Relationship between nematode parasitism of the digestive tract and the characteristics of dairy goat farms in two French regions

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SUMMARY

Twenty goat farms have been surveyed in the Centre and in the South East of France for nematode infection. The intensity of infection was assessed by means of individual faecal egg counts performed four times per year. The possible occurrence of resistance to benzimidazoles on the farms was evaluated by a faecal egg count reduction test. In parallel, information on the typological characteristics of the farms have been collected through a questionnaire on the general structure, the flock and the mode of management of parasitism. A Principal Component Analysis (PCA) was performed in order to examine the associations or oppositions between variables defining the farm and the level of parasitism. On the other hand, a Discriminant Analysis was applied to examine the factors explaining the mean annual number of anthelmintic treatments. Results from the PCA showed that the high level of infection was associated with the size of the flock, the total surface of farm and with the presence of other host species. On the other hand, nematode parasitism was inversely related to the milk production and to the stocking rate. The Discriminant Analysis indicated that farms with a low number of annual treatments (less than 2) were characterised either by a low stocking rate or by a large distribution of concentrates indoors despite the use of pastures. On the other hand, the group of farms with the highest number of antiparasitic treatments (more than 4) corresponded to farms where anthelmintic resistance to benzimidazoles has been identified during the survey.

KEY-WORDS : trichostrongyles - multivariate analysis - anthelmintic - dairy goats.

RÉSUMÉ

Relations entre le parasitisme du tube digestif par des nématodes et les caractéristiques des fermes caprines dans deux régions d'élevage en France. Par S. VALLADE, H. HOSTE, C. GOUDEAU, C. BROQUA, K. LAZARD, Y. LEFRILEUX, C. CHARTIER et E. ETTER.

Au cours d'une enquête effectuée dans 20 élevages caprins du Centre et du Sud-Est de la France, le niveau d'infestation du tube digestif par des trichostrongles a été mesuré à 4 reprises au cours d'une saison de pâturage. La présence éventuelle de résistance aux benzimidazoles a été estimée par un test de réduction d'excrétion des œufs de parasites. Les principales caractéristiques typologiques des exploitations, des troupeaux et du mode de gestion du parasitisme ont été relevées à l'aide d'un questionnaire. Une analyse multivariée en Composantes Principales a permis d'établir les associations et les oppositions entre les principales variables caractérisant les fermes et le niveau parasitaire. Par ailleurs, les facteurs expliquant la fréquence d'emploi annuel des anthelminthiques ont été analysés par une Analyse Discriminante. Les résultats de l'Analyse en Composantes Principales montrent que la sévérité des infestations est associée à la taille du troupeau, à la surface totale de l'exploitation et à la présence d'autres espèces hôtes. A l'inverse, l'importance des infestations est corrélée négativement à la production laitière et au chargement par hectare. D'autre part, les résultats de l'Analyse Discriminante indiquent qu'une faible fréquence d'utilisation des produits antiparasitaires est associée soit à un faible chargement à l'hectare, soit à une forte distribution de concentrés à l'auge malgré l'exploitation du pâturage. A l'opposé, les fermes où une fréquence élevée des traitements a été notée sont celles où des résistances aux benzimidazoles ont été mises en évidence au cours de l'enquête.

MOTS-CLÉS : trichostrongles - anthelminthiques - analyses multivariées - chèvres laitières.

Introduction

One of the main constraints associated with grazing in goats is infection of the digestive tract with parasitic nematodes. The usual way to control this parasitism was represented by strategic or tactic administrations of anthelmintic treatments based on the epidemiological knowledge of infection or related to the appearence of clinical signs in a flock. However, two main factors have raised recently which suggest that the exclusive reliance on anthelmintics to control trichostrongyle infections has to be reconsidered. The first factor corresponds to the general evolution of agriculture towards more sustainable farming systems, implying a general reduction in the use of chemicals. The second factor is the worldwide development and spread out of anthelmintic resistance in nematode populations. Within the world, the phenomenon is particularly prevalent in goat farming [14] and alarming in dairy goats where the number of authorised antiparasitic substances is limited during lactation. Combination of these two factors clearly argue for a reduction in the use of anthelmintics and for the seek of non chemical solutions to control nematode infections of the digestive tract. Several options have been proposed and discussed in sheep and cattle. The efficiency, advantages and consequences of these various methods have begun to be examined in goats (integrated grazing management or biological control [1, 16], improvement of host resistance through genetic selection [18, 19] and/or protein supplementation [15]). On the other hand, another approach to identify alternatives to chemicals is to get a better epidemiological knowledge of the factors influencing nematode infection of the digestive tract. In particular, comparison of the actual farming systems, relying heavily or not on anthelmintics to control parasitism, in order to relate the farm characteristics or system factors with the importance of parasitism can bring valuable information for future integrated methods of control.

