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Validation of the FAMACHA© eye color chart for detecting clinical anemia in sheep and goats on farms in the southern United States

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Abstract

Recent studies on sheep and goat farms in the southern United States indicate that multiple-anthelmintic resistance in *Haemonchus contortus* is becoming a severe problem. Though many factors are involved in the evolution of resistance, the proportion of the parasite population under drug selection is believed to be the single most important factor influencing how rapidly resistance develops. Therefore, where prevention of resistance is an important parallel goal of worm control, it is recommended to leave a portion of the animals untreated. Recently, a novel system called FAMACHA© was developed in South Africa, which enables clinical identification of anemic sheep and goats. When *H. contortus* is the primary parasitic pathogen, this system can be applied on

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less was considered anemic (Tables 6 and 7). Using the most conservative guidelines for treatment (PCV ≤19 and eye scores of 4 and 5), less than 6% of goats would have missed necessary treatment. When more liberal criteria were used, in all cases less than 1% of anemic goats would have failed to receive a required treatment (Tables 6, 8 and 9). Using the most liberal criteria (PCV ≤15 and eye scores of 3, 4 and 5), only 35% would have been correctly treated due to a high false positive rate, but none would have missed a necessary treatment (Table 8).

The percentage of sheep recommended for treatment decreased from 44.6% for eye scores of 3, 4 and 5 to 12.9% for eye scores of 4 and 5 [(true positive + false positive)/total number of sheep × 100]. A similar trend was seen with goats, but percentage of goats requiring treatment was higher. Recommending treatment of goats with eye scores of 3, 4 and 5 gave a value of 68.2% of the total and this decreased to 30.9% for goats with eye scores of 4 and 5. For both sheep and goats, sensitivity was maximized when eye score values of 3, 4 and 5 were considered anemic and PCV cut off was ≤15 (Table 10). Specificity was maximized when eye score values of 4 and 5 were considered anemic and PCV cut off was ≤19 (Table 10). In both sheep and goats, predictive value of a negative was greater than 92% for all anemia and eye score categories, and was greater than 99% for both eye score categories when an anemia cutoff of ≤15 was used. However, because of a large number of false positives, the predictive value of a positive was low for all categories. Box and whisker plots showing the relationship between PCV and eye score categories are presented for sheep and goats (Fig. 1).

Table 10
Comparison of sensitivity, specificity, and predictive values for positive and negative tests in sheep and goats using differing FAMACHA© and packed cell volume (PCV) criteria for positive test results and anemia

	Sensitivity[a]	Specificity[b]	$(a+b)/2 \times 100$	PV_{neg}[c]	PV_{pos}[d]
Sheep					
FAMACHA© values 3, 4, 5 considered positive test results					
PCV cut off ≤19%	92.2	59.2	75.7	98.9	15.6
PCV cut off ≤15%	100	56.9	78.5	100	6.1
FAMACHA© values 4, 5 considered positive test results					
PCV cut off ≤19%	64.1	91.3	77.7	96.9	37.6
PCV cut off ≤15%	82.6	89.1	85.8	99.5	17.4
Goats					
FAMACHA© values 3, 4, 5 considered positive test results					
PCV cut off ≤19%	93.9	35.5	64.7	97.7	16.9
PCV cut off ≤15%	100	32.9	66.5	100	4.9
FAMACHA© values 4, 5 considered positive test results					
PCV cut off ≤19%	57.6	72.8	65.2	92.5	22.9
PCV cut off ≤15%	83.3	70.9	77.1	99.2	9.0

[a] Sensitivity = (true positives/(true positives + false negatives)) × 100.
[b] Specificity = (true negatives/(true negatives + false positives)) × 100.
[c] Predictive value of a negative (PV_{neg}) = (true negatives/(true negatives + false negatives)) × 100.
[d] Predictive value of a positive (PV_{pos}) = (true positives/(true positives + false positives)) × 100.

4. Discussion

Indices typically used to measure the accuracy of diagnostic tests include sensitivity, specificity, and predictive values of positive and negative tests (Gerstman and Cappucci, 1986). Critical to establishing the sensitivity and specificity of a diagnostic test are the decision criteria selected for making a positive diagnosis. These decision criteria can be thought of as the threshold amount of evidence favoring the positive event (presence of disease) that is required to issue a positive diagnosis (Swets, 1988). In choosing decision criteria, it is important to consider: (1) the probability of a positive event; and (2) the benefits ascribed to a correct outcome (diagnosis) and the costs ascribed to an incorrect outcome. When the costs of an incorrect outcome (false negative) are high, lenient (liberal) decision criteria are usually preferred. But using lenient decision criteria will result in a positive diagnosis being made relatively often and proportions of both true and false positives will be high causing both reduced specificity and reduced predictive values for positive tests (Swets, 1988). These issues become quite important when evaluating a test such as FAMACHA© because not treating a false negative may mean that an animal dies, but it is quite acceptable to treat a false positive (non-anemic) animal.

