Chapter 7 Parasitized animal selection in small ruminant production systems: Field conditions alternatives

Capítulo 7 Selección de animales parasitados en producción de pequeños rumiantes: Alternativas en condiciones de campo

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Abstract

The aim is to provide knowledge about animal selection systems in the field that allows to reduce deworming and increase shelter, as part of targeted selective treatment (TST). The access granted by the Autonomous University of Campeche to databases such as Elsevier, Springer and Ebsco Host was used. The level of parasitosis is measured indirectly and animals that require it are dewormed. The count of eggs in feces is the most effective way to know the degree of parasitosis and can be compared with other systems. The degree of anemia is measured with the FAMACHA® card to select animals, applied with hematophagous parasites. Body condition is an indirect measure of body weight and is used as a selection criterion. Diarrhea is used to select animals to deworm. Productive indicators such as low daily weight gain and decrease in milk production are used as selection criteria. The selection using the happy factor system is calculated by dividing the energy deposited by the energy consumed, considering a good nutritional plane, if properly calculated it has proven to be a good indicator of deworming and finally it is concluded that, due to the type of parasites, the production system and breeds involved it is better to combine these systems to find the management that best suits the productive system.

Targeted selective treatment, Selection systems, Anthelmintic treatment

1. Introduction

Nowadays gastrointestinal nematodiasis persists as a problem in small ruminant production systems (Torres-Acosta *et al*., 2012). The latter, although the use of modern anthelmintics (AH) with a broad spectrum of effectivity. However, producers often misused these AHs and propitiated the anthelmintic resistance phenomenon. Most parasitologist now agree that factors affecting the rapid anthelmintic development are the treatment of animals at the same time and in times of years where there are few infected larvae in the pasture, both practices finally leave less infected larvae in refugia (Kaplan, 2009).

Due to latter, alternatives strategies must be used to prolong the useful life of the AH. In this regard, only animals which suffer a parasitosis must be identified and treated. However, most of the times these illnesses are subclinical and is difficult to identified animals without evident signs of parasitosis. In this context, some other factors have been studied and proved to use at field conditions as an indirect way to diagnose parasitosis. I.e., the identification of animal to have a decline in productivity or clinical manifestation of verminosis must be treated (Bath and Van Wyk, 2009).

Nowadays, the fecal egg count (FEC) remains as the gold standard for diagnosed animals parasite populations, and clinical diagnosis for the detection of anthelmintic resistance; the three most important purposes of FEC are: i) screening anthelmintic efficacy, ii) identification of animals with low, medium and high parasite loads, and iii) clinical diagnosis of parasitism in single animals; this system is used to validate the use of others system based in productivity or clinical manifestation of parasitism (Nielsen, 2015).

Many systems have been developed to diagnose verminosis, some of them are focuses in one parasite characteristic, i.e. FAMACHA® system was developed to diagnose anemia in sheep and goats and is used in regions where the main parasites are hematophagous (*Haemonchus contortus*), FAMACHA® chart contains standardized set of five colors which are related with the range of hematocrit values F1,>28%; F2, 27%–23%; F3, 22%–18%; F4, 17%–13%; and F5,<12% (Van Wyk and Bath, 2002).

Body condition score (BCS) is a practical, low-tech measure that is accepted as an indicator of general condition and body reserves and therefore can act as an indicator of resistance to nematode infections mainly in adult sheep and goats (Cornelius *et al*., 2014).

Liveweight gain is non-invasive, and relevant to the economics of the farm, weight changes over short periods can also provide an index of the effects of non-hematophagous parasites such as *Trichostrongylus* and *Ostertagia/Teladorsagia* spp. Changes in body weight are largely an indicator of resilience (i.e. the ability to resist the effect of parasite challenge by these genera) (Van Wyk, *et al*., 2006).

The happy factor system uses energy efficiencies and is calculated by dividing the energy deposited by the consumed energy. If the parasites are not affecting the nutrient utilization means that can be accounted for, as a lack or poor herbage availability, thus, calculating energy efficiency may provide a useful indicator of the drenching time in the sheep farm (Greer *et al*., 2009). The aim of the review was known the main parasitized animal selection systems in the field that allows to reduce the amount of deworming and increase refugia.

2. Methodology

A detailed search was carried out in the databases provided by the Autonomous University of Campeche through CONRICyT such as Ebsco, Elsevier, Springer and the Google Scholar search engine using as keywords selection systems, parasitized animals, methods of selection of parasitized animals, combinations of methods of selection of animals to be dewormed, always using the criterion of used in the field. Those articles that contained the use of parasitized animal selection systems at the field level and those that have been tested and are effective in the production units were selected.

3. Results

A wide range of articles published in the different integrators was found and those that best explain the methodology to be used in the parasitized animal selection system and the results reported were selected. A detailed explanation of each system of selection is presented trough out the revision.

3.1. Using the Fecal Eggs Count System

Adult parasites inside the animal will lay eggs in different quantities according to the parasite specie. Some species lay many eggs like *Haemonchus contortus* and other species lay few eggs i.e., *Trichostrongylus colubriformis*. However, the Fecal egg count system named like eggs per gram of feces (EPG) is an indirect way to know the adult population of adult parasites inside the animals. Due to the variation in nematode lay habits, there is much animal-to-animal variation in the EPG counts, thus many authors recommended sampling a random proportion of the flock the latter to get a clear picture of the parasite load in the animals (USDA 2014).

The MacMaster technique, despite being a laboratory test it is related to field techniques due to the quality and quantity of materials and equipment necessary to develop it, in addition, the training is not complex, and it is not necessary for huge facilities. Furthermore, it is a required technique if you want to be specific in the selection of parasitized animals (USDA 2014).

