ELSEVIER

Veterinary Parasitology 88 (2000) 153–158

veterinary parasitology

www.elsevier.com/locate/vetpar

Short communication

Variability of resistance in goats infected with *Haemonchus contortus* in Brazil

C.A.F. Costa [a,*], L. da S. Vieira [b], M.E.A. Berne [c], M.U.D. Silva [d], A.L. Guidoni [a], E.A.P. Figueiredo [a]

[a] *EMBRAPA — Swine and Poultry Research, CP 21, CEP 89700-000, Concordia, SC, Brazil*
[b] *EMBRAPA — Goat Research, Sobral, CE, Brazil*
[c] *Universidade Federal de Pelotas (UFPEL), Pelotas, RS, Brazil*
[d] *EMBRAPA — Southeastern Animal Husbandry Research, São Carlos, SP, Brazil*

Received 30 April 1999; accepted 13 September 1999

Abstract

The variability between and within breeds with respect to nematode egg counts (EPG), packed cell volume (PCV) and hemoglobin (Hb) was studied in 36 yearling female goats of the Caninde (15), Bhuj (6) and Anglo-Nubian (15) breeds, exposed to *Haemonchus contortus*. Nematode-free goats were turned to a contaminated paddock in late February. From then on, fecal egg per gram counts (EPG), packed cell volume (PCV) and hemoglobin (Hb) were determined at 2-week intervals up to Week 18. The EPG, transformed as [log(EPG + 75)], varied ($P < 0.01$) between goats within breeds and between weeks of exposure, but not between goat breeds ($P > 0.05$). PCV and Hb were affected by goat breeds ($P < 0.05$), by goats within breeds ($P < 0.01$) and by weeks of exposure ($P < 0.01$). Anglo-Nubians had higher ($P < 0.01$) PCV and Hb than Caninde; Bhuj had intermediate values. There were two EPG rises; one between Weeks 6 and 10 and the other between Weeks 14 and 16. The within breed variability was marked during the EPG rise on Week 6, when individual egg counts ranged from 130 to 2500. The EPG rises coincided with drops in Hb. PCV presented a similar trend, though not as marked. *Haemonchus* was responsible for more than 95% of nematode eggs counted. Considering the goat as experimental unit, the correlation coefficients (r) were: -0.45, $P = 0.0064$, between log(EPG + 75) and PCV; and -0.53, $P = 0.0009$, between log(EPG + 75)

* Corresponding author. Present address: Dep. Parasitologia, ICB-UFMG, C.P. 486, CEP 31270-901, Belo Horizonte, MG, Brazil. Tel.: +031-491-5180.
E-mail address: ccosta@inetminas.estaminas.com.br (C.A.F. Costa).

PII: S0304-4017(99)00207-1

and Hb. The negative correlation between egg counts and blood values suggested breed differences in PCV and Hb were related to resistance to *H. contortus* infection and/or to its effects.

Keywords: Goats; Nematoda; *Haemonchus contortus*; Natural resistance; Variability; Brazil

In northeast Brazil, particularly in Ceara state, *Haemonchus contortus* is the most important helminth parasite of goats (Costa et al., 1991). Based on the genetic diversity between and within goat breeds in northeast Brazil (Shelton and Figueiredo, 1981), it was considered that a search for genetic variability in resistance to *H. contortus* might provide an option for nematode control.

