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Review article

The FAMACHA© system for managing haemonchosis in sheep and goats by clinically identifying individual animals for treatment

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Abstract – Escalating anthelmintic resistance has made it essential to develop alternative ways of worm management for reducing selection for worm resistance, and one of the most promising approaches is to treat only those animals unable to cope with worm challenge, thus favouring unselected worms originating from untreated animals. Only clinical evaluation of anaemia (FAMACHA© system) and the body condition score are regarded as being of practical value or having potential, respectively, for repeatedly examining flocks or herds and identifying individuals for treatment. Only the FAMACHA© system has been tested well enough for use under practical farming conditions. However, further investigation is needed on its effect on animal production, and methods to reduce labour. Trials over several seasons showed that most sheep under severe *Haemonchus contortus* challenge required no, or only one treatment over a full summer season. A small minority (usually < 5%) needed more than two treatments. Most sheep could cope without regular treatment. With sufficient training, clinical evaluation of anaemia was found reliable for practical use. The overwhelming majority of trainees (some poorly literate) were able to implement the FAMACHA© system successfully. The dynamics of haemonchosis in a flock can easily be monitored. Farmers, farm workers and veterinarians all rated the system very highly (> 80%) and treatment costs dropped by approximately 58%. The heritability of FAMACHA© values obtained by clinical evaluation was high at 0.55 ± 0.17% in a Merino stud with ± 550 young rams and ewes which were the progeny of 21 sires. The FAMACHA© system may not be as applicable to goats as to sheep, but further work is necessary. The main benefits of the system are the reduction in treatments, its use for discriminating between animals of varying ability to cope with infection (thus allowing genetic selection), and its lowering of selection pressure on *H. contortus* for anthelmintic resistance.

haemonchosis / FAMACHA© / individual animal treatment / anaemia / sheep / goats

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Résumé – Utilisation du système FAMACHA© pour gérer l'hémonchose chez le mouton et la chèvre par l'identification clinique des animaux nécessitant un traitement. L'augmentation de la résistance aux anthelmintiques a entraîné la nécessité de développer des alternatives à la gestion des helminthes, afin de réduire la sélection de résistances, et l'une des approches les plus prometteuses est de traiter uniquement les animaux incapables de résister à la maladie, favorisant ainsi les vers non sélectionnés provenant d'animaux non traités. Seules l'évaluation clinique de l'anémie (système FAMACHA© et la note de condition corporelle sont considérées, respectivement, comme ayant une utilité pratique ou comme ayant un potentiel, pour examiner très régulièrement les troupeaux et identifier les individus devant être traités. Seul le système FAMACHA© a été suffisamment testé pour pouvoir être utilisé dans des conditions d'élevage. Cependant, une étude plus poussée concernant son effet sur la production animale est nécessaire, et sur les méthodes permettant de diminuer la charge de travail. Les essais sur plusieurs saisons ont montré que dans la plupart des cas où des moutons subissaient une forte épreuve de *Haemonchus contortus*, aucun traitement n'était nécessaire, ou un seul traitement sur toute la période d'été. Une faible minorité des cas (généralement moins de 5 %) nécessitait plus de deux traitements. La plupart des moutons pouvait faire face à l'infestation sans traitement régulier. Avec un entraînement suffisant, l'évaluation clinique de l'anémie se révèle fiable dans le cadre d'une utilisation pratique. Une large majorité des stagiaires (certains sachant à peine lire et écrire) était capable de mettre en pratique le système FAMACHA© avec succès. La dynamique de l'hémonchose dans un troupeau peut être aisément enregistrée. Les fermiers, les ouvriers agricoles et les vétérinaires ont tous fait une évaluation très positive du test (> 80 %) et le coût des traitements a diminué d'environ 58 %. L'héritabilité des valeurs FAMACHA© obtenues par évaluation clinique était élevée : 0,55 ± 0,17 % dans un haras Merinos avec environ 550 jeunes béliers et brebis descendant de 21 mâles reproducteurs. Le système FAMACHA© pourrait être moins bien adapté aux chèvres qu'il l'est aux moutons, mais une étude plus approfondie est nécessaire. Les bénéfices principaux du système sont la réduction des traitements, son utilisation pour établir une distinction entre les animaux ayant des capacités variées de se défendre contre l'infestation (permettant de faire une sélection génétique), et de permettre une diminution de la pression de sélection sur *H. contortus* pour la résistance aux anthelmintiques.

hémonchose / FAMACHA© / traitement individuel des animaux / anémie / mouton / chèvre

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1. INTRODUCTION

Anthelmintic resistance in many common pathogenic helminths of small domestic ruminants has escalated to such an extent globally that drastic measures are urgently required to address the problem [25, 27–29, 31, 32, 38]. It appears unlikely, due mainly to the very high costs involved [21, 24, 37], that development of new, unrelated anthelmintics will offer a sustainable solution to the problem. Therefore other strategies which do not rely heavily on the chemical treatment of entire flocks or herds continue to receive special attention.

A practical approach to reducing selection pressure for anthelmintic resistance is to drench only a proportion of the flock or herd, leaving many untreated animals in which unselected, non-resistant worms survive and propagate [6–8], thus ensuring a preponderance of susceptible worms in refugia [19, 26]. The problem to date has been a lack of practical, cheap methods that can be applied on farms to identify animals that are not coping with worm challenge, rather than merely leaving a random proportion untreated. Random treatment of a fixed proportion of a flock or herd will unavoidably lead to the unnecessary treatment of many individuals not requiring it, while also potentially leaving untreated some sheep or goats that do urgently need drenching.

To be implementable on a sustained basis on the majority of farms, methods for identifying those animals in danger of being overwhelmed by worm challenge have to be practical and inexpensive enough to use on large flocks or herds of animals repeatedly, at intervals as short as weekly at the peak of the worm season.

This review concentrates on research into the use of clinical anaemia (the FAMACHA© system) to identify animals at risk, as it has been thoroughly tested for use in animals with haemonchosis.

2. CLINICAL ANAEMIA EVALUATION (FAMACHA© SYSTEM)

The name FAMACHA© was coined to describe the system evolved for treating only those animals unable to cope with current *Haemonchus contortus* challenge on pasture, by using clinical anaemia as the determinant. It is an acronym derived from the name of the originator of the idea, Dr Faffa Malan (**FA**ffa **MA**lan **CHA**rt) [4, 30].