The results presented in the current study correspond to this approach based on a survey conducted in 2 main areas of dairy goat production in France.

Materials and methods

EXPERIMENTAL DESIGN

Twenty dairy goats farms have been involved in the survey. The farms have been selected according to the following criteria : use of pastures by the goats, adhesion of the farmers to the survey, record of individual milk production. The 20 farms originated from 2 separate, main areas of goat production in France. i.e. the administrative regions, Centre and Rhône Alpes.

In each farm, the evolution of nematode infection of the digestive tract has been assessed through regular sampling of a part of the flock. In addition, a questionnaire has been fulfilled by the farmers in order to collect information on **i**) the flock of goats, **ii**) the general characteristics of the farm, **iii**) the methods applied to control nematode parasitism of the digestive tract (see detailed description in "Statistical Analysis").

PARASITOLOGICAL DATA

Within each farm, the flock has been sampled four times per year, during the grazing season (beginning of Spring, end of Spring, beginning of Autumn, end of Autumn). Faecal samples have been taken individually on 50 goats per farm which represented 50 to 100 % of the flock. The sampled goats have been randomly selected except that the proportion of first lactation animals and adult goats within the herd was respected in the sample.

Individual faecal egg counts have been determined using a modified McMaster technique [20]. Larval cultures have been performed twice per year (Spring and Autumn) to examine the main genera occurring on the farms.

Lastly, the prevalence of benzimidazoles resistance on the 20 farms has been assessed using the faecal egg count reduction test. The farms were described as resistant when the reduction in egg excretion following application of benzimidazoles was less than 90 % [2].

STATISTICAL ANALYSES

The STAT-ITCF computer program was used to analyse the relations between the parasitological data and the variables which characterised the farm. Fourteen variables have been used in the analysis (Table I). Six variables were related to general characteristics of the farm and of the flock : Number of goats, Proportion of 1st lactation, Total milk production per year, Number of people working on the farm, Total surface of the farm, Number of other host species (cattle or horse). Five variables aimed at describing the mode of grazing : Number of grazing months, Surface offered for grazing, Number of paddocks used for grazing, Number of hectares offered per goat (reverse of the stocking rate), Daily amount of concentrates given per goat during the grazing season. Last, 3 variables were related to the mode of control of nematode parasitism on the farm : Number of annual treatments, Number of anthelmintic families per year, Mean total number of egg counts in the flock.

Two different multivariate analyses have been performed based on these data.

Firstly, a Principal Component Analysis (PCA) was conducted in order to provide a general description of the relationships between the different variables. PCA was performed on a matrix of 14 variables and 20 lines (farms). The data were standardised before being analysed as actual values — mean values /standard deviation for the variable. The relative position of the variables on the circle corresponded to either a positive association (proximity of variables) or a negative association (variables diagonally opposed on the plane).

Secondly, a Discriminant Analysis was performed to analyse the factors explaining the number of annual anthelmintic treatments. For the analysis, the farms were initially alloted into 3 groups : Group 1 : low number of treatments (1 or 2 per year) ; Group 2 : 3 treatments per year ; Group 3 : more than 4 treatments per year. Nine farms belonged to group 1; 5 to group 2 ; 6 to group 3.

Results

The mean egg counts per year, the number of annual treatments and the resistance status identified on each farm are presented in table II, according to the 2 geographical areas of the survey.

