. Sci. 849, 474–8.

Tsotetsi, A.M., Mbati, P.A., 2003. Parasitic helminths of veterinary importance in cattle, sheep and goats on communal farms in the northeastern Free State, South Africa. J. S. Afr. Vet. Assoc. 74, 45–8.

Zinsstag, J., Ankers, P., Dempfle, L., Njie, M., Kaufmann, J., Itty, P., Pfister, K., Pandey, V.S., 1997a. Effect of strategic gastrointestinal nematode control on growth of N'Dama cattle in Gambia. Vet. Parasitol. 68, 143–53.

Zinsstag, J., Ankers, P., Itty, P., Njie, M., Kaufmann, J., Pandey, V.S., Pfister, K., 1997b. Effect of strategic gastrointestinal nematode control on fertility and mortality of N'Dama cattle in The Gambia. Vet. Parasitol. 73, 105–17.

Zinsstag, J., Ankers, P., Njie, M., Itty, P., Monsan, V., Kaufmann, J., Smith, T., Pandey, V.S., Pfister, K., 2000. Effect of strategic gastrointestinal nematode control on faecal egg count in traditional West African cattle. Vet. Res. 31, 259–66. doi:10.1051/vetres:2000114

Cover photo credit: Sephi Bergerson/GALVmed.

GALVmed

Protecting Livestock – Improving Human Lives