It is common knowledge that during the course of fatal haemonchosis the colour of the conjunctivae of sheep changes from the deep red of healthy sheep, through shades of pink to practically white, as a result of a progressively worsening anaemia. The extent to which these changes relate to a range of haematocrit (Ht) values (chosen as the "gold standard" of anaemia) [13] was, until recently, still undetermined. The feasibility of grading the degree of anaemia clinically in conjunctival mucous membranes was investigated by both photographing the mucous membranes and determining the Ht of sheep which ranged from very healthy to extremely anaemic [4, 16, 18, 30].

2.1. Initial trial

The initial trial took place on a South African farm, with a hot and humid climate, predominantly summer rainfall and mild winters [16, 18, 30]. Irrigated and intensively grazed Kikuyu (*Pennisetum clandestinum*) grass pastures created conditions very conducive to haemonchosis [16, 18]. After an initial flock treatment in March [31], all blanket anthelmintic treatment of ewes on the pastures was suspended for 125 days, and replaced with selective salvage treatment of only the most severely affected animals. The 388 sheep were examined weekly by different people for conjunctival mucous membrane colour and submandibular subcutaneous oedema ("bottle-jaw"). Each animal was classified into one of the following conjunctival colour categories: red, red-pink, pink, pink-white or white (categories 1–5, respectively, in later trials) [16–18, 30]. Every sheep evaluated as either pink-white or white was bled for microhaematocrit determination, and only those with Ht values at or below 15% were treated with levamisole, which had been shown to be highly effective against the population of *H. contortus*. On six occasions over 125 days all the animals in the flock were bled for Ht evaluation, in addition to being classified into one of the 5 conjunctival colour categories. The data collected on these six occasions was analysed statistically for evaluating the reliability of the clinical evaluation method; 16 sheep were excluded from the evaluations because of incomplete data.

2.2. Later trials on commercial farms

The methodology used in the initial trial was further refined to standardise the methods for more extensive trials. Clinical evaluation used was better structured and tested in a series of subsequent trials by standardising the five informal descriptive categories used in the initial trial into five specified Ht ranges of ≥ 28% for category 1, 23–27% for category 2, 18–22% for category 3, 13–17% for category 4 and ≤ 12% for category 5 [4, 30]. A practical full colour card with illustrations was produced to assist on-farm evaluations, depicting conjunctival mucous membranes of sheep in the five selected Ht ranges. The actual illustrations show the expected mucous membranes colours of sheep with Hts of 35% (category 1), 25% (category 2), 20% (category 3), 15% (category 4) and 10% (category 5).

The later trials were conducted at different levels of intensity and involvement of the research team on more than 30 commercial farms, in six provinces in the summer rainfall region of South Africa, where *H. contortus* is the overwhelmingly dominant helminth parasite of small ruminants [3–5, 9, 16–18, 30, 33–36]. The commercial farms were selected to represent a wide range of farming and management systems. On the great majority of these commercial farms, Merinos or Döhne Merinos (a closely allied breed) were used in the trials. There were also some trial farms with S.A. Mutton Merinos (a dual purpose breed), Dorpers (a locally developed mutton breed), Ile de France and Suffolk sheep. Numbers of sheep ranged from approximately 250 to 1600 per farm. Most farms were grazed extensively, but on five farms the main grazing was intensive, artificial pasture. The trial sites were selected for suitability, using predetermined criteria like managerial ability, the severity of haemonchosis and absence of possibly confounding factors, as judged by three evaluators of the research team [3, 5]. One or more trial groups of at least 100 sheep of uniform type and class (with replacement ewes being preferred) were selected per farm and routine anthelmintic treatment on the trial flock was stopped at the commencement of each trial.

Trial sheep were examined periodically by farmers and/or their stockmen (using the FAMACHA© card). Anthelmintic treatment was restricted to animals showing signs of severe anaemia (categories 4 and 5). At the start of the *Haemonchus* season (September to November), the animals were evaluated every three weeks. This frequency increased to fortnightly and, subsequently, to weekly examinations during the height of the *Haemonchus* season (January to March) [5, 27]. Further evaluations were conducted by members of the research team, at intervals varying from 1 to 6 weeks during the *Haemonchus* season. On most farms, treatment was determined on the basis of clinical evaluations alone, but on some treatment was reserved for sheep with Hts at or below15% [18, 30, 33]. The scoring of FAMACHA© categories in each flock was recorded on a simplified flock table so that numbers of animals in each category could be easily recorded and counted. Treated animals were also identified at every treatment by applying a simple semi-permanent marker, comprising a plastic cable tie fastened above the carpus [5].

Each trial lasted at least the eight months of the *Haemonchus* season.

Training: Participants were trained in the use of the FAMACHA© system, using informal information sessions and practical demonstrations [3, 5]. The trainees were then required to independently classify about 20 sheep of known Hts and FAMACHA© categories. More experienced evaluators were also tested using larger groups of sheep of known Ht [5, 33]. The success rates of the participants were evaluated by the degree of variation between the FAMACHA© categories allocated by them, and the corresponding Hts [5, 33]. In addition, incorrect classifications that could have placed animals at risk of dying (by severely underestimating the degree of anaemia of the animal) were progressively penalised, corresponding to the degree of the aberration [5, 33] (see Sects. 3.2. and 3.3. below).

After conclusion of the trials, farmers, stockmen and veterinarians were interviewed, using structured questionnaires to gauge their perceptions of the FAMACHA© system [3, 5].

2.3. Resource-limited (small scale) farmers

The system was also tested on a limited scale on four resource-limited farms. The majority of the animals in these trials were goats, and no groups that were uniform in age, sex and reproductive status, or numbers of 100 or more were available [36]. The animals were of mixed breeds, and the four farms were situated in three provinces [34–36]. The sites were selected partially on the basis of the willingness and suitability of the farmers concerned, but mainly on the availability of an infrastructure in each region, which could support the farmers and research team during and after the trials (Van Wyk, personal observations, 1998). In contrast to the situation in sheep, the FAMACHA© system was therefore tested in a limited range of environmental and managemental conditions in goats, with most data being generated by one investigator's evaluations.

3. RELIABILITY OF CLINICAL EVALUATION OF ANAEMIA

The reliability of the FAMACHA© system was tested in four ways on commercial farms [3, 5, 33] (Tab. I), and also in one further

Table I. Correlation between haematocrits and clinical anaemia estimations.

Data set	Correlation coefficient[a] ($r^2 \times 100$)
Initial trial (n = 370)[b]	
Day 0	8.4
Day 41	38.9
Day 51	28.6
Day 63	20.8
Day 92	25.6
Day 136	25.7
Mean (excl. Day 0)	33.6%
Later trials (n = 172–184)[c]	
1	43.2
2	44.3
3	58.5
Mean	48.7%

[a] Pearson Correlation Coefficient; all correlations highly significant ($P < 0.001$).
[b] Before development of the FAMACHA© chart and evaluation system.
[c] After development of the FAMACHA© system.

manner on the resource-limited farms [36] (Sect. 9).