3.1.1. In which animals should this system be used?

Sheep grazing pasture, especially, ewes and rams which stay on the farm for a long time during their reproductive life and suffer the parasitosis although their age and have a developed immune system. It is important to sample a representative number of animals (10% of the total) and separate adults from lambs, as counts normally are very different, even though the animals share the same pasture (USDA 2014).

Figure 1 Sheep in grazing pastures in tropical conditions, animals do not have a specific breed and two or more breeds are present in the small ruminant production system

Source: Own

3.1.2. How to get the samples

To get samples are necessary two persons: the sampler and one helper. Workers can group the sheep into a corner of a pen and hold them sampler must pick up 4 or 5 grams of feces (8 to 10 pellets each) that are fresh. Use a clean plastic bag or disposable glove to collect, invert and tie off. fecal samples must be taken directly from the rectum to have free environment contamination samples and after that can be placed in a cooler with ice packs. It is important to correctly identify the samples with the identification number of each animal and all the animals should be randomly selected to assure the correct representation of the flock (USDA, 2014).

Figure 2. A) Taking a sample of feces in sheep directly from the rectum, B) feces in a plastic bag. It is necessary to obtain 5 grams of feces

Source: Own

3.1.3. Transportation of the samples

Feces samples must be transported within 24 hours of collection. The best temperature to transport the samples is <5°C, it is important not to freeze the sample until they reach the laboratory facilities. The latter to avoid the hatching which will lead to an underestimation of the real egg count level and a load of parasites. If there is no possibility to run the samples on the same day, it is important to refrigerate the samples and run the analysis within the 5 days of collection (USDA 2014).

3.1.4. Analysis of the samples

Usually, the solution of feces samples and saturated solution deposited in the Mcmaster chamber showed air bubbles, pollen, and other artifacts for this reason it is important that a trained person examine the sample. Another important thing is the use of a quantitative technique, for this case the McMaster technique which allows knowing the number of eggs per gram of feces in the sample. Qualitative techniques can note allow us to differentiate between a moderate (150 to 700 eggs per gram) or severe infection (> 1,000 eggs per gram of feces). The modified McMaster technique is described as follows:

Preparation of the saturated solution. Heat water to a 60°C. On a scale weight 1,280 grams of sugar. Add the sugar to the heated water slowly while mixing the solution, after adding the total sugar let it cool. Label a mortar with a consecutive number and tare labeled mortar with a strainer on the scale. Weight two grams of fecal pellets into the strainer on the scale. Dispense 28 ml of saturated flotation solution into the strainer on the mortar using the pestle crush the pellets against the strainer and mix.

Fill both chambers of the McMaster slide using a pipette, eye dropper, or an insulin syringe. It is important that the chambers do not have large bubbles, if this occurs empty the slide and refill the chamber must be entirely filled and not just the area under the grid. After that, let aside for approximately five minutes before the microscope observations to allow parasite eggs to float to the surface of the chamber.

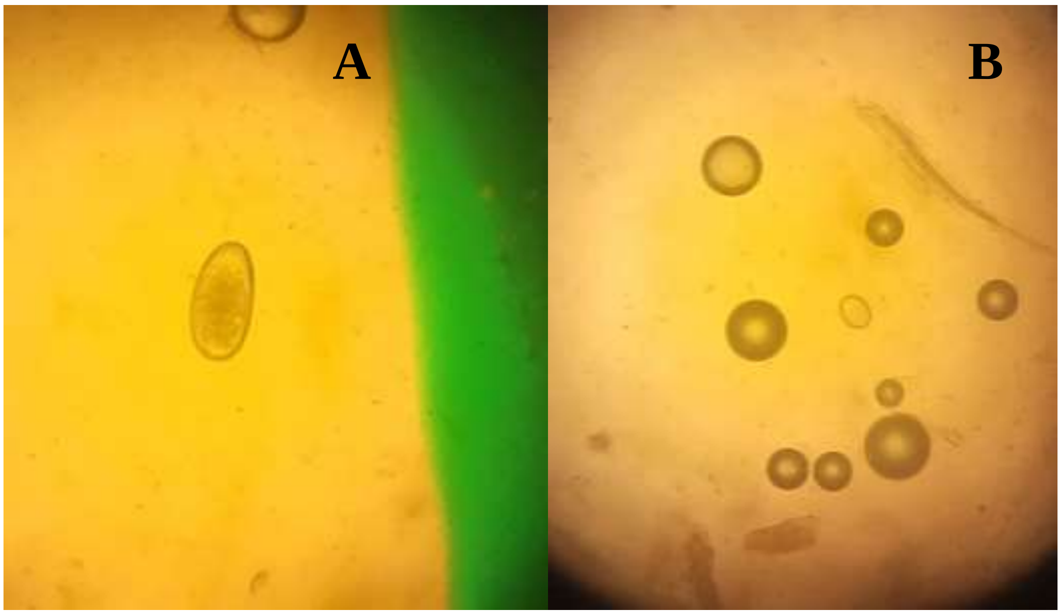
Place the slide onto the microscope stage. Focus the grid lines of the McMaster slide using the low power objective (4X). Turn to the 10X objective and refocus the grid lines. Start at the top or bottom corner of the grid and observe the full McMaster chamber with a zig-zag movement, this way does not lose track of whether you have counted only one or both chambers.

Count all eggs inside the grid areas including eggs on the grid line if greater than ½ egg inside the grid. Count only strongylid eggs (oval-shaped eggs ~80-90 microns long). Even if you only count strongylid eggs this technique allows you to have an idea of other parasites present in the sample and can count them, however, the numbers are often difficult to interpret.

