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Health Impact of Co-Infestation with Gastrointestinal Helminthes Parasites in Cattle in Bangangté Subdivision, West Cameroon

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ABSTRACT: There is growing interest in the scientific community about co-infestations and the determinism of their synergistic action against their hosts, in a prospect of improving animal survival rates and production. A big number of parasitic associations have been tested, most of which include parasites belonging to radically different systematic groups. This study measures the impact of gastro-intestinal parasitic associations in bovines on two health parameters: the PCV and the body condition score. To this end, we conducted a survey in the district of Bangangte from May to July 2022. Six (06) cattle farms (*Bos taurus*) were selected for a total of 300 animals. Blood, Fecal matter collection and careful visual observation for Body score condition recording took place on each animal part of the study. Lab analysis of fecal matters revealed eggs of 11 parasitic helminths species and their respective prevalences was calculated. The species whose eggs were discovered are: *Haemonchus contortus* (from 44,67 % of animals), *Fasciola gigantica* (38,33%), *Trichostrongylus axei* (13,33%), *Nematodirus battus* (8,33%), *Ostertagia ostertagi* (7,67 %), *Cooperia* spp. (6,00%), *Strongyloïdes papillosus* (4,00%), *Paramphistomum cervi* (3,67%), *Moniezia benedeni* (1,33%), *Toxocara vitulorum* (0,67 %) and *Trichuris* spp (0,33%). We found that 70,6% of animals was infested with at least one parasite, while 42% presented at least two parasites. The combinations of parasites having the most negative effect on the hematocrit level were composed of: *O. ostertagi*, *Cooperia* spp and *Strongyloides papillosus.* The one reducing the body condition score the most was the association of *Ostertagia ostertagi* and *Strongyloides papillosus*. More studies in a controlled environment, with artificial infestations, are required to confirm the adverse effects of parasitic associations delighted in this study.

KEY WORDS: Associations, Body condition score, Helminthes, Gastrointestinal, PCV, Parasites.

INTRODUCTION

Parasite infestation is a limiting factor in the production of domestic ruminants. The mortality rate caused by parasitic diseases is not alarming most of the time, but they do have indirect effects on herd productivity (Adedipe *et al.*, 2014). Infestations of gastrointestinal nematodes and flukes are relatively chronic and the economic impact they cause is due to their subclinical nature, causing a drop in growth, milk production and fertility (Charlier *et al.*, 2016). These pathogens (macro-parasites) are responsible for the morbidity observed in animals, although there are rarer cases of acute infestation with death of the host, as is very often the case with micro-parasites.

An increasing number of studies suggest that the pathogenic effects observed clinically in parasitized animals may be due to the joint action of helminthes and protozoa. (Gorsich *et al.*, 2014) helminthes - bacterium (Ezenwa *et al.*, 2021; Kelly *et al.*, 2018; Lucena *et al.*, 2017; Byrne *et al.*, 2019) helminth - helminth (Lello *et al.*, 2018; Corrêa *et al.*, 2020; Hidalgo *et al.*, 2020).

The result of a multiple infestation is not always worse than that of a single infestation in terms of the health impact on the host. The pathogenic effects do not always add up in practice, because parasitic agents can act independently of each other or interact with each other (Thumbi *et al.*, 2014). And when there are interactions between parasites they can be insignificant, unfavourable or beneficial for the host (McArdle *et al.*, 2018) with far-reaching consequences such as changes in the population dynamics of infectious agents, the virulence of agents and the severity of the diseases they cause (Lello *et al.*, 2018).

With a view to improving the profitability of livestock farms, it is more than urgent to include co-infestations as potential sources of deterioration in the health status of animals when they are observed. The aim of this study is to measure the impact of

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multiple infestations due to gastrointestinal parasites on two health parameters judiciously chosen in the cattle herd of the Bangangté district.

MATERIALS AND METHODS

Study area

The Bangangté Subdivision, capital of the Ndé Division, lies at 5°15 north latitude and 10° 50 east longitudes. The climate is the tropical climate of the western mountains (INS, 2017) with temperatures between 14 and 28°C (NOAA, 2022). The climate has two seasons: a shorter, dry season running from mid-November to mid-March, and a rainy season running from mid-March to mid-November. Rainfall in the wet season varies from 1400mm to 2500mm (NOAA, 2022).

The study took place from May to July 2022, at the start of the rainy season. The cattle farms selected for sample collections are located in suburban areas and their respective locations are shown on the maps in Figure 1.

