Chapter 3

Testing for clinical anaemia caused by *Haemonchus* spp. in goats farmed under resource-poor conditions in South Africa using an eye colour chart developed for sheep *

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Abstract

A novel clinical assay for the assessment and subsequent treatment of *Haemonchus* infection in sheep to slow down the development of anthelmintic resistance – the FAMACHA© system – has been developed, tested and validated in South Africa. The system is based on a colour chart with five colour categories depicting varying degrees of anaemia that are compared with the colour of the mucous membranes of the eyes of sheep. The animal is then scored from severely anaemic

* *With the exception of Fisher's Exact Test, the current draft is that published in Veterinary Parasitology 99 (2001) 1-14.*

(pale) through anaemic to non-anaemic (red) and those animals considered in danger of succumbing to the effects of haemonchosis are treated. This method was tested in goats farmed under resource-poor conditions in South Africa. Analyses in goats performed during the summers of 1998/1999 and 1999/2000 show a test sensitivity of 76% and 85%, respectively, meaning that the system may be used to identify correctly 76% to 85% of those animals in need of treatment with an anthelmintic. However, the test specificity remains low at 52% to 55%. This means that a large proportion of those animals that would not require treatment would in fact be treated. However, when the use of the FAMACHA© system is compared with conventional dosing practices where all the animals are treated, using the FAMACHA© system would result in a large proportion of the animals being left untreated. The untreated animals are then able to deposit the eggs of anthelmintic-susceptible worms on the pasture, while the treated ones should pass very few ova, given an effective anthelmintic. This maintains a reservoir of susceptible larvae *in refugia*, and should slow down the development of anthelmintic resistance. The validation of the FAMACHA© system for goats for use by resource-poor farmers, which this paper describes, may have wide application in the tropics and subtropics of sub-Saharan Africa and elsewhere.

Keywords: Anthelmintic resistance; Clinical assay; Eye colour chart; FAMACHA©; Goat; *Haemonchus* spp.

3.1. Introduction

Haemonchosis is ranked among the most important diseases of small ruminants in the summer-rainfall area of South Africa. Anthelmintics are currently almost inexpendable in the control of the disease. However, recent surveys indicate that resistance to anthelmintics has reached high levels on commercial sheep farms in South Africa, and already occurs in the resource-poor farming sector (Van Wyk et al., 1999). As a means to reduce the number of anthelmintic treatments given to sheep within the summer-rainfall area and hence the selection pressure for the development of anthelmintic resistance, a colour chart was developed to depict five categories within a range of ovine haematocrit values from healthy (red, “A”) to severely anaemic (pale, “E”) (Van Wyk et al., 1997b). The chart is compared with the ocular mucous membranes of sheep to assess the need for treatment with anthelmintics and those animals considered to be in danger of dying are selectively treated (categories “D” and “E”). The method presupposes that the anaemia is caused by *Haemonchus* infection. In the latest version of the FAMACHA© chart (Bath, 2000), the letters, “A” to “E”, have been substituted by the numbers, one to five, and hence this latter convention has been used in this paper.

The broad objective of the present study was to apply and evaluate the FAMACHA© system in goats in resource-poor farming areas as a tool for anthelmintic resistance management and integrated parasite control. Within this broad objective, three specific aims were identified as follows: to use the FAMACHA© system to determine which animals require dosing with anthelmintics to prevent mortalities; to use the FAMACHA© system to ensure more effective dosing to slow down the development of anthelmintic resistance; and to investigate the efficacy of the anthelmintics used in the small ruminants following a year of anthelmintic treatment according to the FAMACHA© clinical assay.