	Mean	Range
Number of Goats (NbGt)	76,5	[41 – 111]
Proportion of first lactation (1st LACT)	23,1	[12 – 36]
Mean yearly milk production (MILK)	733	[470 – 990]
Number of other host species (OTHER)	1,5	[0 –10]
Total surface of the farm (SURF)	34,8	[5,2 – 150]
Total surface for grazing (GRZSUR)	9,4	[1 – 21,2]
Number of paddocks (NbPAD)	3,8	[1 – 8]
Number of grazing months / year (GRAZ)	8,2	[6 – 12]
Mean Surface offered per goat while grazing (SURF/Gt) (ares)	142	[48 – 417]
Mean amount of concentrate distributed while grazing (CONC)	1,20	[0.4– 1,7]
Number of people working on farm (WK)	1, 6	[1 – 3]
Mean annual number of treatments (NbTrt)	2,75	[1 – 5]
Number of AH family/ year (NbFAM)	1,3	[1 – 2]
Mean annual egg excretion (EPG)	210	[6– 673]

TABLE I. — Mean and range of the 14 quantitative variables used for the PCA multivariate analysis describing the main characteristics of farms.

	Mean annual egg excretion (min./max.)	Reduction of egg excretion after benzimidazoles	Number of annual anthelmintic treatments
CENTRE			
C1	232 (130 / 350)	- 58 %	2
C2	208 (96 / 303)	- 96%	5
C3	91 (6 / 160)	- 65 %	5
C4	226 (85 / 282)	- 33 %	2
C5	344 (63 / 497)	- 95 %	3
C6	568 (459 / 728)	- 93 %	1
C7	188 (89 / 249)	- 97 %	2
C8	12 (0 / 24)	NP	2
C9	56 (31 / 85)	- 98 %	1
C10	30 (8 / 55)	- 98 %	1
Mean	**195**		**2,4**
RHONE ALPES			
RA1	307 (201 / 478)	- 50 %	4
RA2	427 (226 / 837)	- 5 %	4
RA3	201 (46 / 313)	- 97%	3
RA4	379 (173 /609)	- 35 %	3
RA5	53 (13 /104)	- 94 %	2
RA6	673 (331/1017)	- 27 %	4
RA7	41 (0 / 72)	- 95 %	2
RA8	6 (0 / 15)	NP	3
RA9	47 (18 / 107)	- 93 %	3
RA10	112 (20 / 203)	- 96 %	3
Mean	**225**		**3,1**

NP : Not Performed

TABLE II. — Main parasitological parameters of the 20 farms surveyed in the study.

The mean annual number of egg counts per farm was not different in the two geographical regions and the prevalence of resistance to benzimidazoles was also comparable (33,3 % in the West and 44 % in the South East). On the other hand, the mean number of annual treatments per year was higher in farms from the South East than in those from the Centre.

PRINCIPAL COMPONENT ANALYSIS

The main relationships between the 14 variables included in the multivariate analysis are presented on figure 1 corresponding to the circle of correlations composed with axes 1 and 2. Axis 1 represented 20,3 % of the whole variability whereas 19,5 % of the variation was associated with axis 2.

Axis 1 (horizontal) correlated mainly with the number of paddocks (- 0,8) and, to a lesser extent, with the number of anthelmintic treatment (- 0,57) and with the surface offered per goat (+ 0,54). On the other hand, Axis 2 (vertical) was mainly composed with the following variables : surface for grazing (- 0,82), surface offered per goat (- 0,60) ; amount of concentrate in the diet (+ 0,66) and the percentage of goats in first lactation within the flock (+ 0,58).

The variable EPG characterised the mean annual intensity of nematode infection in each farm. This variable was in close proximity with the number of goats/farm and with the general surface of the farm as well as the number of other host species. On the other hand, this variable related to the importance of parasitism within the flock appeared opposed to the grazing surface offered per goat (inverse of the stocking rate), to the general surface offered for grazing and, to a lesser extent, to the amount of milk production and the length of grazing.

DISCRIMINANT ANALYSIS

The pseudo F (26,8) obtained by the analysis was largely higher than the highest value calculated for each separate variable (F = 8,4). This justified that the Discriminant Analysis was pursued. Axis 1 was correlated on one side to the general surface for grazing (- 0,975), the number of paddocks (- 0,81) and the surface offered per goat (- 0,79) and on