The total eggs recorded in both chambers must be multiplied by 50 as follows: (chamber 1 + chamber 2) * 50 = eggs per gram of feces (EPG)

The multiplication factor of 50 come from the ratio of feces (2 grams) to flotation saturated solution (28 ml). Thus, each egg observed in the sample represents 50 eggs/gram. If you do not observe any eggs in the sample means that the sample has less than 50 eggs in total (USDA 2014).

Figure 3 A) Classical shape of strongylida parasite eggs at 10X magnification; B) Eimeria oocyst and air bubbles in feces sample



Source: Own

3.1.5. Pooled versus individual samples

As was stated the is a large animal-to-animal variation in the result of the egg output, with 30% of the animals being responsible for 70% of the total egg output. Pooled samples can help but it is important to know the grade of parasitism of each animal to take a decision about the deworm action. To run samples of all animals can be expensive, for this reason, it is recommended to check all the animals and to use an alternative that allows to identify animals with signs of parasitosis and to take samples only from these animals.

3.1.6. How many eggs can sheep tolerate?

There is no agreement about the cut-point of the quantity of EPG which indicates a deworming treatment. However, some veterinarians recommended a threshold of 500 to 800 EPG to develop a control program based on monitoring the parasite loads. Normally, EPG <250 is considered low; from 250 to 800 is moderate, and >800 is severe. However, there are several factors that can be considered at the deciding moment of deworming between them the species of gastrointestinal nematodes (GIN) present in the production system; infection from the previous season, grazing heavily infested pasture as well as individual variability in EPG counts (USDA 2014).

3.2. Using the FAMACHA® System

This system has been developed as an indirect way to diagnose anemia in sheep and goats and is used for TST in regions where the main parasites are hematophagous (*Haemonchus* spp). The system uses a score of the color of the mucosa ocular surface in a FAMACHA® chart, this element contains a set of five standardized colors which are related to hematocrit (Ht) values as follows: F1,>28%; F2, 27%–23%; F3, 22%–18%; F4, 17%–13%; and F5, <12% (Van Wyk and Bath, 2002).

During the inspection of the animals the ocular mucosa is compared with the FAMACHA® chart and animals with a score of F4 and F5 are separated and selected to an anthelmintic treatment, while animals in F3 are considered as suspected and are investigated using another selection system like body condition or a sample of feces is taken to run the McMaster technique and calculate the fecal egg count (Van Wyk and Bath, 2002). As other system developed to select animals which can be beneficiated with the anthelmintic treatment the aim of FAMACHA® system is preserve the refugia through the decrease in the frequency of anthelmintic treatment and at the same time delay the resistance of parasite to the active ingredients of the commercial anthelmintics (Bath, 2011; Hoste *et al*., 2011).

However, as all animal selection system the use of the FAMACHA® chart methodology present variations between breeds, production system, animal categories and nematodes species (Rizzon-Cintra *et al*., 2018). About the application of FAMACHA® it is necessary to have in mind the next precautions:

- The system is only applicable where the main parasite is H. contortus, which cause as a clinical sign anemia.
- The redness coloration of ocular mucosa can be caused by another affections like eye disease, environmental irritants or systemic disease and the latter can cause confusion and mask anemia.
- Other causes of anemia can be discharged and the presence of *Haemonchus* worm must corroborated during the grazing season.

It is necessary not only just the elevate score of FAMACHA® it can be using another sign of parasitosis like diarrhea, bottle jaw, poor condition, dull hair coat, intolerance to heat or exercise (USDA 2014).

Figure 4. The FAMACHA® anemia guide cart

Source: (USDA, 2014)

3.2.1. How to examine animals with the FAMACHA® system

It is necessary to expose the lower eye mucous membranes and compare with the equivalent in the FAMACHA® card, the technique include:

- Cover the eye by rolling the upper eyelid down over the eyeball.
- Push down the eyeball. Apply a gentle pressure on the eyelashes of the upper eyelid are curling up over the thumb.
- Pull down the lower eyelid.
- Pop! mucous membrane will pop into view. Be assuring to score the bed of mucous membrane.

Compare the color of the mucous membrane to the FAMACHA® card and avoid shade the eye with your body or something more, try to do the comparison as quick as possible to avoid eye irritation (USDA 2014).

Figure 5. The lower eye mucous membranes are exposed and compared to the colors on the FAMACHA© card to estimate the level of anemia

Source: (USDA, 2014)

3.2.2. How often do the inspection

The inspection of the animals can vary according to the season.

During the wet season the inspection must be every 2 weeks because when the infection dose is high animals can go downhill fast.

During the dry season the nematodes are less active, and the inspection and the interval of inspection could be extended to four weeks (USDA 2014).

3.2.3. Where to use this system

The main criteria are the presence of hematophagous parasites (*Haemonchus* spp), animals must be in grazing system and finally is recommended in adult sheep, under these condition FAMACHA® system is considered one of the best criteria in ewes (Molento *et al*., 2009; Leask *et al*., 2013; Sotomaior and Cintra, 2018)

3.3. Using Body Condition System

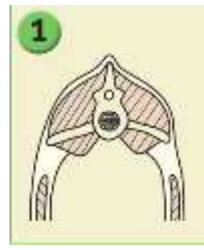
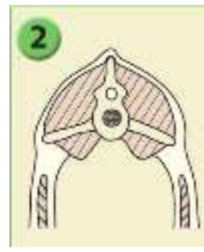
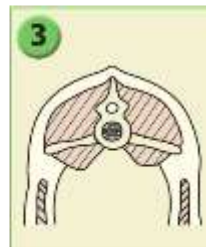
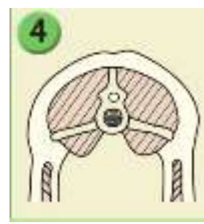
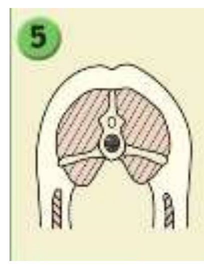
As anthelmintic resistance (AR) is a factor to be reduced in small ruminant populations, herd- and individual-targeted treatment approaches have been introduced to promote sustainable use of anthelmintics.