3.2. Materials and methods

3.2.1. Study sites, animals, sampling, diagnostic techniques and scoring for level of anaemia

The study sites and materials and methods are discussed more fully in Vatta et al. (2000). In short, three study sites were selected within the summer-rainfall area of South Africa: Rust de Winter, Gauteng, Impendle, KwaZulu-Natal, and Kraaipan, North-West Province. A summary of the trial periods and frequencies of visits, sample sizes, breeds of goats, vegetation types and grazing practices, and anthelmintics used for each study site is given in Table 3.1. At Rust de

Table 3.1

Study sites : summary of trial periods and frequencies of visits; sample sizes; breeds of animals; vegetation types and grazing practices; and anthelmintics used

Study site	Trial period	Frequency of visits	Approximate numbers of animals present at each visit	Mean number of animals sampled/ scored (range)	Breed	Grazing	Vegetation[b]	Anthelmintic used (dosage)[c]
Rust de Winter	Sep 1998 - Apr 2000	Fortnightly	18-47	31 (18-47)	Boer goat crossbreed	Private	Mixed bushveld	Levamisole (7.5 mg kg^{-1})[d]
Site 1, Impendle	Nov 1998 - Apr 2000	Monthly	±60	18 (9-22)	Indigenous Zulu crossbreed	Communal	Highland sourveld and Döhne sourveld	Ivermectin (0.2 mg kg^{-1})[e]
Site 2, Impendle	Nov 1998 - Apr 2000	Monthly	±35	19 (14-24)				
Kraaipan	Oct 1998 - Apr 2000	Monthly[a]	±60	16 (10-23)	Indigenous crossbreed	Communal	Sourish mixed bushveld	Levamisole (7.5 mg kg^{-1})[d]

[a]Excepting for two visits over three months at start of trial.
[b]Acocks, 1975.
[c]All anthelmintics were administered *per os*.
[d]Predominantly Tramisol™ liquid (Hoechst Roussel Vet, now Intervet); on a few occasions initially, Levisol™ liquid (Bayer).
[e]Ivomec™ tablets for sheep (Logos Agvet); used extra-labelly in goats: goats less than 25 kg in weight were given ½ tablet (5 mg) each and goats between 25 and 50 kg in weight were given 1 tablet (10 mg) each.

Winter, all the weaner and adult goats present at each visit were sampled. For the two farmers (Sites 1 and 2) at Impendle, a representative sample of the weaner and adult animals was selected based on the first animals brought into the crush at the first visit, and when available the same goats were sampled/scored throughout the trial period. Similarly for Kraaipan, a representative sample of the herd was taken, but the animal numbers started to dwindle and for this reason every 10th goat brought into the crush in May 1999 was added to the sample group. Faecal samples were collected at each visit from the goats and were processed for faecal nematode egg count, following the method of Van Schalkwyk et al. (1995) and at a sensitivity of 100 eggs per gram of faeces (epg), and for identification of third-stage nematode larvae (L_3), using the keys of Van Wyk et al. (1997a) and Dunn (1978). The goats were also bled and their haematocrits were determined by using the microhaematocrit method.

At the scheduled visits, one of the authors (A.F. Vatta) or one of the assistants on the project scored each animal for level of anaemia using the FAMACHA© card. The first author ensured that each assistant for whom scores were recorded had been adequately trained in the method. Excepting for the few visits that the first author could not undertake, the scoring was always performed under his direct supervision. Occasionally, monitoring was done in-between scheduled visits by the farmer at Site 1, Impendle, and by the animal health technicians (AHTs) assisting with the project at Kraaipan. However, these scores were not included in any of the analyses discussed below. Only the animals that were considered to be pale, i.e. categories four and five, were treated with an anthelmintic. At times, animals scored as category three were erroneously treated by the AHTs at Kraaipan and the farmer at Site 2, Impendle, initially misunderstood the aim of the trial and treated all his goats sometime between 24 November and 22 December 1998. On 7 January 1999, one of the goats at Kraaipan showed signs of *Oestrus ovis* infection, indicated by a mucoid nasal discharge. The animal showed difficulty in breathing through the nose and was treated with rafoxanide [Nasalcur™, Hoechst Roussel Vet (now Intervet), 7.5 mg kg^{-1}]. In January 1999, 22 of

Table 3.2.