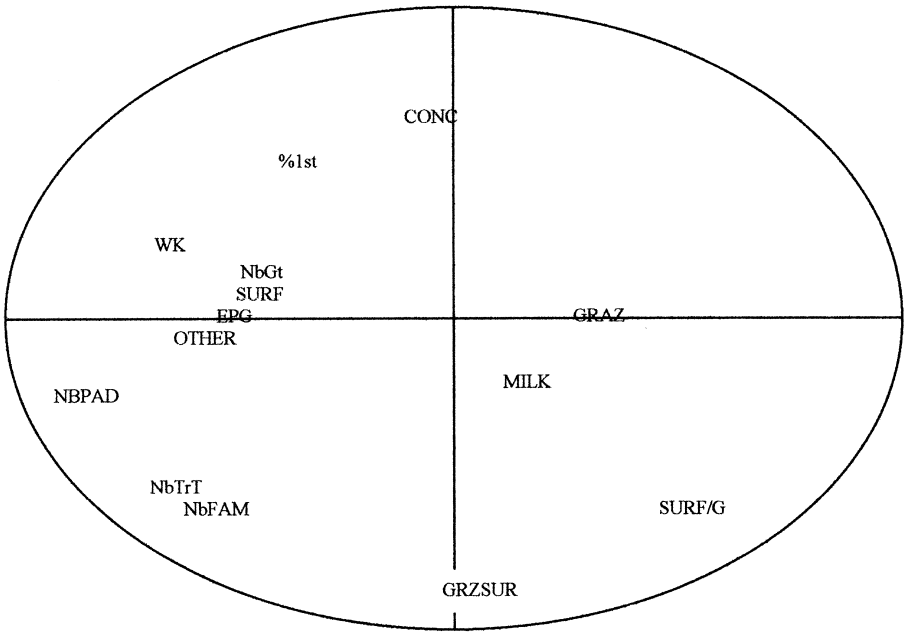

FIGURE 1. — Relationships between the numerical variables of the dairy goat farms derived from the Principal Component Analysis (circle of correlations constructed with axes 1 and 2). Abreviations : CONC : Daily amount of concentrates per goat ; EPG : Mean total number of egg excretion ; GRAZ : Number of grazing months ; GRZSUR : Surface offered for grazing ; %1st : Proportion of 1st lactation ; MILK : Total yearly milk production ; NbTrt : Number of annual treatments ; NbFAM : Number of anthelmintic families ; NbPAD : Number of paddocks used for grazing ; SURF/G : Number of hectares per goat ; NbGt : Number of goats OTHER : Number of other host species ; SURF : Total surface of the farm ; WK : Number of working people on the farm.

the opposite side, to the amount of concentrate in the diet (+ 0,98) the general surface of the farm (+ 0,999) and the percentage of goats in first lactation (+ 0,88).

Axis 2 was composed with the number of goats (- 0,99) the milk production (- 0,99) and the length of grazing on one hand ; the egg excretion (+ 0,97) and the number of other species (+ 0,99) on the other hand. Basically, the farms were discriminated according to axis 1 which characterised the mode of goat production [extensive use of pasture (left side of the circle) to more intensive system defined by a larger part of concentrates in the diet (right side)]. The distribution of farms according to axis 2 was mainly related to the intensity of parasite infection and to the size of the flock (Top : Heavily infected/low number of goats vs bottom : large flock and small number of worms).

The general position of the different variables after the discriminant analysis as well as the repartition of the farms are illustrated on figure 2. To summarize, farms from group 1 were mainly distributed in the right bottom corner. They were associated mainly with variables characterising intensive farming (high amount of concentrate distributed) and actually, a limited use of pasture. Farms from group 2 aggregated mainly in the bottom left corner of the graph. They corresponded to variables related to a large use of pasture combined with a limited intensity of parasite infection. Last, farms from group 3 (top, left corner) were mainly qualified by use of pasture associated with high level of parasitism. Those farms were also associated with the presence of other host species. When examining the repartition of those farms according to the status for anthelmintic resistance, the farms initially alloted to group 3 were also the farms where benzimidazole resistance was detected during the survey.

The discriminant analysis provided the possibility to compare the repartition of farms into the 3 groups before and after the analysis was performed, i.e according to the initial criteria of categorisation or to the newly defined combined factor issued from the analysis. Overall, 90 per cent of the farms were alloted to the same group before and after analysis (Table III). On the other hand, 2 farms were classified into different groups before and after the discriminant analysis. One farm initially in group 1 and another one in group 2 were classified in group 3 at the end of analysis. Interestingly, BZ resistance was also identified in the 2 farms which were eventually ascribed to group 3.