3.1. Comparison of FAMACHA© and haematocrit values

To evaluate the reliability of clinical classifications, Pearson correlation coefficients were computed from the clinical FAMACHA© estimates and corresponding Ht values for the various sets of data from commercial farms. For the computations, each FAMACHA© category was allocated a numerical value of from 1–5, corresponding with its category number. Retrospectively the corresponding numerical values were also used for the categories informally decided upon in the initial trial [18]. The $r^2 \times 100$ values showed that all correlations were highly significant ($P < 0.001$), although in the initial trial the clinical estimates correctly predicted the corresponding Ht categories in only 8–39% of cases (Tab. I) [18]. It is argued that this low accuracy in the initial trial was due to the unrefined methodology employed, since considerably better results were obtained in subsequent trials, where predictions were correct in from 43–59% of cases (Tab. I) [33]. It should be kept in mind, however, that, as discussed below, the great majority of the results classified as "incorrect" in this analysis were in a category adjacent to the correct result, many being on the boundary between categories. Thus this analysis does not accurately reflect the value of the FAMACHA© system in practice.

In Tables I, II and III, data sets 1 and 3 were from evaluations by the same experienced investigator, and set 2 from another similarly experienced person [33].

3.2. Reliability assessed by the appropriateness of treatment decisions

The second method used [33] for evaluating the accuracy of estimates was based on the correctness of the decision whether to drench sheep or not, using a cut-off point of ≤ 15% Ht [33]. Clinical evaluations were also compared with the corresponding Ht values.

The results in the initial trial may appear poor, as 44% of the FAMACHA© estimates were "incorrect" [18]. However, 71% of the FAMACHA© estimates that were incorrect, were in the categories adjacent to the correct ones (calculated from Malan et al. [18]). Thus the degree of error was small.

The problem with estimation of "accuracy" when using the FAMACHA© system is that only five categories are assigned, while Ht values may vary from 8 to over 40% (thus > 30 values). Therefore, a FAMACHA© category that is assigned to an animal in which the Ht falls on or close to

Table II. Correctness of treatment decisions based on FAMACHA© scores, compared with haematocrit determinations.

Analysis	Data set: accuracy			
	Initial[a]	Set 1[b]	Set 2[b]	Set 3[b]
Number of observations	2 367	184	181	172
DECISIONS:				
No treatment required (%)				
Correct (None given)	–	89.8	85.3	86.5
Wrong (Treated)	–	2.8	9.8	8.4
Treatment required (%)				
Correct (Treated)	–	5.1	3.3	3.9
Wrong (Animals at risk)	**2.6**	**2.3**	**1.6**	**1.1**
Total correct (%)	–	94.9	88.6	90.4
Total wrong (%)	–	5.1	11.4	9.6

[a] From paper by Malan et al. [18], in which the subdivision is recorded differently.
[b] From Malan et al. [18] and Van Wyk et al. [33].

Table III. Reliability of FAMACHA© scoring in relation to predetermined haematocrit categories.

Data set No.	Animals (n)	Persons (n)	Index: mean[a]	
			Unpenalised	Penalised
Experienced evaluators				
1	184	1	1.8	2.3
2	181	1	1.4	1.8
3	172	1	1.2	1.4
4	336	1	1.8	2.2
Inexperienced evaluators (newly trained)				
5	20	18	3.9 (2.1–6.3)[b]	4.0
6	20	36	2.2 (1.3–4.3)[b]	2.5
7	19	14	1.9 (1.4–2.6)[b]	2.6
8	31	23	4.8 (3.6–6.0)[b]	4.8
9	20	32	2.4 (0.8–4.8)[b]	2.8

[a] Index: perfect score 0, higher scores increasingly unreliable, to a worst unpenalised score of > 30; penalised: progressive penalty, increasing exponentially with degree of inaccuracy; unpenalised: linear index, not increasing exponentially with degree of inaccuracy (see text).
[b] (range), between trainees in group.

the somewhat arbitrary division between FAMACHA© categories, could almost equally correctly be assigned to either the higher or the lower FAMACHA© category. "Incorrect" evaluations are therefore relative to the degree by which each clinical evaluation varies from the Ht.

The figures in bold of "animals at risk" in Table II indicate those anaemic animals which the evaluators would not have drenched despite Hts which were so low that the sheep may have succumbed to haemonchosis before the next evaluation. This "wrong decision" category differed little between the first and subsequent trials, possibly because the cut-off point for treatment was 15% in all instances.

Correct FAMACHA© evaluations in Data Sets 1–3 (Tab. II) were high (88.6–94.9%), similar to the results using other evaluations (Tab. III) for both trainees and experienced evaluators.

3.3. Progressive penalisation of incorrect decisions (Tab. III)

Since neither simple correlations nor the appropriateness of treatment decisions gave a fair indication of the degrees of deviation of estimates from the correct FAMACHA© categories, two new methods were developed to calculate indices for estimating this extent of deviation [5, 33]. Both methods comprised progressive penalisation of incorrect evaluations, commensurate with the increasing risk to the animals concerned; as the risk to an animal increased, a progressively increased penalty was applied [5, 33].

In Method 1 [5] a value of nil was allocated to correct decisions. This increased progressively with the degree of error (thus with a perfect score of nil, irrespective of the number of animals evaluated). In Method 2, a score of 10 was allocated for each correct decision, decreasing progressively according to the magnitude of the error [5].

The calculated indices in Table III show that using Method 1, the evaluations of experienced evaluators fell mostly in the correct Ht category or in an adjacent category [33], thus confirming the deductions in Table II on reliability. In addition, while the trainees were generally less successful, some of them were as successful as the experienced evaluators, and even practically illiterate persons were able to apply the system successfully (compare in Tab. III a best mean index of 0.8 for a trainee with 1.2 for the best performance by an experienced evaluator) [33].

As could be expected from the small numbers of animals theoretically at risk (Tab. II), the differences between the penalised and unpenalised indices were small (Tab. III) [33].

While Method 2 is not discussed further here, its application is similar to that of Method 1 (Bath and Van Wyk, unpublished observations, 2000).

3.4. Correspondence of the colours of the FAMACHA© chart with the chosen haematocrit ranges

By plotting a graph of the Ht values in Data Set 2 (one of the more accurate data sets – Tabs. II and III) against FAMACHA© estimates by an experienced person, Van Wyk et al. [33] attempted to evaluate how well the colours chosen for the FAMACHA© chart corresponded with the colours of the ocular mucous membranes of sheep in the different FAMACHA© categories. It appears from their graph that, had FAMACHA© category 2 encompassed a wider range of Ht values, the clinical evaluations would have been more accurate, on average. However, considerably larger proportions of the sheep in the tests had Hts in Categories 1 and 2 than in 3 to 5 [33], while equal numbers of sheep in each FAMACHA© category would have been preferable.