Two-way frequency table of haematocrit by FAMACHA© with haematocrit cut-off of 18% (or 19%) and FAMACHA© scores 4 and 5 (or 3, 4 and 5) considered positive test results

		Anaemia	
		Present Ht[a] <18% (Ht <19%)	Absent Ht ≥18% (Ht ≥19%)
FAMACHA© score	Positive 4,5 (3,4,5)	True positive (TP)	False positive (FP)
	Negative 1,2,3 (1,2)	False negative (FN)	True negative (TN)

[a]Haematocrit.

Sensitivity = TP/(TP+FN) x 100

Specificity = TN/(FP+TN) x 100

Predictive value of a negative = TN/(FN+TN) x 100

Predictive value of a positive = TP/(TP+FP) x 100

the goats at Site 1, Impendle, and 25 of the goats at Site 2 were treated with niclosamide [Ex-a-lint™, Hoechst Roussel Vet (now Intervet), 50 mg kg^{-1}] for cestodes.

All the animals utilised for the faecal egg count reduction (FECR) tests (see 3.2.3 below) had not been included in the sampling groups mentioned above, except for one of the goats at Kraaipan. All the goats had no permanent incisors, except for three of the goats at Site 1, Impendle, two at Site 2, Impendle, and 10 at Kraaipan, which goats had two to four permanent incisors. None of the animals had been treated with an anthelmintic effective against nematodes within 12 weeks of the start of the FECR tests at Rust de Winter and Kraaipan, and within 16 weeks at Impendle.

3.2.2. Evaluation of the FAMACHA© clinical assay

Two data sets for 1998/1999 and 1999/2000, respectively, were created from all the FAMACHA© scores and haematocrit values obtained from the goats at Rust de Winter and the representative sample sets at Impendle and Kraaipan. Two-way frequency tables of haematocrit by FAMACHA© were drawn up, with FAMACHA© values four and five (or three, four and five) considered positive for anaemic animals and FAMACHA© values one, two and three (or one and two) considered negative test results, respectively (Table 3.2). Haematocrit was used as the gold standard by which anaemia was measured and two cut-off values for anaemia were assigned (less than 18% and less than 19%, respectively). In establishing the properties of a test, cut-off values are assigned to define the level of a test result that is needed to make or reject a diagnosis, in this case a diagnosis of anaemia (Smith, 1995). Sensitivity, specificity, predictive value of a negative and predictive value of a positive were calculated for the data. Smith (1995) defines sensitivity as the proportion of infected or diseased individuals with a positive test, or in the case of the FAMACHA© clinical assay, the proportion of anaemic animals correctly identified as anaemic. Test specificity is defined as the proportion of disease-free individuals that test negative, or the proportion of non-anaemic animals that are categorised as such. In the case of the FAMACHA© method, predictive value of a negative is the probability that an animal is not anaemic when the test result is negative for anaemia and vice versa for the predictive value of a positive. The sensitivity and specificity were tested statistically by means of Fisher's Exact Test for a two-by-two contingency table. The authors chose to maximise the sensitivity and specificity of the FAMACHA© method in goats when the average of the sensitivity and specificity attains its highest value. This was calculated by the following equation for the present data:

$$(\text{sensitivity} + \text{specificity})/2 \qquad \ldots (1)$$

In order to determine the percentage of animals treated in each case (FAMACHA© cut-off of four as opposed to FAMACHA© cut-off of three), the following calculation was also applied to the data:

$$(\text{true positive} + \text{false positive}) / \text{total number of animals} \times 100 \qquad \ldots (2)$$