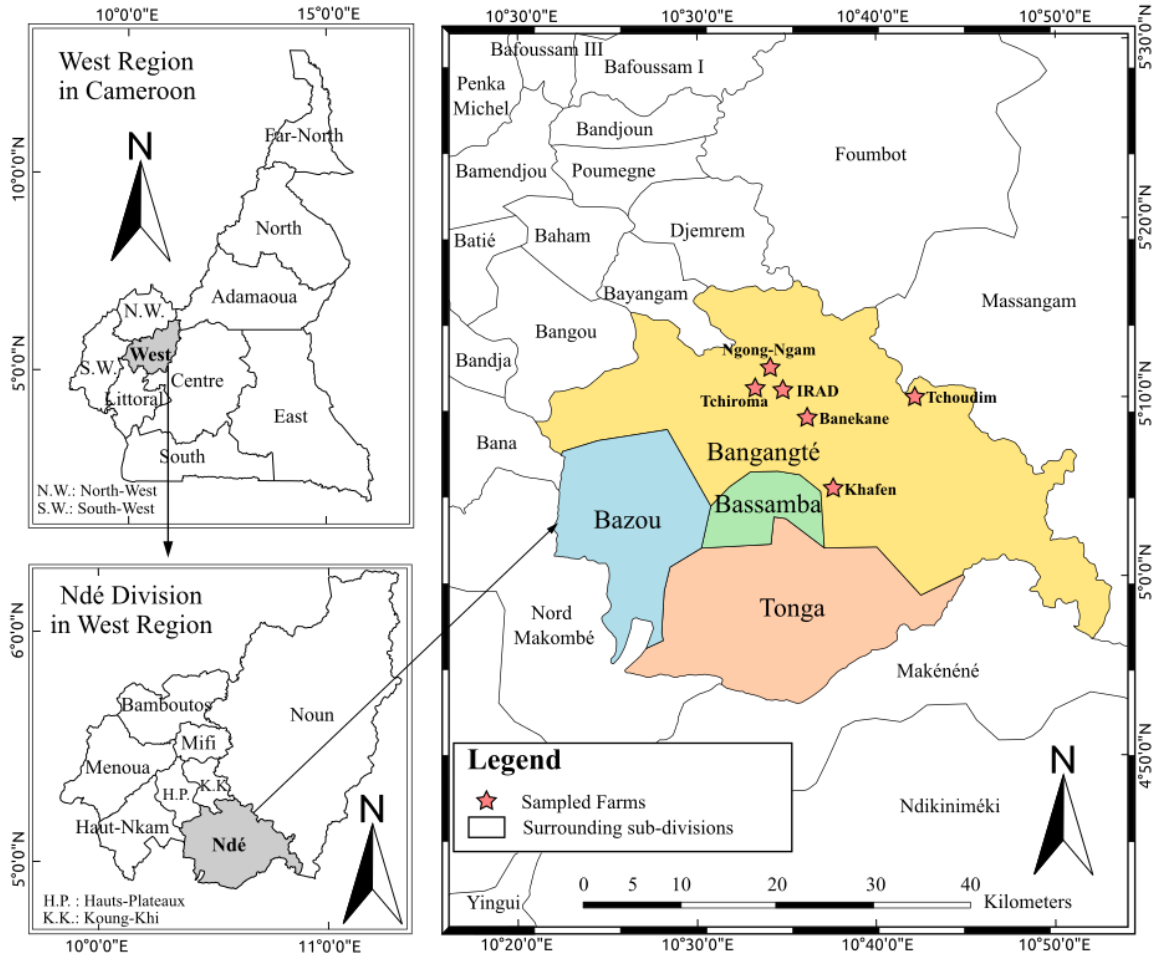

Figure 1: Map of the study area and location of sampled farm

Sampling

Sampling of the animals was random and stratified. In the absence of adequate restraint equipment, and as a safety measure for the shepherds and the animals themselves, many animals had to be released because they were too agitated. Table 1 details the composition of the sample with regard to a number of variation factors.

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Table 1: Characteristics of the sample

Factors		Settlement	Percentage (%)
Gender	**Male**	78	26
	Female	222	74
Sites	**Khafen I**	28	9,33
	Khafen II	33	11
	Ngong-Ngam	39	13
	Tchoudim	40	13,33
	Banekane	50	16,67
	Tchiroma	50	16,67
	IRAD	60	20
Breeds	**Akou**	2	0,67
	Bokolo	3	1
	Red-Fulani	36	12
	White-Fulani	57	19
	Goudali	202	67,33
Age categories	**Veau_Velle**	89	29,67
	Taurillon_Genisse	38	12,67
	Adult	173	57,67

The sample size was calculated using the formula in Thrusfield *et al.*(2018) and a sample size of 87 animals was obtained.

Collecting and transporting samples

The biological samples collected were faeces and blood. Faeces were collected with a gloved hand that was carefully lubricated and inserted into the rectum. Plastic bags labeled with the animal's number were used. Blood was collected by puncture of the jugular vein using syringes mounted on an EDTA tube holder.

Faecal samples were brought back to the laboratory at room temperature in a plastic bag and transported in a cooler containing frozen dry ice to bring them closer to the ideal range [+2 ; +6 °C] as recommended by Mvere *et al* (2008).

Laboratory analysis of faecal matter

Gastrointestinal helminthes eggs were extracted from faeces using the flotation method for nematodes and the sedimentation method for cestodes.

The McMaster blade was used to identify and count the nematode eggs.

Trematode eggs were identified using photographs collected by Gibbons *et al* (2010).

Blood laboratory tests

Blood samples were analyzed to determine the haematocrit level.