Genetic variability with respect to resistance to nematodes in sheep has been well documented, and it has been observed between breeds, between sire lines within breeds and between individuals within breeds (Stewart et al., 1937; Gregory et al., 1940; Jilek and Bradley, 1969). Such variability has encouraged the inclusion of this parameter in several sire selection programs in Australia and New Zealand (Woolaston and Baker, 1996; McEwan et al., 1997). Concerning goats, Preston and Allonby (1978) reported differences in mortality, egg counts and nematode establishment between Saanen, East African and Galla breeds. Buvanendran et al. (1981) reported individual goat variability within the Red Sokoto breed with respect to nematode egg counts. Costa and Pant (1983) observed higher red blood cell counts in Anglo-Nubian kids, when compared with Caninde and Bhuj, exposed to the same natural *H. contortus* infection. Cabaret and Anjorand (1984) reported higher counts of *Muellerius capillaris* larvae in fecal samples of Saanen than in Alpine goats. The Saanen goats also had higher gastrointestinal nematode egg counts than the Alpine goats (Richard et al., 1990). Richard and Cabaret (1993), based on parasitological parameters, classified Alpine × Saanen cross-bred kids into susceptibles, intermediates and resistants to *Telodorsagia circumcincta* primary infection. Mandonnet et al. (1996), in Guadeloupe, found a sire effect on EPG (mean egg counts) from 203 six-month-old Creole kids. Patterson et al. (1996) classified fibre-producing male goats, exposed to natural infection, into responders and non-responders based on individual egg counts. Pralomkarn et al. (1997) observed Thai native goats to be more resistant to trickle infection by *H. contortus* than their Anglo-Nubian crosses. Baker et al. (1998) reported the post-parturient rise in egg counts to be higher in magnitude and more persistent in Galla does than in Small East African does.

The purpose of the present work was to investigate breed and individual variability, with respect to nematode resistance, in Caninde, Bhuj and Anglo-Nubian yearling female goats exposed to natural *H. contortus* infection.

The work was conducted at the EMBRAPA goat research center in the state of Ceara in northeast of Brazil from late February to early July, when transmission of *H. contortus* occurs (Costa et al., 1991). Thirty-six yearling female goats were used: 15 of the Caninde breed, 6 from Bhuj and 15 from Anglo-Nubian breeds. To remove existing nematode parasites, all goats were treated with oxfendazole at 8 mg/kg on Day −14, with levamisole at 15 mg/kg on Day −7 and fenbendazole at 8 mg/kg on Day 0. Once worm-free, the goats were turned out on a nematode-contaminated paddock. From Day 0 onward, EPG, PCV (packed cell volume) and Hb (hemoglobin)were determined at 2-week intervals up to Week 18.

Egg counts were determined by a modified McMaster technique. The mean of three counts was taken as the individual goat EPG value on each week of exposure. The EPG per nematode genus was determined on morphological basis following examination of infective third-stage larvae cultured according to routine procedures. Blood was collected in vaccum tubes coated with EDTA, and the PCV and Hb were determined according to routine procedures. The EPG data were submitted to analysis of variance after being transformed [log(EPG + 75)]. No transformation was applied to PCV and Hb. The EPG, PCV and Hb were first analyzed according to goat breeds, goats within breeds and weeks of exposure main effects, as well as the breed × weeks of exposure interaction. As the goat within breeds effect was significant, the goat breed effect was further analyzed using the goat within breed variance as the error term. For testing goat breed effect, only this last analysis was considered. The EPG, PCV and Hb least-square means for breeds were compared with a SAS (Statistical Analysis System) program (SAS Institute, 1989). The correlation coefficients (r) between EPG, log(EPG + 75), PCV and Hb, and their level of significance, using either single fecal and blood analysis or the goat as experimental unit, were also calculated with a SAS program.

The EPG varied ($P < 0.01$) between goats within breeds and between weeks of exposure, but not ($P > 0.05$) between goat breeds. The PCV was affected by goat breeds ($P < 0.05$), by goats within breeds ($P < 0.01$) and by weeks of exposure ($P < 0.01$). The Hb varied according to goat breed ($P < 0.05$), between goats within breeds ($P < 0.01$) and between weeks of exposure ($P < 0.01$). There was a significant ($P < 0.01$) interaction between goat breed and week of exposure on Hb values.

The average values per breed, for EPG, log(EPG + 75), PCV and Hb, during the entire 18-week period, are presented in Table 1. The Anglo-Nubians had higher ($P < 0.01$) PCV and Hb than Caninde; and Bhuj had intermediate values. Similar trend was observed for EPG, though not significant.