3.2.3. Faecal egg count reduction tests

The efficacies of the anthelmintics used in the trial were assessed by means of the FECR test (Coles et al., 1992; Presidente, 1985; Van Schalkwyk et al., 1995), which uses the reduction in egg counts following anthelmintic treatment as an indication of anthelmintic efficacy. In each FECR test, the faeces remaining after the egg counts had been done were cultured as follows for L_3

recovery: for the initial date per test all the faeces were pooled together (pre-treatment culture), while the faeces for the second date were pooled separately per group (post-treatment cultures). The proportions of L_3 were applied to the strongyle egg counts to estimate the relative contribution of each genus (Coles et al., 1992; Presidente, 1985). In the World Association for the Advancement of Veterinary Parasitology (WAAVP) method for the detection of anthelmintic resistance (Coles et al., 1992), the arithmetic mean of the treatment and control groups at 10 to 14 days after treatment are utilised to calculate the percentage reduction of faecal egg counts and the upper and lower 95% confidence intervals. Resistance is determined to be present if the percentage reduction is less than 95% and the lower confidence interval is less than 90%. If only one of the conditions is met, resistance is only suspected. In the method of Presidente (1985), the geometric or arithmetic means of faecal egg counts both on the day of treatment and 10 to 14 days thereafter are used in the calculation of the percentage reduction. Geometric means were used in the current calculations. Resistance has been said to occur when the percentage reduction is less than 80% in goats (Kettle et al., 1983). Reduced efficacy of anthelmintics in goats may be the result of a faster metabolism of the drugs in this species. Hence the lower value is used for goats when no difference between the dose for sheep and goats is indicated. The WAAVP method is considered to be a more conservative measure of anthelmintic efficacy (Coles et al., 1992). Focus has been placed on this method to allow for comparison between data of different authors, but the method of Presidente was included for completeness' sake.

Table 3.3 gives the mean faecal egg counts of the animals at the visit dates immediately prior to the dates on which the anthelmintic treatments for the FECR tests were carried out. The animals were ranked according to these faecal egg counts from lowest to highest. The animals were then divided into groups of two or three, depending on whether one or two anthelmintics were being tested. Each individual within each group was then randomly assigned to a treatment or control group (Table 3.3), with the help of a table of random numbers. The initial and post-treatment dates of the FECR tests and the sizes of the groups included in the tests are also recorded in Table 3.3.

Table 3.3

Faecal egg count reduction tests : details of groups and results

Location	Mean FEC (interval)[a]	Treatment date of FECR test (interval)[b]	Anthelmintic (dosage)[c]	Control group Mean FEC[d] Pre[e]	Control group Mean FEC[d] Post[e]	Control group *n*	Treatment group Mean FEC Pre	Treatment group Mean FEC Post	Treatment group *n*	FEC reduction (W.A. A.V.P.[f])	95% CI[g] (W.A. A.V.P.)	FEC reduction (Presidente[h])
Rust de Winter	2171 (14)	24 Feb 2000 (13)	Levamisole (7.5 mg kg^{-1})	1791	2438	8	1133	340	10	86%	0%, 98%	99%
Site 1, Impendle	3775 (28)	14 Mar 2000 (15)	Ivermectin (0.2 mg kg^{-1})	5909	4211	5	6824	33	8	99%	97%, 100%	100%
Site 2, Impendle	3147 (28)	14 Mar 2000 (15)	Ivermectin (0.2 mg kg^{-1})	4074	4857	7	3222	13	8	100%	98%, 100%	100%
Kraaipan	778 (28)	29 Feb 2000 (10)	Levamisole (7.5 mg kg^{-1})	-[i]	573	9	-	4	11	99%	98%, 100%	-
			Rafoxanide (7.5 mg kg^{-1})	-	573	9	-	12	11	98%	93%, 99%	-

[a]Mean faecal strongyle egg counts in eggs per gram of faeces at last visit before FECR test (interval in days between last visit and FECR test).
[b]Treatment date of faecal egg count reduction test (interval in days between pre- and post-treatment collection of faecal samples).
[c]All anthelmintics were administered *per os*.
[d]Mean faecal *Haemonchus* egg counts in eggs per gram of faeces.
[e]Pre: Pre-treatment; Post: Post-treatment.
[f]Coles et al., 1992.
[g]Confidence intervals.
[h]Presidente, 1985.
[i]No larval culture results available and hence proportions of *Haemonchus* eggs in mean FEC could not be determined.