Additional information collected

The health parameters chosen to investigate the health effects of co-infections were haematocrit level and body condition score (BCS). Other characteristics specific to each animal, such as sex, age, breed and presence of ticks (control of blood-borne infectious agents with ticks as vectors) were collected following visual observation. Age was determined by inspection of the scratches around the horns or by examination of the dentition when the horns were little or not developed.

Statistical analysis

The data collected was recorded, filtered and cleaned in Microsoft Excel® 2016. Statistical analyses and graphs were produced using R® version 4.1.2 and R-Studio®. In addition to the descriptive statistics, epidemiological parameters were calculated and effects were investigated.

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- **Calculating prevalences**

In the frequents approach, the prevalence p is the apparent prevalence plus the standard error $1{,}96\sqrt{\frac{p(1-p)}{n}}$ where p is the apparent prevalence and n is the sample size (Thrusfield *et al.*, 2018). This error calculation is based on Wald's method and is based on a normal approximation of the binomial distribution .

- **Assessment of the health impact of helminth infestations**

It involved the comparison, using non-parametric Kruskall-Wallis and Willcoxon statistical tests, of health parameters such as haematocrit rate and body condition score (BCS) for different groups of animals subject to various infestations and co-infestations.

- **Effect of co-infections and other factors**

We constructed statistical models based on the determining factors in order to describe the deterioration or improvement in health parameters due to the infestations. Only co-infections with major impacts on the health status of the study subjects were considered as explanatory variables. Three models were calculated: a linear regression to explain the haematocrit level, a logistic regression to explain the occurrence of anemia and finally an ordinal logistic regression to explain the NEC obtained. Logistic regression is a linear classification of anemic and non-anaemic cases. According to Hastie *et al* (2009) the equation (for linear logistic regression) is of the form :

$$Pr\ Pr\ (anaemia = 1 \mid X = x) = \frac{e^{\beta 0 + \beta 1X1 + \beta 2X2 + \cdots + \beta nXn}}{1 + e^{\beta 0 + \beta 1X1 + \beta 2X2 + \cdots + \beta nXn}}$$

Where:

- β_1 , β_2 ... β_n : are coefficients to be determined ;
- β_0 a constant representing random noise in the data and effects not included in the model ;
- X_1 , X_2 ... X_n , the most convincing explanatory variables;

Pr (anemia = 1 | X=x) is the probability of anemia occurring for the data collected in study x. It can take values between 0 and 1 when the model is used for prediction.

The explanatory variables here, which are the same as the risk factors investigated, are either the various zoo technical parameters characterizing the animal, such as age, sex, breed, or the presence, individually or in combination, of various and diverse parasites.

RESULTS AND DISCUSSION

Prevalence of gastrointestinal parasites

During this study, 11 species of gastrointestinal parasites were detected through their eggs. These were: *Haemonchus contortus*, *Ostertagia ostertagi*, *Cooperia* spp, *Trichostrongylus axei*, *Strongyloïdes papillosus*, *Nematodirus battus*, *Moniezia benedeni*, *Trichuris* spp, *Toxocara vitulorum*, *Fasciola gigantica* and *Paramphistomum cervi*.

By filtering the data on the basis of the presence or absence of parasites in the study subjects, we determined that 29.3% of the animals had no parasites, 70.6% of the animals had at least one parasite, 42% had at least two parasites, 10% had at least three parasites and 3% had at least 4 parasites. The prevalences were calculated and summarized in Table 2.

Table 2: Prevalence of helminth species detected

Species	Prevalence in % ± standard error
Haemonchus contortus	44,67 ± 2,87
Ostertagia ostertagi	7,67 ± 1,54
***Cooperia* spp.**	6,00 ± 1,37
Trichostrongylus axei	13,33 ± 1,96
Strongyloides papillosus	4,00 ± 1,13
Nematodirus beaten	8,33 ± 1,60
Moniezia benedeni	1,33 ± 0,66
Toxocara vitulorum	0,67 ± 0,47
***Trichuris* spp.**	0,33 ± 0,33
Fasciola gigantica	38,33 ± 2,81
Paramphistomum cervi	3,67 ± 1,09

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Proportion of animals infested by parasites detected

The proportions of infested animals by species varied according to sex, age class, site, breed or presence of ticks (table 3). There was a significant difference in infestation rates between the sampling sites for all parasites observed. Infestation rates were not significantly different for the sex of the hosts, with the exception of *Ostertagia ostertagi*, *Nematodirus battus* and *Fasciola gigantica*. No influence of race was noted.

All age classes were affected differently by parasites with the exception of *H. contortus* and *P. cervi*. Calves were more infested with *O. ostertagi*, *Cooperia* spp, *S. papillosus* and *N. battus*. However, *Fasciola* gigantica infested adults more than heifers and bull calves, which in turn were more infested than calves. The proportion of animals infested with ticks does not seem to influence the proportions of animals infested with helminths.