3.5. The effect of haematocrit ranges of test sheep on the success rates of trainees

By ranking data from five training sessions, Van Wyk et al. [33] came to the conclusion that the wider the range of Ht values of the sheep used in training and testing trainees, the more successful these persons became in correctly estimating the colours of the conjunctival mucous membranes and assigning animals to appropriate FAMACHA© categories (Tabs. IV and V). This is borne out by the similar rankings per parameter for each data set in Table IV.

Groups of sheep which had relatively narrow Ht ranges seemed to incline trainees to magnify the relatively small differences in colour they observed, to reflect all five FAMACHA© categories they expected to encounter [33]. A factor that may have played a role in the success rate of the trainees was that in each training session the sheep used for demonstrating the principle of the FAMACHA© evaluation included animals with some of the highest and lowest Hts available on that day (Van Wyk, unpublished observations, 2000). Thus it appears necessary to ensure that there are at least some moderately to severely anaemic animals in every group of sheep used for training and testing participants. FAMACHA© categories 4 and 5 are seldom well enough represented in sheep flocks available for training sessions, so it may be necessary to partially exsanguinate some sheep to obtain low Hts [3, 5].

4. REDUCTION IN TREATMENTS ADMINISTERED

During the period of regular clinical evaluation in the initial trial it was found that only 30% of the sheep could not cope with the heavy worm challenge without at least one treatment (Tab. VI) [16, 18, 30]. Moreover, only 10% required more than one treatment, and just 1% required the maximum of 4 treatments, while in previous seasons all the animals would have been treated about 5 times by the farmer

Table IV. Flock haematocrit ranges and ranks of FAMACHA© (F©) categories related to the performance of trainees[a].

Data set No.	F© index[b]		Haematocrit (Ht) distribution in flock[c]							
			Group Ht		Lowest Ht		Sheep/F© category			
							F© 1 + 2		F© 4 + 5	
	Mean	Rank	Mean (%)	Rank	Mean (%)	Rank	%	Rank	%	Rank
5	3.9	4	27	4	16	4	70	4	10	4
6	2.2	2	22	1.5	10	1.5	45	1	30	2
7	1.9	1	22	1.5	10	1.5	47	2	32	1
8	4.8	5	30	5	20	5	90	5	0	5
9	2.4	3	25	3	14	3	65	3	20	3

[a] Calculated from Van Wyk et al. [33]; ranks in ascending order, excepting for sheep in FAMACHA© category 4 + 5 (descending order).
[b] Unpenalised scores only (see text and Tab. III for the corresponding penalised scores); the lower the mean score, the greater the success rate.
[c] Calculated from the haematocrits of the sheep used for testing the success of trainees.

Table V. Proportions of haematocrits of trial sheep in each FAMACHA© (F©) category.

Data set	Animals (n)	Haematocrit analysis					
		Mean % (range)	Percentages of haematocrits in F© categories				
			1	2	3	4	5
Initial	373	27 (10–41)	54	21	16	7	2
1	184	22 (11–35)	14	35	29	22	1
3	172	22 (12–36)	16	31	37	16	1
4	336	26 (9–40)	43	34	19	5	1

during the 125 days of the trial [18]. The reduction in drenching was estimated to be more than 90% compared to previous practice on the farm [16, 18, 30].

As could be expected, only 45% of lactating ewes coped without any treatment (with 23% requiring more than 1 treatment), compared to 83% of the dry, and 71% of the pregnant animals (Tab. VI) [18].

When the clinical evaluation of anaemia was carried out by 10 farmers on their own without Ht determinations, lower reductions in treatments were recorded. Those farmers who could supply worm treatment costs either as estimates (five farmers) or from their records, indicated that after implementation of the FAMACHA© system, there was a mean of 58% reduction in treatment from the previous year or two [3]. The range was 38–80%, with one report of 96% reduction.

5. THE DYNAMICS OF FLOCK FAMACHA© SCORES OVER TIME

Bath et al. [3, 5] developed a form for recording FAMACHA© scores in the field. When completed, the different columns constitute a "histogram" that illustrates the distribution of anaemia scores in a flock and helps the farmer to evaluate changing levels of worm challenge, as the worm season progresses.

Through bar graphs drawn from the "histogram" data, the dynamics of haemonchosis in three of the trial flocks is illustrated in Figures 1 to 3, with superimposed line graphs depicting the percentages of each flock treated with anthelmintics at each examination [4, 5]. Bath et al. did not, however, discuss the implications of the results depicted in the bar charts.

It is clear that these results from the later trials (Fig. 1–3) support those in the initial trial. Most of the sheep remained in categories 1 and 2 throughout the trials, and the combined categories 3, 4 and 5 were seldom above 30% at any examination. When averaged over an entire *Haemonchus* season, only 10% of sheep were in these lower categories (Bath and Van Wyk, unpublished observations, 2000).

Three trials are used as examples in the discussion that follows.

Farm A (Fig. 1). The farmer concerned was largely left to run the trial by himself. The trial flock of young replacement Merino ewes was run on hilly natural pasture in relatively wet and cool conditions where *H. contortus* infection is worst from November until April, while *Trichostrongylus* spp. occur from May to September/October (Van Wyk, unpublished observations, 1999).

The figure shows that ewes in FAMACHA© 1 comprised more than 60% of the flock until the beginning of February,

Table VI. Anthelmintic treatment according to class of sheep (initial trial).