The weeks-of-exposure effect on EPG, PCV and Hb are shown in Fig. 1. The EPG showed two rises, first between Weeks 6 and 10, and again between Weeks 14 and 16. On Week 6, the breed average EPG were 1000, 500 and 650, respectively, for Caninde, Bhuj and Anglo-Nubians. These values ranged from 200 to 2500 in Caninde, 200 to 1030 in Bhuj and from 130 to 1660 in Anglo-Nubians. The EPG rises coincided with two drops in Hb values and may be explained by the negative correlation discussed in the next paragraph.

Table 1
Egg counts [EPG and log(EPG + 75)], packed cell volume (PCV) and hemoglobin (Hb) in yearling female goats from Caninde, Bhuj and Anglo-Nubian breeds exposed to natural *Haemonchus contortus* infection

Breeds	Mean ± Standard Error			
	EPG	log(EPG + 75)	PCV %	Hb g/dl
Caninde (15)[c]	397 ± 51	5.649 ± 0.093[a]	27.17 ± 0.44[b]	9.67 ± 0.16[b]
Bhuj (06)[c]	329 ± 81	5.526 ± 0.147[a]	28.27 ± 0.69[a,b]	10.06 ± 0.26[a,b]
Anglo-Nubian (15)[c]	302 ± 51	5.457 ± 0.093[a]	28.92 ± 0.44[a]	10.33 ± 0.16[a]

[a,b] Values in the same column superscribed with different letters are different ($P < 0.01$).
[c] Goat numbers per breed. The means were based on 10 (EPG and PCV) or 9 (Hb) determinations per goat.

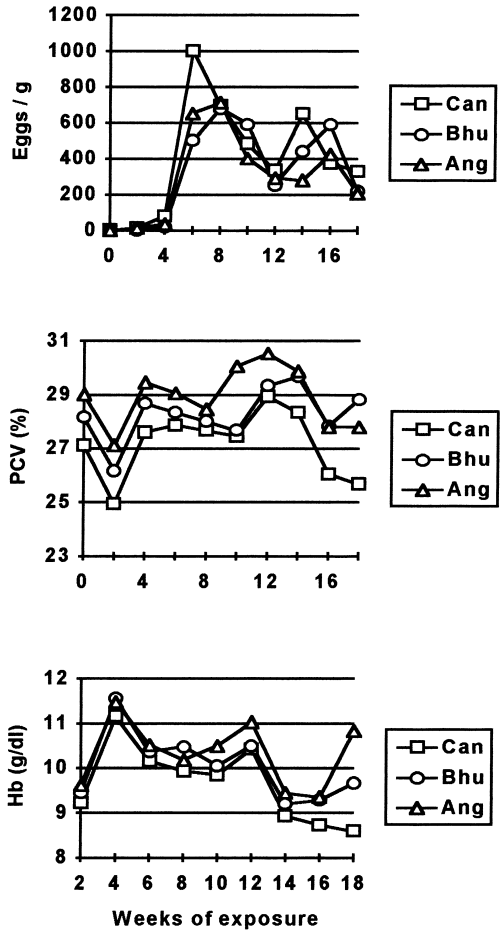

Fig. 1. Mean egg counts (EPG), packed cell volume (PCV), and hemoglobin (Hb) per goat breed and per week of exposure to *Haemonchus contortus*.

Values for PCV presented a similar trend as Hb, though not as marked. *Haemonchus* was responsible for more than 95% of the nematode eggs counted.

There was a negative correlation between egg counts and blood values. Considering the goat as the experimental unit, the correlation coefficients (r) were: -0.54 ($P = 0.0007$) between EPG and PCV; -0.63 ($P = 0.0001$) between EPG and Hb; and 0.92 ($P = 0.0001$) between PCV and Hb and between EPG and log(EPG +75). Transformation of EPG values reduced the correlation coefficients which were still significant [-0.45, $P = 0.0064$ between log(EPG + 75) and PCV; and -0.53, $P = 0.0009$ between log(EPG + 75) and Hb].