Table 3.4.1

Comparison of results for application of the FAMACHA© system in goats during 1998/1999 and 1999/2000

	Sensitivity (%)		Specificity (%)		Predictive value (%)			
					Negative		Positive	
	98/99	99/00	98/99	99/00	98/99	99/00	98/99	99/00
FAMACHA© values 4 and 5 considered positive test results								
Ht cut-off <18% [a]	31.1	35.6	91.2	90.2	95.6	94.9	17.7	21.3
Ht cut-off <19%	23.0	28.4	91.3	90.4	91.9	91.6	21.5	25.3
FAMACHA© values 3, 4 and 5 considered positive test results								
Ht cut-off <18%	80.0	86.7	54.3	50.7	97.8	98.1	9.6	11.6
Ht cut-off <19%	75.7	85.1	55.3	52.0	95.6	96.8	14.9	17.0

[a] Haematocrit cut-off value used.

3.3. Results

3.3.1. Evaluation of the FAMACHA© clinical assay

Periods of heavier worm infection during which time *Haemonchus* was the predominant species occurred from December/January to March/April at Rust de Winter; from December to March/April at Impendle; and from November/December to February/March at Kraaipan (Chapter 4). For this reason, the data used to draw up the two-way frequency tables included paired values of haematocrit and FAMACHA© score from November 1998 to April 1999 and from November 1999 to April 2000. A total number of 787 pairs of haematocrit and FAMACHA© values were included for 1998/1999 and 648 for 1999/2000. The sensitivities, specificities and predictive values for the two different levels of positive FAMACHA© scores (four and five, and three, four and five, respectively), for the two different haematocrit cut-off values for anaemia (less than 18% and less than 19%, respectively) and for the two summer seasons (1998/1999 and 1999/2000, respectively) are given in Table 3.4.1. The results for the application of equations (1) and (2) and for Fisher's Exact Test are recorded in Table 3.4.2.

Table 3.4.2

Comparison of results for application of the FAMACHA© system in goats during 1998/1999 and 1999/2000 (continued)

	(Sensitivity + specificity)/2[a]		Goats treated (%)[b]		P values for Fisher's Exact Test	
	98/99	99/00	98/99	99/00	98/99	99/00
FAMACHA© values 4 and 5 considered positive test results						
Ht cut-off <18% [a]	61.2	62.9	10.0	11.6	4.5×10^{-5}	9.6×10^{-6}
Ht cut-off <19%	57.2	59.4	10.0	11.6	7.1×10^{-4}	5.3×10^{-5}
FAMACHA© values 3, 4 and 5 considered positive test results						
Ht cut-off <18%	67.2	68.7	47.6	51.9	8.6×10^{-6}	6.1×10^{-7}
Ht cut-off <19%	65.5	68.6	47.6	51.9	3.2×10^{-7}	3.8×10^{-9}

[a]Equation 1 (see text).
[b]Equation 2 (see text).

3.3.2. Faecal egg count reduction tests

Strongyloides spp., *Trichuris* spp. and other nematode eggs were detected in the faecal egg counts and *Haemonchus* spp., *Oesophagostomum* spp., *Teladorsagia/Trichostrongylus* spp. and *Strongyloides* spp. were recorded in the faecal cultures. When *Strongyloides* was excluded from the differential counts of the L_3 cultured from the faeces collected on the day of treatment, *Haemonchus* spp. predominated in each case (Table 3.5). In the cultures made for the second visit, *Haemonchus* spp. was the most prevalent genus in the controls. For these reasons, analyses of efficacy were applied only for *Haemonchus* spp. The calculation of anthelmintic efficacy according to the methods of Coles et al. (1992) (WAAVP method) and Presidente (1985) are given in Table 3.3. The results indicate that resistance was not found for any of the groups tested, except for the goats at Rust de Winter where resistance to levamisole was detected. This is indicated in the WAAVP method by the fact that the percentage reduction is less than 95% and the lower confidence interval is less than 90%. Resistance was not detected by the method of Presidente.