Ewes in trial		Treatments per ewe (% of class)				
Class of sheep	Number (n)	0	1	2	3	4
Dry	206	83	14	2	0.5	0.5
Lactating	112	45	32	16	5	2
Pregnant	51	71	22	6	2	0
Lactating + Pregnant	3	100	0	0	0	0
Total number (% of total number)	**372 (100)**	**260 (70)**	**75 (20)**	**26 (7)**	**8 (2)**	**3 (1)**

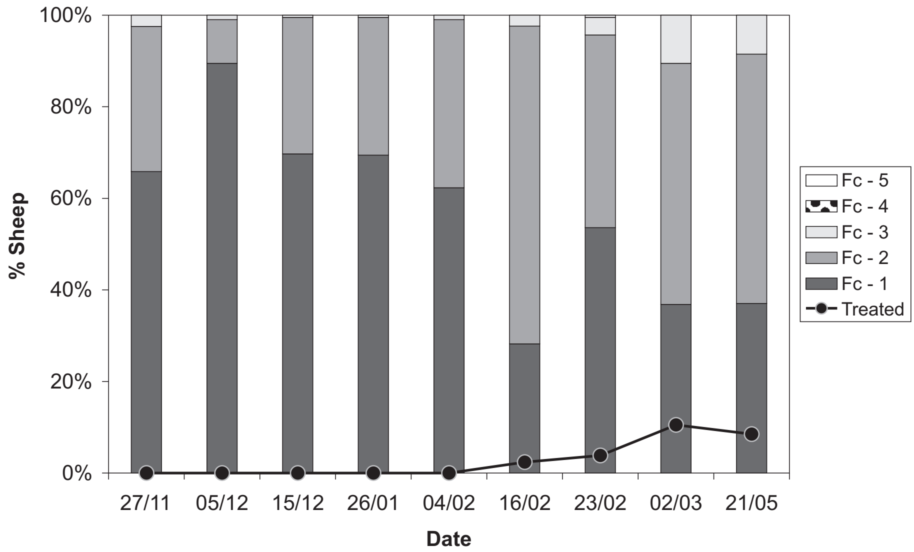

Figure 1. Seasonal changes in proportions of FAMACHA© scores in a flock of young replacement ewes: Farm A (approximate flock size: 210–290).

when a dramatic decrease in this category was accompanied by a reciprocal increase of FAMACHA© 2, and a few animals (2%) appeared in FAMACHA© 3, leading to the first selective anthelmintic treatment. Conventionally, all the animals would have been treated twice by then.

Despite only 25% of the flock being treated over the entire *Haemonchus* season, no cases of severe clinical haemonchosis were recorded. *Trichostrongylus* spp. should have been monitored, however, since after all the sheep had been treated in June, the condition of the flock improved considerably.

Farm B (Fig. 2). The summer was warmer than on farm A. *H. contortus* was the principal worm species encountered, to

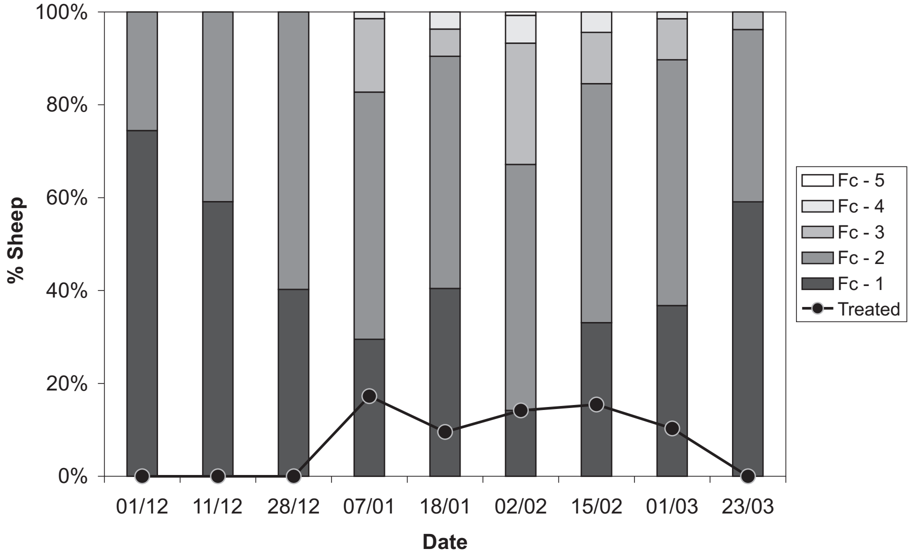

Figure 2. Seasonal changes in proportions of FAMACHA© scores in a flock of young replacement ewes: Farm B (approximate flock size: 140).

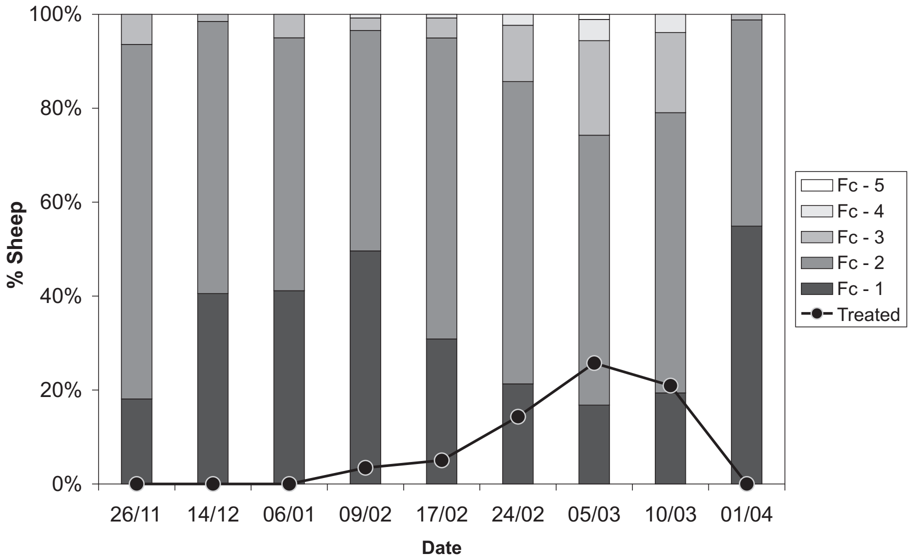

Figure 3. Seasonal changes in proportions of FAMACHA© scores in a flock of young replacement ewes: Farm C (approximate flock size: 260).

Table VII. Percentages of flock treated and growth performance (commercial farm).

Treatments (*n*)	Sheep (*n*)	% of flock	Mean mass (kg)
0	81	32.4	33.8
1	139	55.6	32.6
2	28	11.2	32.7
3	2	0.8	29.8

the practical exclusion of others. The farmer also made the decision when to drench individual animals with anthelmintics, the decision being based on clinical anaemia/submandibular oedema alone (Bath and Van Wyk, unpublished observations, 1999).

More liberal drenching suppressed clinical haemonchosis, but some severely anaemic sheep were found in January and February, suggesting that some animals in FAMACHA© category 2 should have been included with those that were treated, when the proportion of sheep in category 1 started to decline.

Farm C (Fig. 3). This farm was visited regularly by the research team, who also treated animals as required (summarised in Tab. VII). Despite weekly examinations, 4 sheep out of 250 were lost from haemonchosis at the most severe time of *Haemonchus* challenge. Drenching should probably have been increased when there was an obvious reduction in numbers of FAMACHA© 1 and the first sheep with category 3 membranes appeared. More details of the treatments on this farm are given in Section 6.2.