Average counts of parasite eggs detected as a function of a number of variation factors

Average parasite egg counts according to sampling site, breed, age category and presence or absence of ticks are shown in table 4. The Kruskal-Wallis statistical test on groups of animals separated by sampling sites showed a significant difference in egg counts for all parasites detected. This suggests that for all the parasites detected, there are always farms that are much more parasitized than others. Females appeared to be more parasitized than males for the parasites *Ostertagia ostertagi*, *Nematodirus battus* and *Moniezia benedeni*. All breeds of cattle appeared to be equally attacked by helminths, with the exception of *Strongyloides papillosus* ($p<0.001$). However, this result could pose a problem of representativeness, as the breed most infested with *S. papillosus* is very much in the minority: only two animals of this breed (Akou) are present in the sample. The egg counts differed overall between the age classes, with the exception of *Haemonchus contortus*, which parasitised all age classes equally. It can be noted that calves are always more parasitized. The presence of ticks does not seem to influence the parasite egg count.

Table 3: Proportion of animals infested by the various parasites detected as a function of some variation factors and P-values obtained from Kruskal-Wallis tests of comparisons of the groups thus formed.

Factors		Hc		Oo		C_spp		Your		Sp		Nb		Fg		Pc	
		%	p	%	p	%	p	%	p	%	p	%	p	%	p	%	p
Sites	Banekane	44	<0,001 ***	8,0	<0,001 ***	6,0	<0,001 ***	6,0	<0,001 ***	2,0	<0,001 ***	2,0	<0,001 ***	50	<0,001 ***	0,0	<0,001 ***
	IRAD	27		0,0		0,0		26,7		1,7		10,0		22		0,0	
	KhafenI	50		10,7		17,9		21,4		10,7		14,3		54		3,6	
	KhafenII	33		18,2		21,2		21,2		15,2		9,1		3		30,3	
	Ngong-Ngam	28		0,0		0,0		10,3		0,0		0,0		18		0,0	
	Manko'o	66		6,0		0,0		6,0		2,0		0,0		52		0,0	
	Tchoudim	68		17,5		7,5		2,5		2,5		27,5		70		0,0	
Gender	Male	46	0,45	5,9	0,05	5,9	0,86	12,2	0,31	3,1	0,21	5,0	<0,001 ***	47	<0,001 ***	4,5	0,19
	Female	41		12,8		6,4		16,7		6,4		17,9		14		1,3	
Breeds	Akou	100	0,13	0,0	0,82	0,0	0,39	50,0	0,23	50,0	<0,001 ***	0,0	0,10	50	0,04 *	0,0	0,24
	Bokolo	67		0,0		0,0		0,0		0,0		0,0		100		0,0	
	Goudali	40		8,9		7,9		15,3		5,5		11,4		34		5,5	
	Red-Fulani	53		5,6		2,8		11,1		0,0		0,0		42		0,0	

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	White-Fulani	53		5,3		1,8		7,0		0,0		3,5		49		0,0	
Age groups	**Adult**	46	0,77	4,0	<0,001 ***	2,9	<0,001 ***	9,8	0,02 *	2,3	0,01 *	5,2	0,03 *	54	<0,001 ***	4,0	0,43
	Taurillon-Genisse	47		2,6		0,0		26,3		0,0		7,9		37		0,0	
	Veau-Velle	42		16,9		14,6		14,6		9,0		14,9		9		4,5	
Ticks	**No**	38	0,65	7,7	1,0	7,7	0,79	15,4	0,82	7,7	0,49	7,7	0,93	23	0.25	7,7	0,43
	Yes	45		7,7		5,9		13,2		3,8		8,4		39		3,5	

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

Table 4: Means of the parasite egg counts detected as a function of some variation factors and P-values of the Kruskal-Wallis tests for comparison between the groups thus formed.

Factors		**Hc**		**Oo**		**C_spp**		**Your**		**Sp**		**Nb**		**Mb**	
		fec	**p**	**fec**	**p**	**fec**	**p**	**fec**	**p**	**fec**	**p**	**fec**	**p**	**fec**	**p**
Sites	**Banekane**	53	<0,001 ***	6,0	<0,001 ***	4,00	<0,001 ***	8,0	<0,001 ***	1,00	0,01 *	1,0	<0,001 ***	0,0	0,08
	IRAD	32		0,0		0,0		33,3		0,83		8,3		0,0	
	KhafenI	264		5,4		10,71		19,6		5,36		23,2		0,0	
	KhafenII	118		33,3		121,21		19,7		10,61		6,1		325,76	
	Ngong-Ngam	22		0,0		0,0		7,7		0,0		0,0		0,0	
	Manko'o	139		3,0		0,0		4,0		1,00		0,0		114,0	
	Tchoudim	182		21,2		11,25		1,2		1,25		28,8		0,0	
Gender	**Male**	92	0,59	6,8	0,05	6,98	0,85	14,6	0,39	1,80	0,21	4,0	<0,001 ***	0,45	0,02 *
	Female	135		13,5		43,59		11,5		3,85		21,1		209,62	
Breeds	**Akou**	50	0,54	0,0	0,80	0,0	0,38	25,00	0,29	25,00	<0,001 ***	0,0	0,10	0,0	0,21
	Bokolo	83		0,0		0,0		0,0		0,0		0,0		0,0	
	Goudali	110		11,1		23,78		16,3		3,22		11,6		53,22	
	Red-Fulani	96		2,8		2,78		13,9		0,0		0,0		158,33	
	White-Fulani	87		3,5		0,88		5,3		0,0		3,5		0,0	
Age groups	**Adult**	84	0,96	2,6	<0,001 ***	3,76	<0,001 ***	11,6	0,02 *	1,16	0,01 *	4,3	0,03 *	0,0	0,01 *
	Taurillon-Genisse	89		2,6		0,0		34,2		0,0		14,5		0,0	
	Veau-Velle	146		22,5		48,31		9,6		5,62		14,0		184,83	
Ticks	**No**	62	0,55	15,4	0,95	3,85	0,83	11,5	0,84	3,85	0,49	3,9	0,93	0,0	0,67
	Yes	105		8,2		17,07		13,9		2,26		8,7		57,32	