Table 3.5

Percentage of *Haemonchus* spp. in larval cultures made from faecal samples taken pre- and post-treatment for faecal egg count reduction tests

Location	Anthelmintic	Pre-treatment percentage (n^a)	Post-treatment percentage (n^a)	
			Control group	Treatment group
Rust de Winter	Levamisole	75% (28)	100% (3)	0
Site 1, Impendle	Ivermectin	92% (97)	94% (100)	88% (99)
Site 2, Impendle	Ivermectin	98% (100)	100% (96)	100% (19)
Kraaipan	Levamisole	-[b]	82% (99)	2% (45)
	Rafoxanide	-[b]	82% (99)	6% (32)

[a]Number of larvae counted - *Strongyloides* spp. was initially included in the differential larval counts, but has been excluded here.
[b]No larval culture results available

3.4. Discussion

3.4.1. Evaluation of the FAMACHA© clinical assay

A cut-off haematocrit value for anaemia of less than 18% was assigned when the two-way frequency table was drawn initially. The reason behind assigning this cut-off value was that the range of haematocrit values subjectively determined for sheep for categories four and five were 13-17% and <13%, respectively (Table 3.6). For the period 1998/1999, the sensitivity of the FAMACHA© system to identify animals that are anaemic (i.e. with a haematocrit less than 18%) when only those animals falling into FAMACHA© categories four and five are treated was poor at 31,1%. The specificity of the method was, however, good at 91,2%. It was then hypothesized that considering FAMACHA© categories three, four and five as anaemic may render a better sensitivity. The sensitivity at a

Table 3.6

Relationship between FAMACHA© score and haematocrit range for sheep

FAMACHA© score	Approximate haematocrit[a]	Haematocrit range[b]	Recommendation with regard to dosing
1	35 %	≥28%	Do not dose
2	25 %	23-27%	Do not dose
3	20 %	18-22%	Dose if uncertain
4	15 %	13-17%	Dose
5	10 %	≤12%	Dose

[a]Van Wyk et al., 1997b.
[b]Van Wyk, 2000.

haematocrit cut-off of less than 18% increased from 31,1% to 80,0%. However, the specificity decreased from 91,2% to 54,3%.

Schalm's Veterinary Hematology gives a normal haematocrit range for goats as 19-38% (Jain, 1986). Using a cut-off value of 19% and where FAMACHA© categories four and five are considered anaemic, the sensitivity and specificity for the 1998/1999 data are 23,0% and 91,3%, respectively (Table 3.4.1). These values change to 75,7% and 55,3%, respectively, where categories three, four and five are considered anaemic. One notices that as the sensitivity increases, so the specificity decreases when one changes from a FAMACHA© cut-off of four to a cut-off of three. This is expected for any diagnostic test (Smith, 1995). Where FAMACHA© categories four and five are considered anaemic, Fisher's Exact Test shows that the sensitivity of the FAMACHA© system to detect animals with a haematocrit less than 19% is highly significant but not as significant as with a haematocrit less than 18%. This may indicate that the subjectively assigned range for categories four and five (less than 18%, Table 3.6) may be accurate. However, the sensitivities for a FAMACHA© cut-off of four do not compare favourably with those for a cut-off of three. Moreover, for the latter sensitivities, Fisher's Test also gives more highly significant P values.