It is often difficult to differentiate between the colours of the conjunctivae of sheep in FAMACHA© categories 1 and 2, particularly in those with Hts at the lower range of category 1. Despite this fact, however, it is revealing to note in the three examples above (Figs. 1–3) the extent to which a downward trend in the proportion of sheep in FAMACHA© category 1 heralded approaching outbreaks of clinical haemonchosis.

6. THE EFFECT ON ANIMAL PRODUCTION

Because the animals were stressed and treated only when severely anaemic, some loss of production could be expected with application of the FAMACHA© system. While this remains to be tested thoroughly, some data from the various trials gave an indication of losses that may be anticipated.

6.1. Veld ram club trial

Veld ram clubs in South Africa comprise groups of farmers who annually select the best rams in the lamb crop phenotypically for comparison on common natural pasture with the rams of similar age from other breeders [5, 9].

About 180 young club rams shared common pasture for six months during summer and were left untreated for helminthosis, while regularly being weighed and evaluated by the FAMACHA© system [5]. *Haemonchus contortus* was the over whelmingly dominant worm species during the trial. From August, rams with pale conjunctival mucous membranes (categories 3, 4 and 5) were bled for Ht determination and treated only if the Ht had dropped to 15% or less. At the end of February all the rams were treated [9]. The mean mass and average daily gain (ADG) of the animals (illustrated in Fig. 4) rose until the end of November, when the worm challenge, as reflected by faecal worm egg counts, was rising fast, eventually to reach mean levels of 11 559 and 22 400 for untreated and

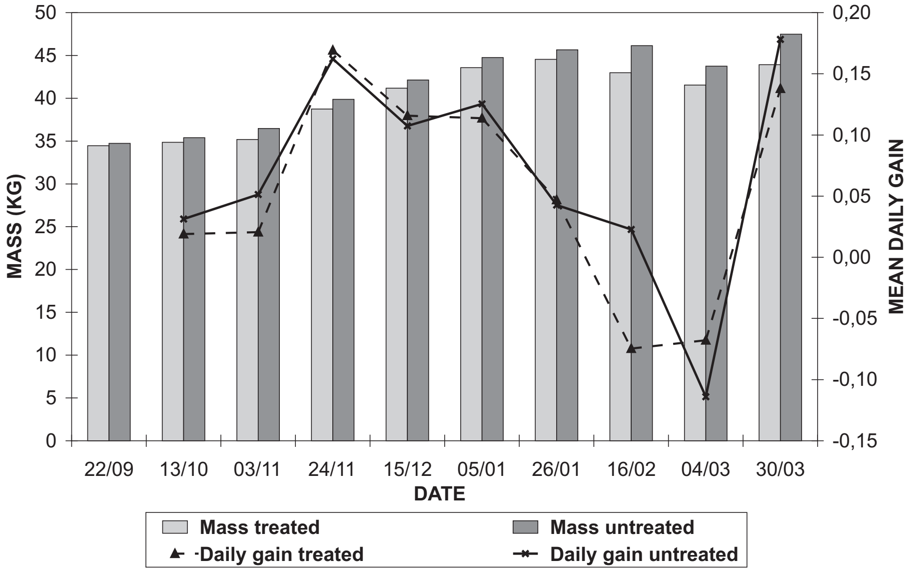

Figure 4. Mean mass and average daily gain (ADG), in kg, of treated and untreated weaner rams on the FAMACHA© system (Van Wyk and Bath, unpublished results).

Table VIII. Comparisons between severely affected (treated) and minimally affected (untreated) animals in the trial at a ram club [9].

Trait	Treated	Not treated[b]
Live-weight (kg)	43.4	46.0**
Weight gain (kg) (3 months)[a]	2.5	3.9**
Condition score	2.3	2.5*
Haematocrit %	15.7	24.0**
FAMACHA©	3.5	2.2**
Faecal worm egg count	22 400	11 559**

[a] The majority of the "treated" animals were dosed shortly before the end of the trial. Those treated earlier remained susceptible, explaining the lack of satisfactory response to treatment.
[b] Significance of differences between the groups: * $P < 0.05$; ** $P < 0.01$.

treated sheep, respectively (Tab. VIII). This coincided with a steep fall of their ADGs, which showed a marked recovery after anthelmintic treatment (Fig. 4).

The general trend in the weight changes of animals drenched once or more was similar to animals remaining untreated until the end of the trial; it was only when weighed for the last time before all the rams were dewormed on 16 February, that the mean ADG of the treated sheep was lower than that of the animals which had not been treated (Fig. 4) (Van Wyk and Bath, unpublished observations, 1999). This is reflected in the significant ($P < 0.01$) difference of 1.4 kg (lower) in the mean weight gain of the treated group, compared to the untreated sheep over the test period (Tab. VIII) [9].

The absence of suppressively drenched sheep for comparison prevents full assessment of the potential loss in production associated with the use of the FAMACHA© system in this trial.

6.2. Number of anthelmintic treatments

On one farm (Tab. VII) young replacement ewes not requiring any treatment were heavier at the end of the trial than those treated (Tab. VII) [3]. Those that required most treatments also tended to be lighter, probably because they were unable to cope with the worm challenge.

More than 90% of farmers surveyed were strongly of the opinion that the FAMACHA© system was not inimical to animal production (Sect. 8 below) [3, 5].

7. GENETICS AND HERITABILITY

Bisset et al. [9] investigated the heritability of resistance and resilience of sheep to haemonchosis in a South African Merino stud that comprised 523 weaner rams and ewes (the progeny of 21 rams), separated by sex into two flocks running on different pastures. The worm challenge was adjudged severe enough to create sufficient phenotypic variation in FAMACHA© score and FEC for genetic selection when some category 5 sheep were seen, and the FECs varied from 0–30000.

Performance records of live weight, greasy fleece weight, fibre diameter, Ht, FAMACHA© score and FEC values were obtained. These were analysed using multi-trait restricted maximum likelihood (REML) procedures to provide heritability estimates for each of the traits as well as phenotypic and genetic correlations amongst them (Tab. IX). The following fixed effects were taken into account in the analyses: sex, age of dam, birth rank and date of birth [5, 9].