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

Effects of parasites on a number of health markers

- ***Individual effects of the presence of parasites***

Table 5 shows that there is some effect of the parasites *Ostertagia ostertagi*, *Paramphistomum cervi* and *Nematodirus battus* on NEC, and of the parasite *Cooperia* spp. on haematocrit levels. The p-values obtained from these tests are identical to those obtained by comparing parasite loads.

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Table 5: P-values of the Wilcoxon test performed on haematocrit levels and NEC as a function of the presence of gastrointestinal parasites

Parasites	Haematocrit rate	BCS
Haemonchus contortus	0,56	0,87
Ostertagia ostertagi	0,06·	0,03*
***Cooperia* spp.**	0,02*	0,14
Trichostrongylus axei	0,11	0,84
Strongyloides papillosus	0,06·	0,68
Nematodirus beaten	0,42	0,04*
Moniezia benedeni	0,26	0,70
Fasciolia gigantica	0,65	0,54
Paramphistomum cervi	0,24	<0,001***

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

- ***Individual effects of infestation magnitudes on health parameters***

The egg count values corresponding to these categories (heavily infested, moderately infested and lightly infested) depend on the parasite species considered, as shown in Table 6. The NEC shows no significant difference between the degrees of infestation. However, the Wilcoxon test applied to populations heavily and lightly infested with *Ostertagia ostertagi* showed a significant difference in haematocrit levels, but also in anemia counts. The significant difference observed between the comparison of anemic populations lightly infested or moderately infested with *Cooperia* spp. is not representative, as only one subject was detected as anemic among the moderately infested subjects. This fact does not obscure a general trend that seems to be occurring: the rates of anemia in heavily infested subjects are always higher than those obtained in moderately or lightly infested subjects. Levels of infestation with other species appear to have a non-detectable effect on haematocrit levels and the number of cases of anemia.

Table 6: Summaries of infestation magnitudes based on haematocrit levels and average NECs

Species	Levels of infestation	Number of cases	Number of cases of anaemia	p	PCV medium	p	NEC averages	p
Haemonchus contortus	Heavy	15	3	0,49	30	0,95	2,5	0,10
	Moderate	35	5		30		2,5	
	Light	250	27		30		2,6	
Ostertagia ostertagi	Heavy	5	4	<0,001***	24	0,03*	2,4	0,27
	Light	295	31		30		2,5	
***Cooperia* spp.**	Moderate	1	1	0,01*	20	0,10	2,5	0,85
	Light	299	34		30		2,5	
Trichostrongylus axei	Moderate	40	7	0,22	29	0,11	2,5	0,84
	Light	260	28		30		2,5	

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

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1.1.1. Effects of parasite associations

We assessed the effect of various parasite associations on NEC and haematocrit levels. The most important associations were those constituted by parasites which, individually, showed some effect on haematocrit and BCS in the preceding tables or via the PCA (*Principal Component Analysis*). We excluded the species *Trichuris* spp. and *Moniezia benedeni* because of the effect size problem they cause due to their extreme rarity in our sample.

This analysis, presented in Figures 2 and 3 show that *Cooperia* spp., *Ostertagia ostertagi* and *Strongyloides papillosus* are strongly correlated with haematocrit levels, but negatively. *Nematodirus battus, Haemonchus contortus* and *Trichostrongylus axei* appear to have almost no correlation with haematocrit levels. A linear regression model would work rather well between these 04 variables. The PCA shows us that these 03 species tend to be found together on the same subjects. Similarly, *Haemonchus contortus*, *Nematodirus battus* and *Trichostrongylus axei* are negatively correlated with NEC.

According to the PCA, 04 parasites have a negative effect on haematocrit levels (figures 2 and 3): Oo, Mb, C_spp and Sp, and 03 other parasites have a negative effect on NEC: Hc, Ta and Nb. Tables 7 and 8 show the pools of combinations within these two groups of parasites.