The capability of a host to withstand parasite infection has been classified as follows: resistance — the ability to suppress establishment and/or subsequent development of infection (Albers et al., 1987); and resilience — the ability to withstand the pathogenic effects of parasite infection (Riffkin and Dobson, 1979). As reviewed by Bisset and Morris (1996),

the major factor underlying resilience of sheep to *H. contortus* effects is simply the ability to limit the size of infection. That is, in sheep–*H. contortus* interaction, host resilience would be related to resistance. As clinical effects of *H. contortus* infection, altered PCV and Hb are in fact markers of host resilience, as considered by Bisset and Morris (1996). However, as a result of correlation between *H. contortus* infection and anemia, these parameters have also been used to measure resistance in sheep (Albers et al., 1987), as well as in goats (Baker et al., 1998).

In the present study the goats were exposed to natural *H. contortus* infection from the time they were turned on to pasture in late February to early July. As yearlings raised under pasture conditions in the same area, all had prior exposure to infection before the experimental period. The goat breeds did not differ in EPG, but the Anglo-Nubians presented higher PCV and Hb than the Caninde. The negative correlations between individual goat egg counts and blood values suggested that breed differences in PCV and Hb were related to host resistance to *H. contortus* infection and/or effects. The Caninde are native to the region of study, which has a semi-arid climate, whereas, the Anglo-Nubians originate from more humid regions. Pralomkarn et al. (1997) and Baker et al. (1998) also found more resistant goat genotypes to originate from humid climates, which might be explained by natural selection under conditions of higher challenge.

The within breed individual variability observed for EPG, PCV and Hb has been extensively reported in sheep (Woolaston and Baker, 1996) and goat breeds (Patterson et al., 1996; Pralomkarn et al., 1997) and part of this is genetically controlled. The heritability of EPG and PCV in sheep infected with *H. contortus* has been shown to range, respectively, from 0.26 to 0.34 and from 0.35 to 0.45 (Albers et al., 1987). The heritability of EPG in sheep has also been estimated as 0.23 (McEwan et al., 1997). In goats infected with *H. contortus*, the genetic role for the within breed individual variability of EPG and PCV values is not as defined as in sheep, but as reviewed by Mandonnet et al. (1996), the heritability for PCV in goats naturally infected with *H. contortus* has been estimated to be 0.22. Considering the importance of the within flock variability in sheep, which has been exploited for resistance selection in several breeding programs (McEwan et al., 1997) and the significance of this phenomenon in the goat breeds studied now; it should receive major research attention in future. Within breed variability has to be considered for at least two major reasons. First, further work has to be conducted to estimate heritabilities for these parameters in goats under our local conditions and to study correlations between these parameters and production traits. Second, the impact of within breed variability has to be considered in the epidemiology and control of gastrointestinal parasites of goats.

The authors are grateful to Helena Araújo da Ponte and to Felipe Cavalcante Machado for technical assistance.

References

Albers, G.A.A., Gray, G.D., Piper, L.R., Barker, J.S.F., Le Jambre, L.F., Barger, I.A., 1987. The genetics of resistance and resilience to *Haemonchus contortus* infection in young Merino sheep. Int. J. Parasitol. 17, 1355–1363.

Baker, R.L., Mwamachi, D.M., Audho, J.O., Aduda, E.O., Thorpe, W., 1998. Resistance of Galla and Small East African goats in the sub-humid tropics to gastrointestinal nematode infections and the peri-parturient rise in faecal egg counts. Vet. Parasitol. 79, 53–64.

Bisset, S.A., Morris, C.A., 1996. Feasibility and implications of breeding sheep for resilience to nematode challenge. Int. J. Parasitol. 26, 857–868.