Targeted selective treatment (TST) is based on realistic thresholds for pathophysiological and/or production-based treatment indicators, such as clinical signs, body condition score (BCC), fecal egg count (FEC), weight gain or milk production (Bath and van Wyk, 2009; Charlier *et al*., 2014).

Body condition is a method of scoring the condition of the animal based on the following points (Table 1):

- The prominence of the spinous processes of the anterior lumbar vertebrae is assessed by palpation.
- The sharpness and degree of the cover of the ends of the transverse processes and the extent of the muscular and fatty tissues beneath them are assessed by spanning the lumbar vertebrae with the fingers and thumb.
- The depth of the musculus longissimus dorsi and the degree of subcutaneous fat cover is assessed by palpating the region between the spinous processes and the transverse processes.

Table 1 The scale used for the measurement of body condition in sheep

Grade 0: extremely emaciated and on the point of death.	
Grade 1: spinous processes prominent and sharp; transverse processes also sharp, fingers pass easily under the ends, and it is possible to palpate between each process; Mm. longissimus dorsi shallow and practically without subcutaneous fat cover.	
Grade 2: spinous processes are prominent but smooth, and individual processes can only be palpated as fine corrugation; transverse processes are smooth and rounded, and fingers can pass under the ends with little pressure; longissimus dorsi muscle of moderate depth with little subcutaneous fat cover.	
Grade 3: spinous processes have only a small elevation, are smooth and rounded, and individual apophyses can only be palpated with pressure; transverse processes are smooth and well covered and firm pressure is required to palpate the ends; Mm. longissimus dorsi full with moderate subcutaneous fat cover.	
Grade 4: spinous processes can be detected with pressure as a hard line between the ends; Mm. longissimus dorsi and associated subcutaneous fat; transverse processes cannot be palpated; Mm. longissimus dorsi full with thick subcutaneous fat cover.	
Grade 5: The spinous processes cannot be felt even with firm pressure and there is a depression in the subcutaneous fat where the spinous process is normally felt; the transverse processes cannot be felt; Mm. longissimus dorsi is very full with very thick subcutaneous fat; there may be large fat deposits over the rump and tail.	

Source: Romero, 2015

Body condition score (BCS) is a practical, low-tech measure that is accepted as an indicator of general condition and body reserves and therefore can act as an indicator of resistance to nematode infections mainly in adult sheep and goats (Cornelius *et al*., 2014).

As the FAMACHAⒸ system is not applicable to non-hematophagous worm species, body condition scoring (Cottle, 1991) was tested on one farm, where despite a predominance of *H. contortus*, periodic problems with *Trichostrongylus* spp. infections occur. Initial results with condition scoring on this farm are encouraging regarding the levels of both phenotypic and genetic correlation with hematocrit values and fecal egg counts (Van Wyk and Bath, 2002). The role of body condition scoring must be evaluated, particularly on farms with predominantly *Ostertagia/Teladorsagia* spp. and/or *Trichostongylus* spp. infection (Van Wyk, *et al*., 2006).

In a study by Cornelius *et al*., 2014, with Merino ewes in two production units using 271 3-year-old and 258 4-year-old animals, a relatively higher body condition response to treatment was observed in low body condition ewes prior to lambing compared to better condition ewes on a farm where nutrition was suboptimal and parasite load was high. Ewes with low pre-lambing body condition were 3 times more likely to fall into critically low body condition (<2.0) if left untreated.

It can be recommended to treat ewes with lower body conditions and leave a proportion of ewes with higher body conditions untreated in a targeted selective treatment program. A study by Soto-Barrientos with ewes in tropical conditions in 2018 showed that BSC was a good method to detect parasitized animals with a load > 750 HPG in ewes with a BSC < 2 with a 1.1% false-negative rate. This study involved a total of 724 animals between 6 and 11 months of age, hair breeds, mainly Pelibuey and Katahdin with some Blackbelly and Dorper crosses.

In a study by Calvete *et al.* (2019), sheep of the Aragonese breed and its variants with Romanov were studied, a total of 590 females with aged between 0.8 and 10.9 years old were studied. The study demonstrated the importance of BSC as a selection system for parasitic animals, where BSC < 2.75 required selective deworming, this selective deworming prior to mating increased the fertility of the ewes and the proportion of lactating ewes that became pregnant in the first ovulation cycle. It should also be noted that the HPG count must be greater than 600 to consider targeted selective deworming.

3.4. Using Bodyweight Gain System

Of the targeted selective treatments (TST), the use of liveweight gain is non-invasive, in the pen, and relevant to the economics of the farm. Weight changes over short periods can also provide an index of the effects of non-hematophagous parasites such as *Trichostrongylus* and *Ostertagia/Teladorsagia* spp. Unlike a static weight figure, which is related to body size, changes in body weight are largely an indicator of resilience (i.e., the ability to resist the effect of parasite challenge by these genera) (Van Wyk, *et al*., 2006).