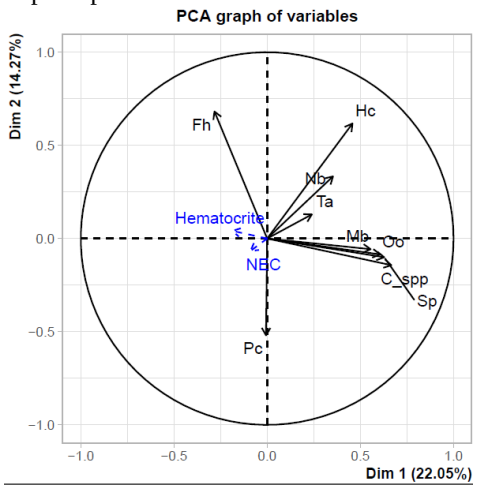

Figure 2: Individual effects of the presence of parasites

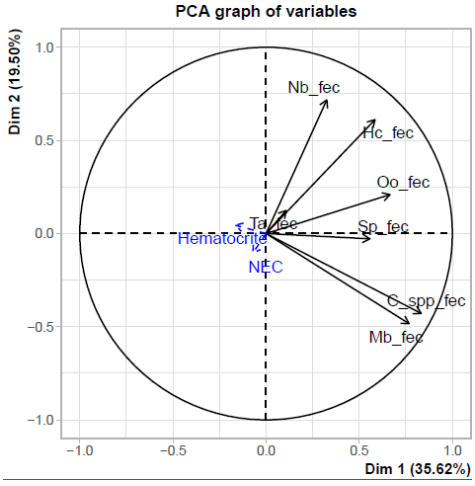

Figure 3: Individual effects of parasite egg counts

Table 7Arrangements of parasites with a potential effect on haematocrit levels and which actually appeared in the data

Combinations	Formulas
Combi_1	Oo & C_spp
Combi_2	Oo & Sp
Combi_3	C_spp & Sp
Combi_4	Oo & C_spp & Sp

Table 8: Arrangements of parasites with a potential effect on NEC that actually appeared in the data

Combinations	Formulas
Combi_5	Hc & Oo
Combi_6	Hc & Ta
Combi_7	Hc & Nb
Combi_8	Hc & Pc
Combi_9	Oo & Ta
Combi_10	Oo & Nb
Combi_11	Oo & Pc
Combi_12	Ta & Nb
Combi_13	Ta & Pc
Combi_14	Nb & Pc
Combi_15	Hc & Oo & Ta
Combi_16	Hc & Oo & Nb
Combi_17	Hc & Oo & Pc
Combi_18	Hc & Ta & Nb
Combi_19	Hc & Nb & Pc

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The figure 4 and 5 represent the projections on a plane of the principal component analyses carried out. It can be seen that only combinations 5, 6, 9, 10, 12, 13 and 15 are diametrically opposed to the NEC and therefore negatively correlated with it. Similarly, combinations 1, 2, 3 and 4 are negatively correlated with haematocrit levels. It is these combinations that will be chosen for the construction of the model. We preferred to select combinations that were antagonistic to the health parameters.

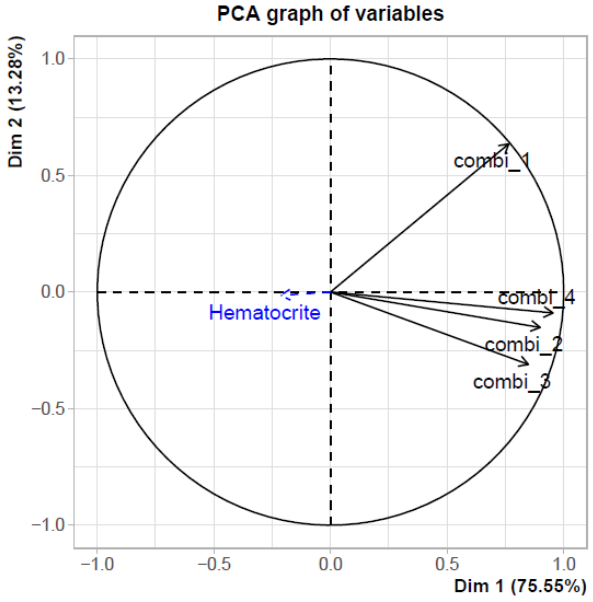

Figure 4: Projections of parasite combinations with a potential effect on haematocrit levels

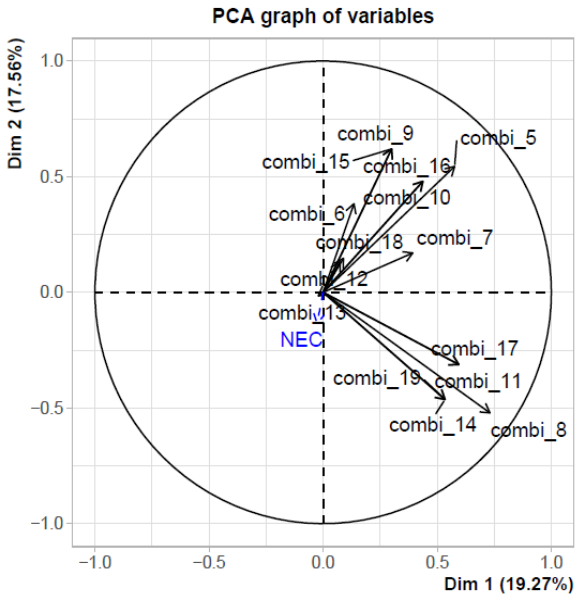

Figure 5: Projections of parasite combinations with a potential effect on NEC

1.1.2. Effects of some variation factors on health parameters

The table 9 shows the effects of a number of factors on health parameters. Mean haematocrit levels, anaemia rates and mean NECs differed significantly between sampling sites. No significant differences were observed for sex or breed. However, the age category variable seemed to have an effect on average NECs. The presence of ticks produced differences with p-values at the limit of significance for mean haematocrit levels and mean NECs. The NEC could therefore be partially explained by the "Sites", "Age category" and "Ticks" factors, whereas the haematocrit rate could be explained by the "Sites" and "Ticks" variables.