From Table IX it can be seen that the heritability estimates for FEC, FAMACHA© and hematocrit readings were all relatively high (0.47 ± 0.2 for FEC and 0.55 ± 0.2 for each of the other two), suggesting that good genetic progress should be possible in selective breeding programmes. Genetic correlations amongst these traits were also very high, being close to unity in all cases. Thus the sire progeny groups which on average suffered the least reduction in Ht values (and lowest FAMACHA© scores), were consistently those which also had the lowest worm egg counts and vice versa [9]. In addition, strong favourable correlations with production traits indicated that these sire progeny groups were also those best able to remain productive in the face of heavy worm challenge. This result was in line with the results of Australian studies with Merinos infected with *H. contortus* [1], but not with those of Bisset and Morris [7] in New Zealand, who found unfavourable correlations between FEC and productivity in Romney sheep exposed to natural challenge with *Trichostrongylus* spp. and *Ostertagia* spp. In the South African study, fibre diameter was correlated with Ht and FAMACHA© score, with sire groups that suffered most from anaemia also tending to have the lowest fibre diameters [5, 9]. Selection for low fibre diameter under these circumstances could thus unwittingly result in the selection of more susceptible sheep.

Possibly the most important result emanating from this trial is the high heritability

Table IX. Heritabilities, phenotypic and genetic correlations among various traits estimated by multivariate ASREML analysis[a].

Trait	Weight gain	Log FEC	F©[b]	Haematocrit	Fleece weight	Fibre diameter
Weight gain	**0.22 ± 0.1**	–0.08 ± 0.1	–0.12 ± 0.1	0.13 ± 0.1	0.16 ± 0.1	0.21 ± 0.1
LogFEC	–0.91 ± 0.2	**0.47 ± 0.2**	0.59 ± 0.1	–0.72 ± 0.1	–0.18 ± 0.2	–0.15 ± 0.1
F©	–0.63 ± 0.2	1.0 ± 0.1	**0.55 ± 0.2**	–0.73 ± 0.1	–0.17 ± 0.1	–0.12 ± 0.1
Haematocrit	0.73 ± 0.2	–0.99 ± 0.1	–0.99 ± 0.1	**0.55 ± 0.2**	0.16 ± 0.1	0.19 ± 0.1
Fleece weight	0.17 ± 0.4	–0.64 ± 0.3	–0.75 ± 0.2	0.63 ± 0.3	**0.21 ± 0.1**	0.24 ± 0.1
Fibre diameter	0.76 ± 0.2	–0.66 ± 0.2	–0.65 ± 0.2	0.57 ± 0.2	–0.30 ± 0.4	**0.36 ± 0.1**

[a] Heritabilities on diagonal (bold), phenotypic correlations above and genetic correlations below the diagonal [9].
[b] F©: FAMACHA© estimates.

of the clinical estimates of FAMACHA© scores (Tab. IX). If this is confirmed in further studies, it should be possible for farmers with the necessary training to apply the FAMACHA© system to collect the data for host resistance/resilience progeny testing themselves. On the other hand, preliminary results indicate that the heritability of the FAMACHA© scores may not have been so high, had the worm challenge been at a lower level. In other words, genetic progress in breeding programmes based on FAMACHA© scores will probably be slower if the animals are not challenged to a similar extent as in this trial [9].

For farmers not in a position to undertake progeny testing, the relatively high heritability estimates suggest that a phenotypic selection strategy using FAMACHA© scores could still be a useful option to achieve genetic improvement in their sheep. However, by using this approach, progress is likely to be relatively slow [9].

8. PERCEPTIONS OF PERSONS APPLYING THE FAMACHA© SYSTEM

Two sets of questionnaires (one for farmers, the other for stockmen and veterinarians) were compiled for gauging the experience and perceptions of the FAMACHA© system of those involved in the trial [3]. The questions were designed to elicit their perceptions on six key aspects: understanding (training and pamphlets); practicability (labour requirement, reliability); animal production (poor growth, deaths and other problems); financial aspects (cost/benefit analysis); awareness (worms, anthelmintic resistance, control measures, stockman awareness of other diseases and conditions); and overall usefulness (will use again and recommend to others). In interviews the farmers, stockmen and veterinarians were overwhelmingly positive (88, 89 and 100% of interviewees, respectively) about the FAMACHA© system in their subjective responses to the questions put and statements made on the method [3]. A very small percentage of responses from the three groups of respondents rated the system as either bad (1.5%), poor (3.6%), or fair (1.7%) overall, while 24.4% of ratings were good and 68% were excellent, giving a total positive rating of 92%. This varied little between farmers, stockmen and veterinarians.

9. USE OF THE FAMACHA© SYSTEM IN GOATS

Vatta et al. [34–36], working with relatively small numbers of goats of resource-limited (small-scale) farmers, reported that the best value for the mean of the sensitivity and specificity (67–69%) for correctly identifying goats requiring treatment for haemonchosis (< 18% Ht) is achieved when animals in FAMACHA© categories 3, 4 and 5 are considered to be in need of treatment. Vatta (personal communication, 2001) is of the opinion that the range of colours in conjunctivae is smaller in goats than in sheep, therefore making the FAMACHA© system more difficult to apply. Furthermore, in view of the small numbers of animals and evaluators in their trials (as also emphasised in [5, 36]), and the limited range of conditions under which the trials were conducted by them, it is obvious that much more testing is needed for validating the use of the FAMACHA© system in goats to the same extent as in sheep. Despite the fact that the system has great potential for application in resource-limited communities, it is advisable that the suggested testing in goats is done under a range of conditions where larger groups of relatively uniform classes of animals can be included. It is important also to test goats on higher levels of nutrition than can usually be achieved in resource-limited communities.

An important consideration is that, when tested with sheep, the level of formal education did not seem to be important for successful implementation of the FAMACHA© system. Hence, if resource-limited farmers, many of whom are semi-literate, can indeed apply the system as effectively in goats as is the case with semi-literate persons in sheep, it implies that those goats that at present die due to insufficient resources for treating every animal when worm challenge is high, can probably be saved very cheaply.

10. PROBLEMS ENCOUNTERED WITH THE USE OF THE FAMACHA© SYSTEM

A number of problems were encountered during the trials on the FAMACHA© system, including incorrect diagnoses by farmers when sheep in the trial died [3]. Deaths due to bluetongue, pasteurellosis or pulpy kidney disease were ascribed by farmers to haemonchosis (thus potentially negatively impacting on the perceived value of the FAMACHA© system) on some farms where the management and/or application of the FAMACHA© system was not up to standard. In some cases trichostrongylosis and fasciolosis complicated the application of the system. On another farm the system appeared to be ineffective, but this was found to be caused by the inefficacy of the anthelmintic used for treating the anaemic animals (Bath and Van Wyk, personal observations, 1999).

Wrong FAMACHA© category choices were also encountered when farmers became complacent and too confident of their ability to score sheep without reference to the FAMACHA© card for calibration. When the animals were examined irregularly or at too long an interval during the peak *Haemonchus* season, some sheep may have died in the last third of the summer period [3].