Average daily liveweight gains for each animal are calculated as the difference between its first and last recorded weight divided by days in the trial. The predicted target weight is calculated for all animals in the trial. To determine the effect on the production of leaving animals untreated, short-term (4 weeks) weight gains are compared between their predicted target weight in the weeks of treatment and lambs with TST that in the same weeks had reached their predicted target weight and, therefore, would not be treated. The system allows the prediction of the live weight of an individual lamb or group of lambs over a short period by considering the nutrition available to the animal, the lamb's stage of development, and environmental factors such as temperature. Only those lambs that failed to reach the target weight gain will receive anthelmintics. This approach was found to be able to sensitively identify those animals that were underperforming (Kenyon *et al*., 2013).

A study on the use of liveweight gain as a marker for TST using Scottish Blackface to Texel sheep breeds (Kenyon *et al*., 2013) showed very encouraging results in slowing the development of anthelmintic resistance, while effective control of gastrointestinal parasitism was achieved.

In a study by Busin *et al*., 2014, the practical application and effect of a TST approach were investigated through liveweight gain as an alternative for the treatment of parasitic gastroenteritis in lambs (n = 385) over a period of 2 years. Liveweight, buttock fouling, and anthelmintic treatments were recorded individually at 14-day intervals during the grazing season. Adopting a TST approach did not have a negative effect on lamb liveweight gains, finishing time, or buttock fouling measures compared to routinely treated (RT) lambs; however, a 50% decrease in anthelmintic treatment was observed in the TST group. The implementation time of this system averaged 2min per lamb. It is concluded that TST through liveweight gain could be suitable for commercial sheep farms, in association with automated weighing systems, potentially reducing selection for anthelmintic resistance, without having a negative effect on production. An important benefit of using weight change as an index of relative parasitism is the potential for automation in situations where the cost of time and labor required for inspection of individual animals is prohibitive (Van Wyk, *et al*., 2006).

Using automated weighing systems, radio frequency identification (RFID) ear tags are electronically interrogated to identify sheep as they walk towards a weighing platform, and the body weight at a particular time is recorded in a computer database. Differences in individual weights can be automatically calculated in successive evaluations, and animals that do not meet pre-set weight change criteria can be identified. Electronic gates linked to the database then direct animals to different pens according to treatment decisions based on weight changes. These systems, introduced for sheep in Australia, can process a few hundred animals per hour and have been used as a basis for individual nutritional decisions (Rowe, 2004).

While automated systems are technically feasible, the guidelines for treatment decisions based on production performance indices are less clear than those aimed at preventing serious parasitic diseases such as haemonchosis. Differentiation between the relative effects of parasites and nutrition may be difficult unless simultaneous assessments of parasite load are made. Another important issue concerns the relationship between parasite egg counts and clinical helminthiasis: high parasite egg counts do not necessarily reflect an inability to cope with the current parasite challenge, with the result that treating poorer performing animals may not prevent considerable contamination of pastures with parasite eggs from resilient animals (Van Wyk, *et al*., 2006).

3.5. Using Evidence of Diarrhea

Diarrhea is one of the most serious health problems faced by small ruminants in grazing system around the world, as it leads to loss of weight and body condition. In many cases, diarrhea is related to a poor or nonexistent gastrointestinal nematode (GIN) control program that leads to high herd loads, mainly of *Teladorsagia circumcincta, Trichostrongylus* spp. and *Nematodirus* spp. In other cases, diarrhea is due to interactions between the animal and its diet, weather conditions, and the presence of bacterial and protozoal infections. The relationship between diarrhea and GIN infection is complex, it is an interaction between the direct effects of the infection and the host's immune response. The ingestion of GIN larvae during grazing is an important cause of diarrhea in adult animals (mainly females) of all ages. However, it is unclear whether the infective larval load and/or adults are responsible for diarrhea or the host animal's immune response that leads to diarrhea, like enteric food allergies in humans (Williams and Palmer, 2012).

As animals grow, they gradually develop immunity to GINs and may mount an immune response against larval stages, adults, or both (Hein *et al*., 2010). During primary infection with abomasal GIN such as those mentioned, there is colonization of the mucosa that leads to goblet cell hyperplasia, decreased villus-crypt ratio, shedding of enterocytes into the intestinal lumen, and other pathophysiological events that may result in diarrhea. caused by a large amount of GIN that inhabit the mucosa of the digestive system of animals (Pullman *et al*., 1989). The latter, suggests that diarrhea in young animals is highly likely to be caused by GIN. Broughan and Wall (2007) found a positive correlation between diarrhea and fecal egge count (FEC) in young lambs (3–6 months of age) and postulated that fecal soiling in young animals may be an indirect indicator of GIN load. However, as the age of the animals increases, there is an inverse correlation between diarrhea and FEC (Jacobson *et al*., 2009). In other words, there is a tendency for adult animals with lower FEC to suffer more intense diarrhoea, complicating the scenario at certain times such as inadequate nutrition (times of drought) or in mothers close to childbirth or lactating (Kahn, 2003). Several studies have verified this inverse correlation between the FEC and the presentation of diarrhea. Douch *et al*., (1995) reported that sheep that have been selected as resistant to GIN based on low FEC tend to have a higher incidence of diarrhea than sheep from unselected animals.

It is clear then that elevated GIN FECs do not necessarily lead to significant diarrhea, and it is also evident that sheep that are more resistant to GIN infection may be more prone to diarrhea. This suggests that the nematode-associated diarrhea seen in grazing small ruminants may be due to the inflammatory response to ingested infective larvae, in other words, to immunopathological mechanisms that result in shedding of parasites as part of the response acquired immune. So, in young pre-weaning animals it is possible to associate diarrhea with high parasite loads and decide to deworm the animals, but in post-weaning and adult animals it is not the most indicated, since these animals have low FEC and receiving an anthelmintic treatment does not it would alleviate the situation and it is probable that the resistance of the parasites to the anthelmintics will be increased.