Discussion

The approach aiming at relating the level of nematode parasitism of the digestive tract with the main characteristics of the farms has been developed previously for goat farms in France [4, 21]. However, this previous study was restricted to one limited geographical area in the Centre of France and it appeared useful to expand the observations to other French areas of goat production. In addition, major differences occurred in the control of parasite infection in dairy goats

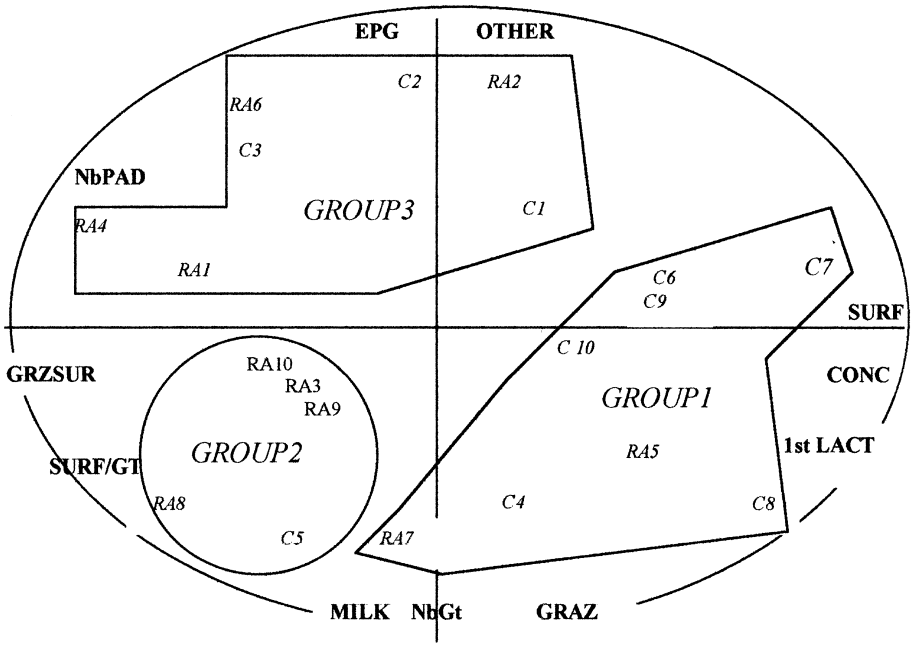

FIGURE 2. — Repartition of the variables (Bold, Codes see captions of figure 1) and groups of individual farms (Italics, C : Region Centre ; RA : Region Rhone Alpes ; see list in table II for correspondance to anthelmintic resistance) following the Discriminant Analysis.

	Initial repartition of farms *before* analysis	Group 1	Group 2	Group 3	% of agreement in classification
Treatment < 2	9	8		1	88,9
Treatment = 3	6		5	1	83,3
Treatment > 4	5			5	100

TABLE III. — Comparison of the classification of farms according to the 3 criteria used in AFD based on the number of treatments.

since the study by CABARET *et al* [4]. Firstly, some anthelmintic drugs used in 1986 have been discarded from milking does. Secondly, resistances to benzimidazoles have been repeatedly identified in various French geographical areas. As a consequence, recommendations have been emitted in order to limit the spread of this resistance phenomenon within the worm populations [2, 14]. Lastly, the general tendency in agriculture for a reduction in the use of chemicals also occurs in goat industry. Overall, these points were arguing for an actualisation of the observations.

Results form the Principal Component Analysis indicated that egg excretion in the farms was positively correlated with the size of the flock and the total surface of the farm. It was also associated with the presence of other host species on the farm. This last result confirmed previous observations acquired from a survey on 16 goat farms in Touraine, where the intensity of egg excretion was negatively related to the sole presence of goats on farm [5]. This possible positive association between other host species and the intensity of parasitic infection should be clarified as alternate or common grazing between different host species is usually considered to represent an alternative to limit the contamination of pastures with trichostrongyle larvae [1, 11].