It is also clear that the system was designed for the control of haemonchosis only (thus principally useful for warmer climates, with mainly summer rainfall), and must be used with caution with other haematophagous worm species. Insufficient testing in goats renders its use in this species less reliable than for sheep.

Regular and progressively frequent inspections of all sheep in the flock are mandatory to implement the system safely during the summer. This implies that good handling facilities and adequate trained labour are essential for success. In some countries high labour costs could limit its potential for implementation, unless ways could be found to reduce the labour requirement.

Although the system has only been thoroughly tested in South Africa to date, the initial results from production trials in Uruguay lend support to its usefulness elsewhere

(Salles and Castells, personal communication, 2002). Thus it seems reasonable to assume that its potential for use can extend to all countries where sheep are farmed and where haemonchosis is a major problem (summer rainfall and high temperatures). Local modifications may well be necessary to deal with unique problems or situations.

The labour requirement on farms with large numbers of sheep may be regarded as a limitation. However, the reduced selection for anthelmintic resistance with use of the FAMACHA© system is of almost inestimable value for sustainable sheep production. It should be investigated whether it may be sufficient if only the most susceptible classes of sheep are examined until the worm season has advanced to the point where haemonchosis becomes important. Similarly, it may be necessary to examine only representative samples of animals in a flock until anaemic sheep are encountered.

11. COMPARISON OF FAMACHA© WITH OTHER METHODS

Since in grazing ruminants almost all stock are infected with helminths at any time [11], the method of identifying individuals for treatment must simply and cheaply differentiate the severity of the infection, so that untreated animals can propagate unselected, susceptible worms at the expense of resistant worms [6–8, 26]. Furthermore, because of wide variations in pathogenicity between helminth species, this discrimination should ideally be at the genus level.

The explosive nature of outbreaks of worm infection [22] would make it necessary to evaluate the severity of worm infection at short intervals over peak worm seasons that last for as long as 4–5 months. For example, in the case of *H. contortus* infection the Hts of individual sheep have been observed to drop up to 7 percentage points in 7 days (Malan and Van Wyk, unpublished observations, 1991). Thus an animal with a relatively slight degree of anaemia can be on the brink of death within just over a week.

Taking the above requirements into account, the available methods for diagnosing worm infection in ruminants have been ranked for the 7 most important characteristics indicating how practical their application is for the frequent examination of individual animals, to identify and treat only those that are unable to withstand current worm challenge (Van Wyk and Bath, personal observations, 2002). The methods considered comprise FAMACHA©; Body Condition Score; weighing with an electronic scale, spring balance or weighband; Ht; plasma pepsinogen; Dag score [14, 15]; and serum antibody.

The average ranking of these methods identified FAMACHA© as the most useful criterion for treatment (but only for haematophagous worms), followed by Body Condition Score [10] and finally weighing, especially using a computerised electronic scale.

These three best methods all suffer from the problem of non-specificity. For example, anaemia in sheep can be caused by many factors [12, 20, 23] but in areas where *H. contortus* is the predominant helminth parasite, the most likely cause will usually be haemonchosis. Bearing this in mind, the test is reasonably specific, at least in terms of helminths. Nevertheless, consideration of other haematophagous parasites is always necessary, particularly *Fasciola, Bunostomum* and *Gaigeria* species.

Body Condition Score, likewise, is subject to an extremely wide range of diseases and problems, starting with malnutrition and including just about every disease affecting the host. Despite these disadvantages, Body Condition Score has a distinct advantage over weighing, for example, in that it is much quicker and involves virtually no cost, other than labour. As it is independent of body size, it is also able to eliminate a tendency to favour larger frame sizes, a shortcoming inherent in weighing animals, unless the Average Daily Gain is calculated per animal at each weighing. Body Condition Scoring now needs to be tested as thoroughly as the FAMACHA© system. Hopefully, by combining the two test systems (that are practical to apply simultaneously to a given flock of sheep or goats), the full potential of clinical evaluation can be realised, for both haematophagous and non-haematophagous worm infections.

12. DISCUSSION AND CONCLUSIONS

From the foregoing brief review it is clear that no single measurement or strategy on its own will be ideal for monitoring verminosis, or for identifying animals for treatment at a given time. In other words, no single parameter can be used simplistically to make decisions. This is partly because the parameters themselves are neither very precise nor specific, but also because different worm species give rise to different clinical manifestations, or different severities of clinical signs. Furthermore, different degrees of symptoms will be observed as a result of the signalment (type of animal) involved. Climatic conditions and grazing pressure also have to be considered.

The success of the FAMACHA© system in identifying those animals suffering most severely from haemonchosis for selective treatment, is based on the well-known phenomenon of overdispersion of worm burdens between animals in relatively uniform flocks on common pasture [2, 18]. This is well illustrated in the case of outbreaks of haemonchosis, where a considerable proportion of the sheep have Hts in the upper ranges of normal [13], while other animals are dying from severe anaemia, with Hts as low as 8–10 (Malan and Van Wyk, unpublished observations, 1993) [16]. This is also supported by the trials under present review (Tab. V).

The clinical evaluation of anaemia has been shown to be sufficiently reliable, both in its specificity and sensitivity, to be a useful adjunct to other measures for managing haemonchosis. Training of farmers and workers, even if functionally illiterate, has been found to be easy and practical. The dynamics of haemonchosis in a flock over time can readily be monitored and effective decisions based on this, can be made. The perceptions of both farmers and their workers have been overwhelmingly positive, and the practical implementation of the system can be considered wherever haemonchosis is endemic. Such problems as may be encountered can usually be readily overcome.

The FAMACHA© system has many benefits, the immediate one felt by farmers being a significant drop in treatment costs. This aids its acceptance. In the longer term, identification of individuals either best or worst able to cope with infection levels makes it possible to breed sheep more suited to the environment. Although not specifically proven, it is theoretically likely that reduction in treatment, especially of whole flocks, will help slow down the emergence of anthelmintic resistance.

In conclusion, although some aspects remain to be investigated, it has been shown that the FAMACHA© system can be used to determine the severity of haematophagous worm infection in individual sheep in flocks of moderate to small size. However, some important problems remain to be investigated, particularly the effect of application of the FAMACHA© system on production when the animals are subjected to high levels of worm infection, and its use by resource-limited farmers. Similarly, unless a similar method that can be applied by farmers is found for identifying animals unable to cope with non-haematophagous worm infection, the concept will have limited application. The most promising method for practical use on farms to identify severe infections with non-haematophagous worm species is the body condition score; there is little doubt that faecal worm egg counts, Ht, and body weight determinations are generally not feasible or cost-effective for the weekly monitoring that is required in the peak worm season. A possible exception is in the case of very small flocks, where weighing may be practical.

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