3.5.1 Genetic selection

In Australia, they have selected sheep with low FEC and low propensity for diarrhea and found that these sheep regulate parasitic loads through an IgA-mediated immune response that inhibits the ingestive behavior and fecundity of the parasites in the mucosa, which would be a mechanism more neutralizing for the control of GIN. Contrary to the rapid and efficient IgE-mediated immune response that leads to the immediate expulsion of GIN (Williams *et al*., 2010).

3.5.2. DISCO (Diarrhea Score)

This indicator of diarrhea is based on the dry matter content of sheep feces (mainly lambs) at the time of taking sample, and it refers to the consistency of feces, which is valued in a scale from 1 to 3. Feces with a value of 1 are considered normal if they are firm and consistency, those with a value of 2 are classified as soft, and those with a value of 3 are diarrheal. Values 1, 2 and 3 correspond to 40%, 26% and 16% dry matter, respectively. A score of 3 correlates with diarrhea and consequently with a high number of gastrointestinal nematodes.

This technique is proven for *T. circumcincta*, *Trichostrongylus axei*, and *Cooperia cuticei* infections. This indicator correlates very well with FEC (r=0.42) and when it has been used, the number of treatments with commercial anthelmintics has been reduced by up to 20% (Kenyon and Jackson, 2012). Bentounsi *et al*., (2012) tested the efficacy of three indicators for the implementation of targeted deworming treatment in lambs in Algeria: anemia indicator (FAMACHA©), diarrhea indicator (DISCO) and weight gain. These indicators were compared with the FEC. The results indicate that the DISCO indicator proved to be the most effective, correctly identifying 80% of the sheep that need treatment. It was followed by FAMACHA© with a 50% accuracy level and finally weight gains, which were not a useful indicator.

Likewise, according to these results, it is suggested that the DISCO technique can be used by producers on their farms according to their specific situations, however, precautions must be taken during its application because it may be likely that they may be occurring losses in the production system before the clinic sign of diarrhea. Likewise, erroneous interpretations of the indicator may occur, in cases in which other pathogens of the digestive tract such as coccidia, which can cause diarrhea. For these reasons it is necessary to point out that the application of the indicator requires, of an adequate interpretation, to have an available knowledge of the situation of the endoparasites present in the farm (Cabaret *et al*., 2006).

3.5.3. DAG score

Dags are the dried feces that hang from the wool or hair on the back of sheep. Fecal consistency (formed granules, soft granules, watery diarrhea) may reflect the parasitic load of GIN in small ruminants (although not due to *Haemonchus contortus* whose main affectation is anemia). The score ranges from 0 (no dirt) to 5 (a lot of dirtiness) (Table 2).

Table 2 Dag Score apply to sheep and goats as selection criteria to use an anthelmintic treatment

Score	Description	Action
0	No fecal dirt at all	None
1	Very light dirt on the edge of the tail	None
2	Light dirt on the edge of the tail	None
3	Moderate dirt, dag formation	Consider treatment
4	Lots of dirt, serious dag formation	Recommended treatment
5	Very severe watery diarrhea spreading to the hocks	It is essential to deworm

Source: (Edith et al., 2018)

3.6. Using Milk Production and Lamb Nursing

There is few information about the use of milk production and lamb nursing as indicators of parasitosis, however, during its use in the field showed to be a good alternative to use in TST programs. At this respect Hoste *et al*. (2002a) found that goats in their first lactation and high milk production have a high FEC. The establishment of TST strategy to treat goats with higher milk production with anthelmintic, results were that, in two years of study reduced anthelmintic treatments by 48% and 66% respectively without negative effects on milk production compared to conventionally treated animals (Hoste *et al*., 2002b). In another study, the TST strategy was tested on 11 dairy farms in France for two years, resulting in a 40% reduction in anthelmintic use with no significant changes in milk production or FEC, compared to conventionally treated animals (Hoste *et al.* al., 2002c), these results show that milk production could be an appropriate marker to identify those goats that require treatment, thus contributing to the delay of anthelmintic resistance.

This selection system has been used in Italy and appears to be very user-friendly approach for sheep farmer who are used the system with good results in southern Italy (Cringoli *et al*., 2009), While is considered a poor treatment indicator in cows (Ravinet *et al*., 2014). For the case of sheep Schwarz *et al* (2020) using Lacaune dairy sheep found and increasing EPG in ewes with high milk production indicating high yielding ewes to be less resistant to GIN infection and this effect was most pronounced in earlier lactation but remains along the lactation period in a moderate range; and their results indicate the potential use of milk yield data as TST indicator. There is evidence that ewes nursing multiple lambs have higher FECs than ewes nursing a single lamb. This is likely due to increased nutritional stress and energy deficit in ewes nursing multiple offspring, leading to a relaxation of immunity that normally occurs in the peripartum period and consists of a transient increase in shedding. NGI eggs during the last third of gestation and the first weeks of lactation (Beasley *et al.*, 2012).

3.7. Using the Happy Factor System

Anthelmintic resistance phenomena must lead to managing the parasite population unexposed to treatment (known as refugia), the latter to slow the development of resistance (Jackson and Waller, 2008). In this sense, it may be achieved treatment all the flock at specific times (when it is considered the season with the highest parasite prevalence), i.e. wet season in tropical conditions or summer drenching in Western Australia (Besier and Love, 2003) or apply the treatment only a selected proportion of the animals of the flock at any one time using some productions traits or heaviest animal (Leathwick *et al*., 2006).