Buvanendran, V., Sooriyamoorthy, T., Ogunsusi, R.A., Adu, I.F., 1981. Haemoglobin polymorphism and resistance to helminths in Red Sokoto goats. Trop. Anim. Health Prod. 13, 217–221.

Cabaret, J., Anjorand, N., 1984. Comparaison de l'infestation naturelle par les strongles et *Moniezia* sp. chez les races caprines Alpine et Saanen. Bull. Soc. Fr. Parasitol. 2, 49–52.

Costa, C.A.F., Pant, K.P., 1983. Contagens de eritrócitos e leucócitos em caprinos de diferentes raças, antes e depois de medicações anti-helmínticas. Pesq. Agropec. Bras. 18, 1127–1132.

Costa, C.A.F., Vieira, L. da S., Berne, M.E.A., 1991. Influência das instalações de pernoite, do tipo de pastagem e da suplementação volumosa sobre o parasitismo por nematódeos em caprinos. Pesq. Agropec. Bras. 26, 521–533.

Gregory, P.W., Miller, R.F., Stewart, M.A., 1940. An analysis of environmental and genetic factors influencing stomach worm infestation in sheep. J. Gen. 39, 391–400.

Jilek, A.F., Bradley, R.E., 1969. Hemoglobin types and resistance to *Haemonchus contortus* in sheep. Am. J. Vet. Res. 30, 1773–1778.

Mandonnet, N., Aumont, G., Fleury, J., Gruner, L., Bouix, J., Vu Tien Khang, J., 1996. Genetic variability in resistance of Creole goats to natural infection with Trichostrongylids in Guadeloupe. Ann. NY Acad. Sci. 791, 421–431.

McEwan, J.C., Bisset, S.A., Morris, C.A., 1997. The selection of sheep for natural resistance to internal parasites. In: Barrell, G.K. (Ed.), Sustainable Control of Internal Parasites in Ruminants: Animal Industries Workshop Lincoln University. Canterbury, New Zealand, Lincoln University, pp. 161–181.

Patterson, D.M., Jackson, F., Huntley, J.F., Stevenson, L.M., Jones, D.G., Jackson, E., Russel, A.J.F., 1996. Studies on caprine responsiveness to nematodiasis: segregation of male goats into responders and non-responders. Int. J. Parasitol. 26, 187–194.

Pralomkarn, W., Pandey, V.S., Ngampongsai, W., Choldumrongkul, S., Saithanoo, S., Rattaanachon, L., Verhulst, A., 1997. Genetic resistance of three genotypes of goats to experimental infection with *Haemonchus contortus*. Vet. Parasitol. 68, 79–90.

Preston, J.M., Allonby, E.W., 1978. The influence of breed on the susceptibility of sheep and goats to a single experimental infection with *Haemonchus contortus*. Vet. Res. 103, 509–512.

Richard, S., Cabaret, J., 1993. Primary infection of kids with *Teladorsagia circumcincta*: susceptibility and blood constituents. Vet. Parasitol. 47, 279–287.

Richard, S., Cabaret, J., Cabourg, C., 1990. Genetic and environmental factors associated with nematode infection of dairy goats in Northwestern France. Vet. Parasitol. 36, 237–243.

Riffkin, G.G., Dobson, C., 1979. Predicting resistance of sheep to *Haemonchus contortus* infections. Vet. Parasitol. 5, 365–378.

SAS Institute, 1989. SAS language guide for personal computer. 4th ed., Version 6.

Shelton, M., Figueiredo, E.A.P., 1981. Types of sheep and goats in Northeast Brazil. Int. Goat Sheep Res. 1, 258–268.

Stewart, M.A., Miller, R.F., Douglas, J.R., 1937. Resistance of sheep of different breeds to infestation by *Ostertagia circumcincta*. J. Agric. Res. 55, 923–930.

Woolaston, R.R., Baker, R.L., 1996. Prospects of breeding small ruminants for resistance to internal parasites. Int. J. Parasitol. 26, 845–855.