In contrast, the egg output appeared negatively related to 3 variables (grazing surface per goat ; total surface for grazing, duration of grazing) which in fact are qualifying an extensive mode of farming. This result from PCA therefore strongly suggests that the level of parasitic infection was particularly limited in those conditions of goat breeding. This observation is in agreement with the usual opinion that the intensity of nematode infection of the digestive tract in grazing ruminants is inversely related to the stocking rate although studies in sheep have shown that the relationship is not exactly linear [22, 23]. Moreover, this result confirmed also observation from the previous survey in goat farms in the Western part of France (Touraine) where egg excretion

was negatively related to the number of hectares of pasture per goat [3].

The egg excretion was negatively related to the annual milk production. In several studies, a higher susceptibility to parasites has been identified in goats exhibiting the higher level of milk production. However this inverse relationship was based on milk production data estimated in the absence of any worm infection [9]. In the present study, the inverse relationship between both variables more probably reflected the depressive effect of nematode infection on milk yield as previously stated in experimental [8, 9, 10] or natural conditions [6, 12]. Surprisingly, in contrast with previous surveys [3], the level of egg excretion was not clearly opposed to the number of annual treatments. Explanations for this paradoxical result were obtained from the discriminant analysis.

The main objective of the epidemiological survey and application of the multivariate analyses was to identify factors which could explain the differences in frequency of anthelmintic use amongst goat farms. For this purpose, a discriminant analysis was applied, based on the repartition of farms according to the annual frequency of treatments in order to examine which system factors were associated with this initial classification. In a recent questionnaire survey on the use of anthelmintics in French goat farms collected from the main areas of production, the estimated mean number of treatments per year was 2.74 [13]. Therefore, the farms were initially classified for the discriminant analysis depending whether the number of treatments was equal, less or more than 3.

The farms with less than 3 annual treatments were characterised by a large surface and by a high percentage of concentrates in the diet (more than 1,2 kg). Recently in an experimental study, it has been shown that when significant amount of concentrates are given indoors to goats using pastures, the part of grazing in the diet could be actually quite limited, particularly when the quality of grass offered was low [17]. This "so called" phenomenon of substitution of grass by concentrates has obvious consequences on nematode infection as the number of infective larvae ingested is related to the amount of grass consumed. This could explain that in farms from group 1, anthelmintics were scarcely given although goats were bred outdoors.

On the opposite, farms with more than 4 annual antiparasitic drenches were characterised by a high level of egg excretion. This could first be interpreted as the need for repeated anthelmintic drenches to control the parasitic risk. However, in its vast majority, this group of farms corresponded to flocks where resistance to benzimidazoles has been detected during the survey. Therefore, the association between the high number of trichostrongyle eggs and the high frequency of treatments can more probably be interpreted as the repeated use of inefficient drugs in an attempt to control resistant worm populations.

The prevalence of resistance to benzimidazole detected in the present survey in the Centre (33.3 %) or in South East (region Rhone Alpes) (44 %) appeared lower than values obtained from recent surveys in dairy goat flocks from other parts of France [7]. Nevertheless, the paradoxical association between the high level of egg excretion and the high number of treatments shows that the occurrence of anthelmintic resistance on farm is often not diagnosed. This last observation underlines the need to clearly identify the occurrence of resistance in goat flocks in order to avoid the repeated use of treatments without any actual efficiency. In addition, this practice could also have negative implications by increasing the selection for anthelmintic resistance within worm populations.