In evaluating the ability of FAMACHA© to correctly identify anemic animals in need of treatment, the cut-off for PCV used for declaring anemia will have a great impact on the results. We therefore decided to evaluate our results using two different cut-off values: PCV $\leq$19 and PCV $\leq$15. The higher level was selected because the normal range for PCV in goats is 19–38 (Jain, 1986) and in epidemiologic studies, a PCV of 19 or less is sometimes used as an indication of anemia and the need for salvage treatment. But in reality, an animal with a PCV of 19 is not in any immediate health danger unless pasture conditions of severe *H. contortus* challenge exist. Based upon ranges selected for PCV in sheep scored by FAMACHA©, an animal with a PCV of 18–22 would be scored as a 3, whereas an animal with a PCV of 13–17 would be scored as a 4 (Vatta et al., 2001). Furthermore, initial investigations into the feasibility of using ocular mucous membrane color as a measure for clinical anemia in sheep successfully used a PCV of 15 as a cutoff for administering treatment (Malan et al., 2001). Consequently, a PCV of 19 may be too cautious a cutoff to assess fairly the accuracy of FAMACHA©, and a PCV of 15 may be a more appropriate level to apply. Using liberal criteria for treatment (eye score of 3, 4 or 5) and a definition of anemia of PCV $\leq$15, sensitivity in both sheep and goats was 100% (Tables 4, 8 and 10). This means that using these criteria, every animal scored with the FAMACHA© eye chart that was truly anemic and in need of treatment would have received treatment. When the same eye score criteria were used but PCV $\leq$19 was used as a cutoff, sensitivity decreased to 92 and 94% for sheep and goats, respectively due to small numbers of false negatives (animals with PCV 16–19 that were scored as a 1 or a 2) (Tables 2, 6 and 10).

When eye scores of 4 and 5 were used as criteria for treatment, sensitivity decreased noticeably but there was a concurrent increase in specificity. Importantly, the number of false negatives also increased. Using a PCV cutoff of $\leq$19, the percentage of false negatives was 2.7 and 5.2% for sheep and goats, respectively (Tables 3 and 7). This level would not be considered acceptable under most management conditions. However, if the more reasonable cutoff of $\leq$15 was used, percentage of false negatives fell to 0.5 and 0.6% for sheep and goats, respectively (Tables 5 and 9). At this level, death from anemia would be

Wyk and Bath, 2002). Considerably less work has been carried out in goats than in sheep and given the apparent lesser accuracy of the FAMACHA© system in this species, it is recommended that animals scored as 3 always be treated. Along with these recommendations is always the warning that FAMACHA© should only be used in conjunction with a properly designed worm control program and when veterinary guidance is available.

Based on the results of this study for both sheep and goats in the southern US and the US Virgin Islands, it appears that treatment could be safely withheld until animals score as 4s or 5s as long as animals are in good body condition and good overall general health, are examined frequently (e.g. every 2 weeks) and good husbandry is used to identify animals in need of treatment (e.g. unthrifty, anorexic, lagging behind, bottle jaw) between FAMACHA© examinations. Using this approach, the number of anthelmintic treatments administered will be greatly reduced, resulting in diminished selection pressure for resistance and a concomitant reduction in drug costs. However, since animals need to be checked at frequent intervals, labor costs will be increased. Furthermore, it is recommended that this approach should only be applied to adult animals. Lambs and kids have comparatively small blood volumes and can progress rapidly from moderate to severe anemia. This precaution should also be extended to ewes and does extending from the periparturient through the lactation period, since these animals have decreased immunity to GIN (Courtney et al., 1984; Herd et al., 1983; Miller et al., 1998; Rahman and Collins, 1992). These and other animals that may be stressed by disease or poor body condition should always be treated if scored as 3s.

An alternative approach could be to treat all 3s, 4s and 5s. This will result in many more treatments being given to non-anemic animals, but will virtually eliminate the possibility that an anemic animal will fail to receive treatment. Also, because many animals scored as 3s still have high FEC, treating this group will greatly reduce egg contamination of pastures. Although many more treatments will be given, significant refugia will be maintained and the evolution of anthelmintic resistance should still be slowed considerably.

On farms where low to moderate levels of resistance has been diagnosed to one or more drugs (60–95% reduction in FEC), a useful strategy to help gain the full benefits of both treatment and resistance prevention could be to use these "less-effective" drugs either singly or in combination on all animals scored as 3s. Using drugs that are less effective in this group should not cause clinical problems to develop because the few 3s that are moderately anemic and in need of treatment, should receive a sufficient reprieve from infection until the next FAMACHA© examination, and the majority of the 3s which are not anemic do not need to be treated. This strategy will help preserve the efficacy of the drugs that are still fully effective by saving them only for the 4s and 5s, and also will help to minimize egg contamination of pastures.

Although FAMACHA© sounds easy to use, experience in South Africa and the southern United States suggests that proper training of farmers is required to effectively use this method. It is critical that users of FAMACHA© understand the risks of incorrect use of this system (e.g. animal mortalities) and necessary precautions that should be taken. Because animals are not treated until they become anemic, it is important that efficacy of anthelmintics is determined prior to using FAMACHA©. If anthelmintic treatments had been applied at frequent intervals prior to using FAMACHA© resistance may have been masked, especially if a rotation of drugs was used. In contrast, if treatment is withheld until animals are scored as 4s or 5s and a drug that has moderate to poor efficacy due to worm resistance is used,

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