Table 9: Summaries of average haematocrit levels, anaemia rates and average NEC as a function of some variation factors

Factors		Average haematocrit levels	p-values	Rate of anaemic animals	p-values	Average NEC	p-values
Sites	Banekane	26	<0,001 ***	28,0	<0,001 ***	2,4	<0,001 ***
	IRAD	32		0,0		2,7	
	KhafenI	28		21,4		2,4	
	KhafenII	27		24,2		2,8	
	Ngong-Ngam	32		7,7		2,4	
	Tchiroma	32		6,0		2,7	
	Tchoudim	32		2,5		2,4	
Sex	Female	30	0,49	12,6	0,39	2,6	0,32
	Male	30		9,0		2,5	
Breeds	Akou	33	0,80	0,0	0,92	2,8	0,31
	Bokolo	30		0,0		2,3	

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	Goudali	30		11,9		2,6	
	Red-Fulani	30		13,9		2,6	
	White-Fulani	30		10,5		2,5	
Ages	**Adult**	30	0,10	9,8	0,18	2,6	<0,001 ***
	Heifers-Young Bulls	31		7,9		2,5	
	Calves	29		16,9		2,5	
Ticks	**No**	28	0,05 *	23,1	0,19	2,4	0,06
	Yes	30		11,2		2,6	

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

2. Discussion

Eleven parasites were observed when the samples were analyzed. *Haemonchus contortus* was the most prevalent species (44.67%), followed by *Fasciola gigantica* (38.33%), *Trichostrongylus axei* (13.33%), *Nematodirus battus* (8.33%), *Ostertagia ostertagi* (7.67%), *Cooperia* spp. (6.00%), *Strongyloides papillosus* (4.00%), *Paramphistomum cervi* (3.67%), *Moniezia benedeni* (1.33%), *Toxocara vitulorum* (0.67%), and *Trichuris* spp. (0.33%). The prevalence obtained for *Fasciola gigantica* is similar to that found by Simo *et al* (2021) at the Bangangté municipal abattoir (33%), but much higher than that found by Ntonifor & Ndaleh (2012) and Takang *et al.* (2019) in Yaoundé and Douala respectively. As the latter two cities belong to different agro-ecological zones from our study area, this result could reflect spatial variation in stave distribution in Cameroon. These studies were conducted in abattoirs where the origin of the animals was unknown. However, the results of the survey conducted by Kouam *et al* (2021) in the North-West region of Cameroon are generally inferior to our own: *Trichostrongylus* spp (5.97%); *Oesophagostomum* spp (5.47%); *Haemonchus* spp (2.48%); *Bonostomum* spp (1.74); *Cooperia* spp (1.49%). *Toxocara* spp (0.24%); *Ostertagia* spp (0.50%); *Nematodirus* spp (0.74%); *Trichuris* spp (0.50%); *Moniezia* spp (0.50%); *Eimeria* spp (0.50%). Only the rarity of the species *Toxocara* spp., *Moniezia* spp. and *Trichuris* spp. is a constant between the two study areas. These low infestation rates could be linked to the traditional control techniques used by shepherds in the north-west. Indeed, Kouam et al. Kouam *et al* (2021) reported the intensive use of medicinal plants in addition to commercial anthelmintic products to control parasitic infestations. The herders in our study admitted to using only pharmaceutical products for pest control. However, parasite control is not the only management method responsible for variations in infestation rates. It would be important to carry out a more or less exhaustive survey of farming systems and to detect those that have a significant influence on parasite loads.

The proportions of infested animals varied significantly between sampling sites. This could be the result of the isolation of parasite habitats that are not colonized in the same way. The parasites' preferred habitats then form islands into which the hosts penetrate. According to Morand & Poulin (1998) the density of host populations also determines the intensity of transmission. However, this density varies little over time within a herd (notably because of the slow rate of births and deaths). It could vary significantly within a given geographical area as the grazing areas used by different herds overlap. It is not always possible to confirm the proximity of a herd given the extensive geographical areas of the ranches. In order to verify this assertion, it would be necessary to map all the herds in a given area and check that the most densely populated sub-areas are indeed the most heavily parasitized.