On a day-to-day basis, one is more concerned with the sensitivity of the FAMACHA© chart since the consequences of not treating an anaemic animal (possible mortality) are more severe than treating an animal that did not actually require treatment. A greater sensitivity is preferred as one does not wish to miss animals that are anaemic. If the assumption is made that the most important cause of the anaemia is haemonchosis (Chapter 4), then by extension, one does not want to miss animals that are suffering from haemonchosis. In considering the first specific objective of the study, to use the FAMACHA© system to determine which animals require dosing with anthelmintics to prevent mortalities, one can say that the FAMACHA© clinical assay may be used with a sensitivity of between 76% and 85%, provided that animals in categories three, four and five are treated and one wishes to identify animals with haematocrits less than 19%. Using this grouping of animals into anaemic (categories three, four and five) and non-anaemic (categories one and two), the sensitivity and specificity are maximized (equation 1, Table 3.4.2). This applied to the data both for 1998/1999 and 1999/2000. It should be borne in mind that the FAMACHA© assay is a clinical estimate of anaemia and that these results reflect the scores of only a few workers including the first author and those trained by him. However, until work by other authors reveals otherwise, the cut-off for anaemia should be taken as FAMACHA© category three in the goat.

The results for 1999/2000 are similar to those of 1998/1999, although better results for the calculation for sensitivity were obtained overall for 1999/2000 than for 1998/1999. The specificity of the method decreased marginally in 1999/2000. The improvement in sensitivity of the FAMACHA© method during the second summer season may be an indication of greater proficiency in its use.

Resource-poor farming in South Africa has been neglected in terms of agricultural extension, i.e. those activities aimed at providing farmers with the results of research, innovative technology and other information that may assist them to improve their agricultural production. These aspects are currently being addressed, however. Recommendations that resource-poor farmers are receiving as a result reflect the convention of commercial agriculture, i.e. to treat all the small ruminants for worms every

Table 3.7

Anthelmintic treatment programme supplied to farmer at Rust de Winter

Month	Deworming aimed at
January	Nasal bot (*Oestrus ovis*), wireworm (*Haemonchus* spp.)
February	Nodular worm (*Oesophagostomum* spp.), wireworm
March	Wireworm, nasal bot, liver fluke (*Fasciola* spp.)
May	Nasal bot, liver fluke
July	Bankrupt worm (*Trichostrongylus* spp.), nasal bot
September	Wireworm, nasal bot, liver fluke
October	Wireworm, nasal bot
December	Wireworm, nasal bot
Lambs[a]	Milk tapeworm (*Moniezia* spp.)

[a]A recommendation was made that lambs be treated for milk tapeworm (*Moniezia* spp.), but no time of year was supplied.

time that it is deemed necessary for any individual animal in the flock or herd (personal observation, 1998/1999). An example of an anthelmintic treatment programme given to one of the farmers before the current trial was implemented is shown in Table 3.7. Horak et al. (1976) recommended four to five strategic anthelmintic treatments for roundworms per year. However, to achieve maximum production in lambs during their first year, these authors recommended that regular, short-interval treatment be applied, presumably even at four-weekly intervals, which was the regimen tested in the study. However, the emergence of anthelmintic resistance and investigations into its subsequent causes have shown that high frequency of anthelmintic treatment of all the animals in a herd within or close to the prepatent period of the worm in question increases the selection pressure for the development of anthelmintic resistance (Jackson, 1993). In a sense, then, the fact that extension to resource-poor farmers was not as effective as to the commercial sector may be a blessing in disguise since the extension may now take anthelmintic resistance into account. It is critical that resource-poor farmers do not follow the same path of those commercial farmers who, with their frequent drenching of all the animals in a flock, have in many cases selected for severe anthelmintic resistance (Van Wyk et al., 1999). The question that arises, then, is whether the application of the FAMACHA© system represents a potential improvement on the recommendation to treat the whole herd at any one time, irrespective of whether an animal requires treatment or not (second objective of the study). Based on the fact that only between 47,6% and 51,9% of the animals are treated when goats categorised as three, four or five are dewormed (equation 2, Table 3.4.2), the authors believe that the use of the FAMACHA© method would reduce the selection pressure for anthelmintic resistance because a large proportion of the animals would be left untreated (Besier, 1997). For the resource-poor farmer wanting to control haemonchosis in goats, the use of the FAMACHA© system represents an attractive tool to be employed in implementing integrated internal parasite control on the farm.