In addition, to this factor, we must consider the parasite species of the region, the breed of the animals in the production system, as well as the challenge likely to be encountered (Kenyon *et al*., 2008). In this sense, one such selection indicator uses to identify which are candidates to be dewormed in many different environments and that not relying on clinical signs or production traits is necessary. A solution can be nutrient utilization, which has been shown to be affected by gastrointestinal parasites in both pens (Sykes and Coop, 1976) and field (Thamsborg and Agergaard, 2002) infections. This system uses energy efficiencies and is calculated by dividing the energy deposited by the consumed energy. If the parasites are not affecting the nutrient utilization means that can be accounted for, as a lack or poor herbage availability, thus, calculating energy efficiency may provide a useful indicator of the drenching time in the sheep farm.

The suggested formula uses the liveweight gain calculation, Eq. 6 (AFRC, 1993) multiplied by the liveweight gain of the farm.

MEm = 0.4 liveweight0.75 (4)
where MEm = ME required for maintenance (MJ)

MEg ¼ MEI MEm (5)
where MEg = ME available for growth (MJ)

NE per kg ¼ 4:4 þ 0:35 liveweight (6)
where NE = net energy (MJ)

According to the formulae energy available for growth (MEg) but not ed up as NE deposited in carcasses would have dissipated as heat, this proportion can be used as a measure of inefficiency. Thus, efficiency can be calculated as 1 less the energy dissipated as heat Eq.7 (Greer *et al*., 2009). Differences in the way of calculating the efficiency of energy utilization came from both sub-optimal pasture levels of mass and temperature (Ames and Brink, 1977) were accounted for by dividing the product of Eq. 7 by the product of each Eq. 9. Finally, the efficiency is estimated using the formula of Eq. 9.

Energy utilization efficiency = 1 - (MEg) - NE (7)
MEI

TE = -0.0018 x T2 + 0.0492 x T + 0.6606 (8)

where TE = correction for efficiency due to temperature.
T = mean temperature (°C)

Energy utilization = ((1 - ((MEg - NE) /MEI)) /PI) /TE) (9)

Greer *et al*. (2009) validating the model during at the star grazing season of 2006 and 2007 in Scotland and they compare with animals in a neo suppressive treatment; for the grazing season of 2007 the calculated treatment threshold was 0.65 and was calculated from the data of partial observations of the previous grazing season in 2006, any animal which not reach the target was dewormed; these authors find an optimum threshold efficiency value of 0.66 with a sensitivity of 74% and specificity of 87%. The pasture mass was not affected by the treatment and finally, animals using the model of selection showed less FEC during the study. In this context, the model appears to be successful to identify animals that need an anthelmintic treatment and could be used as part of a selective anthelmintic treatment program at a farm level. The model allows for reducing the proportion of nematode eggs with resistant alleles deposited onto the pastures through the selection of animals and this effect may be expected to be increased with time due to the identification of animals with less anthelmintic treatment (resilient) and their selection (Greer, *et al*., 2009).

Another study by Kenyon *et al*. (2013) evaluated the impact of different treatment approaches including the TST (using the happy factor) in a five-year replicated trial and compared it with the neo suppressive treatment (ivermectin); these authors did not find differences in the liveweight gain between the suppression treatment (NST) and the targeted selective treatment (TST), since they report a reduction of 2%; the latter may be explained by the fact that animals are treated based on its performance would provide protection against the production loss and confirm the efficiency value of 0.66 sets since the beginning of the trial. In addition, the TST regimes allow for an increase in the parasites in refugia, which in long term slows the decline of drug efficacy and provide a balance between the animal performance and provision of refugia in temperate grazing environments.

Recently, McBean *et al*. (2021) studied if the standard threshold calculated in a previous study done by Greer *et al*. (2009) can be used on farms in another location, with different conditions and different animal breeds; these authors found that all farms had a reduction in anthelmintic use ranged from 30% to 89%, despite this reduction were obtained the variations on breeds, temperature, pasture quality suggests that the standard threshold for this study was to low. However, its use although not optimal for all farms could be used initially in TST schemes, since reducing the drug application, maintaining the parasite's refugia, and allowing the opportunity to refine the treatment threshold.

3.8. Combination of the different systems

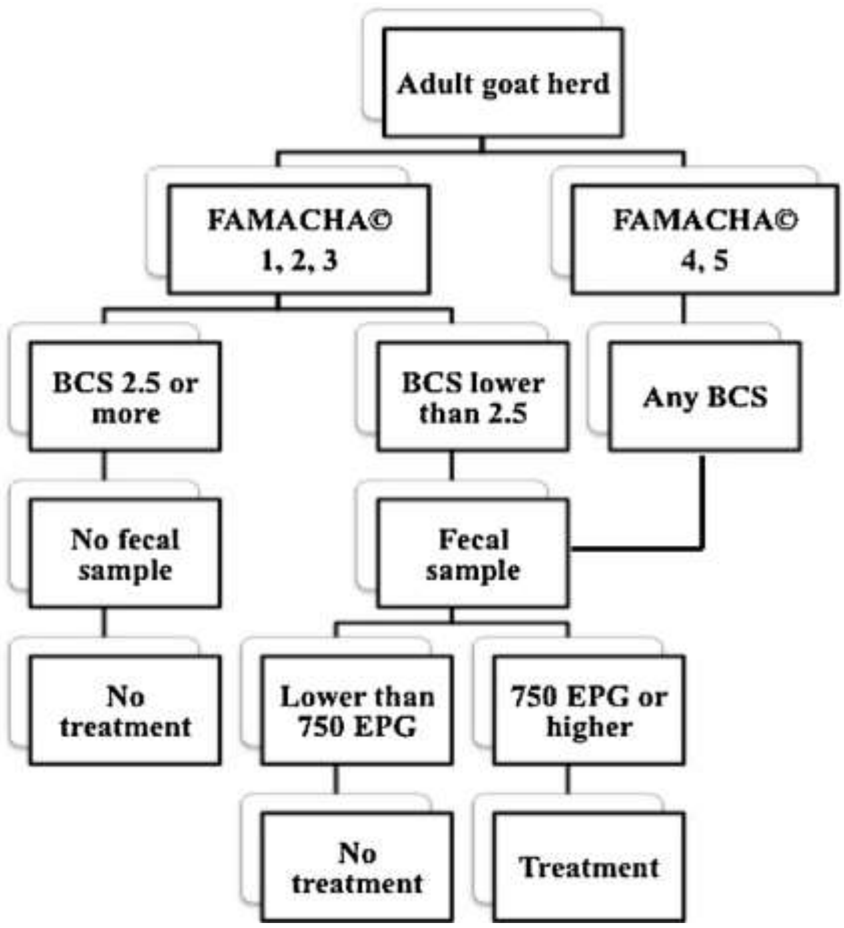
The main limitation of any TST scheme remains to be the difficulty of identifying those animals that are not coping with worm challenge. Only the FAMACHA© score and body condition score (BCS) have been regarded as being of practical value or having the potential for repeatedly examining herds and identifying individuals for AH treatment (VanWyk and Bath, 2002).