The species of parasites found are varied and diverse in their action on the host organism. They can be roughly classified as haematocrit depressors and body protein depressors. Some parasites have both effects to varying degrees of importance. Parasites with a definite effect on haematocrit levels are *Ostertagia ostertagi*, *Cooperia* spp. and *Strongyloides papillosus*, while those with an effect on NEC are *Haemonchus contortus*, *Nematodirus battus* and *Trichostrongylus axei*. These effects are reinforced by the results of infestation magnitudes which show that these parasites, when they infest their hosts heavily, tend to create anemia in the latter, even though this effect is not statistically significant. The fact that heavily infested animals are much rarer than moderately and lightly infested animals has a lot to do with this. The average NEC in heavily infested animals is always less than or equal to that of moderately and lightly infested animals. Statistical tests again failed to detect a significant difference in these cases. These results are similar to those presented by Thumbi *et al* (2014) who noted an increased chance of mortality of an animal affected by *Haemonchus contortus* above 1000 eggs/gram faeces. Similarly, Dorny *et al* (2011) found a statistically significant negative relationship between egg counts of gastrointestinal parasitic nematodes and NEC. They also detected a statistically significant

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negative relationship between the presence of *Fasciola* spp. and *Paramphistomum* spp. flukes with NEC and the FAMACHA® anaemia index. These results could be explained by the fact that, in their statistical models (linear and logistic regressions), they included egg counts and the presence of parasites as response variables to be explained. This raises an important limitation of statistical models: they do not establish causal relationships. It is impossible to know whether morbidity is caused by parasites or whether parasites take advantage of pre-existing morbidity to establish themselves.

Data exploration using principal component analysis revealed negative correlations between certain combinations of parasites with haematocrit levels and NEC. These combinations are for haematocrit rate: combi_1 (*O. ostertagi* and *Cooperia* spp.), combi_2 (*O. ostertagi* and *Strongyloides papillosus*), combi_3 (*Cooperia* spp. and *Strongyloides papillosus*) and combi_4 (*O. ostertagi*, *Cooperia* spp. and *Strongyloides papillosus*). The linear regression model for haematocrit levels gave us negative coefficients for combinations 1, 2 and 4. These three combinations appear to have a negative effect on haematocrit levels, but not a significant one, as they occur rarely in our sample. Combination 3 appears to have a positive effect on haematocrit despite the negative individual effects of the components of the combination. This could reflect a dilution of effects previously described by Civitello *et al* (2015). The latter hypothesised that a loss of a diverse parasite community limits the spread of disease via mechanisms that are as yet unknown. If this hypothesis is confirmed, *Cooperia* spp and *Strongyloides papillosus* would be so divergent (phenotypically and genetically) that they would inhibit each other. Combination 4 (*O. ostertagi*, *Cooperia* spp and *Strongyloides papillosus*) is the one that leads to the greatest increase in the probability of anaemia. This combination contains the most parasites. The individual effects of the parasites could therefore be cumulative.

Ordinal logistic regression of NEC on parasite combinations gave negative coefficients for combinations 6 (*H. contortus* and *T. axei*), 9 (*O. ostertagi* and *T. axei*), 10 (*O. ostertagi* and *N. battus*) and 12 (*T. axei* and *N. battus*) with combination 10 the most harmful. Moreover, for this last combination, the prediction of the probability of obtaining different NECs was higher for the lowest NECs, i.e. 2 and 2.5 (0.593 and 0.369 respectively). One salient fact is that it is only pairs of parasites that seem to influence animal morbidity. In fact, when the data were explored, combinations with more than 2 parasites were strongly correlated with certain combinations with 2 parasites, suggesting that the additional information provided by the addition of one or more parasites to a pair of parasites was negligible. In order to confirm the findings of this study, we could consider setting up experiments with artificial infestations in order to control the effect sizes and obtain statistically significant coefficients.

CONCLUSION AND OUTLOOK

The search for gastrointestinal parasites in cattle in the Bangangté district enabled us to identify 11 helminth species: *Haemonchus contortus*, *Ostertagia ostertagi*, *Cooperia* spp, *Trichostrongylus axei*, *Strongyloides papillosus*, *Nematodirus battus*, *Moniezia benedeni*, *Toxocara vitulorum* and *Trichuris* spp, *Fasciola gigantica* and *Paramphistomum cervi*, with prevalence rates of 44.67%, 7.67%, 6%, 13.33%, 4%, 8.33%, 1.33%, 0.67%, 0.33%, 38.33% and 3.67% respectively. Three combinations of these parasites were found to reduce haematocrit levels: *O. ostertagi* with *Cooperia* spp, *O. ostertagi* with *S. papillosus* and the combination of *O. ostertagi*, *Cooperia* spp and *S. papillosus*. Similarly, four parasite combinations had a reducing effect on NEC: *H. contortus* with *T. axei*, *O. ostertagi* with *T. axei*, *O. ostertagi* with *N. battus* and *T. axei* with *N. battus*. The combination of parasites with the greatest negative effect on haematocrit levels was *O. ostertagi*, *Cooperia* spp and *Strongyloides papillosus*, while the combination with the greatest reduction in NEC was : *Ostertagia ostertagi* and *Nematodirus battus*. The coefficients obtained after training our statistical models were not significant, at least for the egg count variables and the presence of parasite combinations variables. The null hypothesis posed a priori before data collection cannot therefore be rejected. However, many grey areas remain and the research problem needs to be explored further.

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