3.4.2. Faecal egg count reduction tests

Coles et al. (1989) showed that levamisole at 7.92 mg kg^{-1} was only 83% effective against immature *Haemonchus contortus* in goats. At a dosage of 11,8 mg kg^{-1}, immature worms were still present in five of the seven goats treated. Coles et al. (1989) speculated that the reason for the poor efficacy is due to a faster metabolism of levamisole in goats than in sheep, in which species the drug is considered highly effective at 7.5 mg kg^{-1} (Coles, 1986). In the present study, the dosage recommended by the manufacturer (7.5 mg kg^{-1}) was used at all times, and no difference in dosage was indicated between sheep and goats. In a goat herd in Eastern Virginia, USA, Zajac and Gipson (2000) initially found that levamisole showed an efficacy of 0.75% at a dosage of 11.8 mg kg^{-1}. Use was discontinued and seven months later, efficacy appeared to have improved and was then 74%. The following year, the efficacy of levamisole was found to be 97% and use of the drug was reinstated. When the drug was again tested a year later, efficacy was found to be 73%. Grimshaw et al. (1996) have shown that treatment with levamisole at 7.5 mg kg^{-1} was only 88% effective against the immature stages of a levamisole-susceptible, benzimidazole-resistant strain of *H. contortus* in lambs. It is conceivable that immature nematodes could develop into adults, the eggs of which are detected when samples are analysed more than 10 days after treatment. In the first two tests of Zajac and Gipson, samples were collected 5 days post-treatment. These authors speculated, then, that the efficacy of levamisole might have been underestimated during the first two tests. For the same reason, the efficacy of levamisole at Rust de Winter may have been underestimated since samples were collected 14 days after treatment. However, Martin et al. (1985) proposed that levamisole causes a temporary suppression in egg laying in *Ostertagia* spp., which egg production may resume only 10 days after treatment. If samples are taken before this time, the efficacy of the anthelmintic may be overestimated. It is the authors' opinion that levamisole resistance is present in the goats at Rust de Winter. Although the origin of the goats was not confirmed, it was understood that the animals were brought on to the farm in 1989 when the farmer settled there. During the trial period, the farmer also moved some of the goats between the farm and the farmer's actual place of residence, a township where communal grazing of animals is practised. It is possible that the animals were infected with resistant worm strains on the communal grazing, or more likely, on commercial farms before being bought at local auctions by the resource-poor farmer. Since a FECR test was not carried out at the start of the trial, it is not possible to determine whether the resistance status of the flock changed over the trial period. As such, it is difficult to speculate on the role that the treatment of animals according to the FAMACHA© system may or may not have played in the development of the resistance. An advantage of the clinical assay is the fact that a large proportion of the animals are left untreated and are able to contaminate the pasture with the eggs of, in particular, anthelmintic-susceptible worms. This practice contributes to the maintenance of a large proportion of anthelmintic-susceptible infective larvae on the pasture which is able to dilute the larvae of any resistant strains and in that way delay the emergence of anthelmintic resistance (Jackson, 1993). This would suggest that the application of the FAMACHA© clinical assay might not have played a large role in the development of the resistance.

The FAMACHA© assay represents a potential revolution in internal parasite management and its validation for goats for use by resource-poor farmers, which this paper describes, is of particular relevance for South Africa and indeed for the tropics and sub-tropics of sub-Saharan Africa and elsewhere. In many of these areas, haemonchosis represents a major disease constraint on increasing production in small ruminants. The principle on which the FAMACHA© method is based, namely the treatment of only those animals that are susceptible to the disease, provides a method by which tremendous savings in the use of anthelmintics can be realised. Where appropriate, the method should be taught as part of an integrated approach to worm control within participatory rural extension programmes. Further testing of the FAMACHA© clinical assay should also be pursued in other goat farming systems.