However, both methodologies have limitations when applied to adult goats even under conditions where *Haemonchus contortus* is abundant: (i) the sensitivity of FAMACHA© scores 4, 5 to detect anemia in goats is low (23–31%; Vatta *et al*., 2002a), (ii) anemia can be caused by many factors (Van Wyk and Bath, 2002), (iii)BCS is also influenced by management and health aspects other than GIN infections (Vatta *et al.*, 2002b). It has been suggested that the combination of FAMACHA© and BCS, which can be applied simultaneously to a given flock, may achieve the full potential of clinical evaluation for hematophagous and non-hematophagous GIN infections (Van Wyk and Bath, 2002).

3.8.1. FAMACHA©, Body Condition Score, and Faecal Egg Count.

The FAMACHA© method is a selective deworming strategy based on the degree of anemia of an animal through the paleness of its ocular mucosa using a card. This card consists of 5 colors ranging from deep red to pale or white, where it is used to measure on a scale of 1 to 5 the coloring of the palpebral mucosa of sheep (Kaplan *et al*., 2004). This method together with the measurement of body condition and a copro-parasitological examination as well as fecal egg count (FEC) allows the formulation of a deworming criterion (Moors and Gauly, 2009). This method is a very useful tool to identify the parasitic risk caused by *H. contortus* in small ruminants (Harlow, 2016, Golcalves-da Silva *et al*., 2017); however, it must be performed by a trained professional for its correct use.

Figure 6. Decision tree in the combined targeted selective treatment (C-TST) scheme for goats with the criteria used for every step to determine when an animal was treated with an anthelmintic drug. (BCS = Body condition score; EPG = Eggs per gram of feces)



Source: Torres-Acosta et al. (2014)

The use of a combined decision key based on FAMACHA©, body condition score, and FEC has shown promise in Switzerland, and when used in the same goats, trained farmers achieved comparable scores to veterinarians resulting in a 49.7 percent reduction of anthelmintic treatments compared with strategic drenching three times per season (Charlier *et al*., 2014)

Torres-Acosta *et al*. (2014) proposed a combined TST scheme in which a fecal sample is obtained from animals with FAMACHA© scores ≥ 4 or BCS ≤ 2, and the AH is dosed only to those animals crossing an FEC threshold in naturally infected animals at farm level. Such TST scheme was built and validated for sheep and goats under hot humid tropical conditions of México using a threshold ≥ 750 eggs per gram of feces (EPG), and such TST scheme avoided unnecessary AH treatments for > 70% of sampled adult hair-sheep (Medina-Pérez *et al*., 2015).

Table 3. Evidence-based indicators to support targeted selective (TST) anthelmintic treatments against gastrointestinal nematodes in ruminants

	Growing lambs	Dairy sheep/goats
Targeted selective treatment	Liveweight gain Production efficiency FAMACHA* FEC Diarrhea score	Grazing management Milk production level† Body condition score FAMACHA, body condition score, and FEC, in combination

Source: Charlier et al. (2015)

3.8.2. Faecal Egg Count, Body Condition Score, Antibodies

Genetic selection of resistant animals. Genetic resistance (GR) is the variation in immune response represented by a population of animals with the ability to control an infection or disease. To make a selection of animals (SA) with a resistance phenotype in a population, it is necessary the evaluation and measurement of various standards related to parasitological, immunological, and pathogenicity parameters, among which are the determination of EPG, body condition, percentage of hematocrit, the concentration of antibodies (IgA, IgE), the degree of eosinophilia in blood, among others (Maza, *et al*., 2020, Estrada-Reyes, *et al*., 2017, 2019, Reyes-Guerrero *et al*., 2016).

A research topic that is receiving more attention is that of automation of parasite diagnostic processes. FEC-, antibody- and DNA-based technologies are all suitable for further automation (Mes, *et al*., 2001, Roeber, *et al*., 2012). Provided large numbers of samples can be analyzed, diagnostic costs can be reduced by automation, while there is also potential for greater deployment of diagnostic tests at the pen-side (for example, McCoy *et al*., 2005).

4. Conclusion

Due to the different epidemiological conditions i.e., production system, animal breeds, and species of parasite, found in the animal production systems is better to combine some animal selection systems to find the management that best suits to the animal production systems to improve productivity

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