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References

1. — BARGER I.A. : The role of epidemiological knowledge and grazing management for helminth control in small ruminants. *Int. J. Parasitol.*, 1999, **29**, 41-48.
2. — BEUGNET F. and KERBOEUF D. : La résistance aux antiparasitaires chez les parasites des ruminants. *Le Point Vétérinaire*, 1997, **28**, 167-174.
3. — CABARET J., ANJORAND N. and LECLERC C. : Parasitic risk factors on pastures of French dairy goat farms. *Small Rum. Res.*, 1989, **2**, 69-78.
4. — CABARET J., ANJORAND N. and LECLERC C. : Les élevages caprins en Touraine : I modes d'élevage, parasitisme et estimation des pathologies chez la chèvre adulte. *Rec. Med. Vet.*, 1986, **162**, 575-585.
5. — CABARET J. and GASNIER N. : Farm history and breeding management influences on the intensity and specific diversity of nematode infection of dairy goats. *Vet. Parasitol.*, 1994, **53**, 219-232.
6. — CHARTIER C. and HOSTE H. : Effect of anthelmintic treatments against digestive nematodes on milk production in dairy goats : comparison between high- and low-producing animals. *Vet. Res.*, 1994, **25**, 450-457
7.— CHARTIER C., PORS I., HUBERT J., ROCHETEAU D., BENOIT C. and BERNARD N. : Prevalence of anthelminthic resistant nematodes in sheep and goats in Western France. *Small Rum. Res.*, 1998, **29**, 33-41.
8. — FARIZY P. : Intérêt d'un traitement anthelminthique au thiabendazole chez la chèvre en lactation. *Rec. Med. Vet.*, 1970, **146**, 251-260.
9. — HOSTE H. and CHARTIER C. : Comparison of the effects on milk production of concurrent infection with *Haemonchus contortus* and *Trichostrongylus colubriformis* in high- and low- producing dairy goats. *Am. J. Vet. Res.*, 1993, **54**, 1886-1893.
10. — HOSTE H., CHARTIER C., COUTINEAU H., GRIERS P., PORS I., PELLET M.P., BENOIT C. and KOCH C. : Conséquences d'infestations parasitaires par les trichostrongles sur la production de lait chez les caprins. *Renc. Rech. Ruminants*, 1995, **2**, 291-294.
11. — HOSTE H. and CHARTIER C. : Perspectives de lutte contre les strongyloses gastrointestinales. *Le Point Vétérinaire*, 1997, **28**, 181-187.
12. — HOSTE H., LE FRILEUX Y., POMMARET A., GRUNER L., Van QUACKEBEKE E. and KOCH C. : Importance du parasitisme par des strongles gastrointestinaux chez les chèvres laitières dans le Sud Est de la France. *INRA Prod. An.*, 1999, **12**, 377-389
13. — HOSTE H., CHARTIER C., ETTER E., LEFRILEUX Y. and GOUDEAU C. : A questionnaire survey on the use of anthelmintics in dairy goats in France. *Vet. Res. Comm.,* 2000, **24**, 459-469.
14. — JACKSON F. : Anthelmintic resistance : the state of play. *Brit. Vet. J.*, 1993, **149**, 123-138.

15. — KNOX M. and STEEL J. : Nutritional enhancement of parasite control in small ruminant production systems in developing countries of South East Asia and the Pacific. *Int. J. Parasitol.*, 1996, **26**, 963-970.
16. — LARSEN M. : Biological control of helminths. *Int. J. Parasitol.*, 1999, **29**, 139-146.
17. — LEFRILEUX Y., POMMARET A. and Van QUACKEBEKE E. : Influence des apports énergétiques sur la production laitière de chèvres en pâturage continu. *Fiche PEP caprin*, 2000.
18. — MANDONNET N., AUMONT G., FLEURY J., GRUNER L., BOUIX J., VU THIEN KHANG J. and VARO H. : Résistance aux strongles gastro-intestinaux des caprins. Influence de différents environnements tropicaux sur l'expression du potentiel génétique de résistance. *INRA Prod. An.*, 1997, **10**, 91-98.
19. — PATTERSON D.M., JACKSON F., HUNTLEY J.F., STEVENSON L.M., JONES D.G., JACKSON E. and RUSSEL A.J.F. : Studies on caprine responsiveness to nematodiasis : segregation of male goats into responders and non-responders. *Int. J. Parasitol.*, 1996, **26**, 187-194.
20. — RAYNAUD J.P. : Étude de l'efficacité d'une technique de coproscopie quantitative pour le diagnostic de routine et le contrôle des infestations parasitaires des bovins, ovins, équins et porcins. *Ann. Parasitol. Hum. Comp.*, 1970, **45**, 321-342.
21. — RICHARD S, CABARET J and CABOURG C. : Genetic and environmental factors associated with nematode infection of dairy goats in Northwestern France. *Vet. Parasitol.*, 1990, **36**, 237-243.
22. — SAUL G.R. : Effects of two pasture systems on faecal nematode egg counts in breeding ewes. *Aust. Vet. J.*, 1996, **74**, 154-155.
23. — THAMSBORG S.M., JORGENSEN R.J., WALLER P.J. and NANSEN P. : The influence of stocking rate on gastrointestinal nematode infections of sheep over a two-year grazing period. *Vet. Parasitol.*, 1996, **67**, 207-224.