Research Article
Volume 15:04, 2024

Journal of Veterinary Science & Technology

ISSN: 2157-7579 Open Access

Effect of *Chlamydia abortus* on Hematological and Biochemical Parameters of Infected Small Ruminants in Plateau Department (Southern East) of Benin Republic

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Abstract

In Benin, abortion significantly affects the productivity of small ruminant herds. This study assessed the impact of *Chlamydia abortus* on hematological and biochemical parameters in infected small ruminants in Plateau department. Blood samples from 25 infected sheep and goats across five districts were analyzed. The results showed a marked decrease in red blood cells, particularly hematocrit levels (22.7 ± 4 in Sakété). Animals under two years old also exhibited a significant drop in hematocrit levels (23.2 ± 2.9). In the white blood cell lineage, there was a substantial decrease in neutrophils (22.8 ± 2.4 in Ifangni), lymphocytes (39.0 ± 4.8 in Kétou), and an increase in monocytes (7.3 ± 2.1 in Pobè) and basophils (4.0 ± 1.8 in Adja-Ouèrè). Among animals under two years old and those that had aborted once, only lymphocyte levels showed a significant decrease (38.2 ± 5.5* and 38.9 ± 5.3* respectively). Biochemical analysis indicated elevated globulin levels (6.0 ± 1.6 in Kétou) and total protein (8.7 ± 1.5 in Pobè, 8.8 ± 3.0 in Kétou), while total protein and albumin levels decreased in Ifangni (4.4 ± 2.1) and Adja-Ouèrè (1.9 ± 0.2). Increased total protein levels were noted in animals under two years old (8.2 ± 3.3) and those that had aborted (8.5 ± 3.0). Hepatic profiles showed increased total bilirubin in Pobè. Ionic profile results revealed decreased calcium (8.5 ± 1.3) and sodium (134.2 ± 5.6) in Adja-Ouèrè, with increased phosphorus (6.2 ± 2.8 in Ifangni, 5.3 ± 1.8 in Sakété) and magnesium (2.9 ± 0.2 in Ifangni) levels. The study concludes that infection in these animals leads to hypochromic anemia, renal function disruption, and phospho-calcic metabolism imbalance, evident from the low red and white blood cell parameters, and altered biochemical and ionic profiles.

Keywords: *Chlamydia abortus* • Hematological parameters • Biochemical parameters • Plateau department • Benin republic

Introduction

Small ruminants are vital for meat supply in rural areas where cattle slaughter is infrequent and are also important for religious and festive rites such as marriage and Tabaski. Given their numerical importance and integration into agricultural operations in sub-Saharan Africa, sheep and goat breeding requires attention. Understanding potential obstacles to sheep and goat farming is essential. According to Zaibet L, et al. [1] animal health is crucial for improving livestock performance. The prevalence of animal diseases and their re-emergence highlight the need for surveillance to define control methods [2]. These diseases cause various issues, notably abortions.

Abortion in small ruminants is a significant problem, causing economic losses due to fetal mortality, high morbidity, and reduced milk production. It can occur sporadically or in enzootic outbreaks [3]. Chlamydiaceae, responsible for abortions in small ruminants, are Gram-negative obligate intracellular bacteria with a global presence, causing various infections in animals and humans [4]. *Chlamydia abortus* can be transmitted *via* inhalation, ingestion, eye inoculation, and venereal transmission [5]. The most prominent sign is the expulsion of dead or weak lambs 2 to 3 weeks before expected lambing. Although these lambs appear mature, they may show subcutaneous edema [6].

Blood, as a carrier of essential nutrients and oxygen, plays a central role in maintaining physiological balance. Hematological indicators are key predictors of an animal's adaptability to its environment [7]. Hematological and biochemical analyses are crucial in veterinary medicine for diagnosing animal diseases, providing information on oxidative stress, nutritional aspects, and physiological states [8]. These analyses, combined with medical history, guide medical decision-making, helping to determine disease types, assess tissue and organ damage, and analyze defense mechanisms [9].

This study aims to determine the effect of *C. abortus* infection, on hematological and biochemical parameters in small ruminant.

Materials and Methods

Material

Small ruminants, aged between 2 and 4 years, exclusively female, and in a pregnant state. These animals are susceptible to *C. abortus* contamination due to inadequate biosecurity measures and, significantly, a history of abortions.

In this study, 25 sheep and goats from the governorates Plateau were positive for *Chlamydia abortus*, underwent hematological and biochemical examination to assess the disease's impact on their blood parameters.

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Received: 15 July, 2024, Manuscript No. jvst-24-141642; **Editor Assigned:** 17 July, 2024, PreQC No. P-141642; **Reviewed:** 29 July, 2024, QC No. Q-141642; **Revised:** 05 August, 2024, Manuscript No. R-141642; **Published:** 12 August, 2024, DOI: 10.37421/2157-7579.2024.15.253

Study area

The Plateau department, also known as Agricultural Development Pole 6, is a region of Benin comprising the communes of Kétou, Pobè, Adja-Ouèrè, Ifangni, and Sakété. The region is mainly rural and renowned for its agricultural and livestock activities. Livestock is diversified, mainly including poultry, cattle, goats and pigs. The Plateau benefits from climatic conditions and soils that are favorable to agriculture and livestock farming, making it a key area for agro-pastoral development in Benin.

Methodology of hematological and biochemical analysis

Animals were segregated and fasted a day prior to blood collection. Blood was drawn using a single-use needle inserted into the jugular or saphenous veins of small ruminants. The blood was collected in a dry tube with a red lid. After collection, a pressure dressing was applied to prevent hematoma formation. Each tube was labeled with the animal's information, including the breeder's name and farm number, recorded beforehand. Subsequently, the tube was refrigerated and sent to the Bohicon veterinary laboratory for analysis using the Sysmex XN-Series automated device, commonly known as a hemato-analyzer. A continuous loading technique was employed to manually load the samples. The analysis results were displayed on the device screen and could be printed.

The MS200 Automated Chemistry Analyzer is a laboratory instrument used to perform biochemical analyses on biological samples such as blood. It operates by utilizing specific analysis kits to measure various biochemical parameters. In this study, this equipment was used to perform the biochemical aspects of infected blood from pregnant women and small ruminants.

Statistical analysis

Statistical analysis included calculating means and standard deviations for hematological and biochemical parameters. A one-way ANOVA test was performed to examine the relationships between hematological and biochemical measurements and variables such as animal location, age, species, and physiological stage, with significance determined at a p-value of less than 0.05.

Results

Hematological data from the erythrocyte lineage of animals infected with *C. abortus* in various municipalities

Normocytic normochromic anemia was observed in all municipalities, with particularly severe cases documented in Ifangni, as evidenced by a substantial drop in hemoglobin levels. Mean Corpuscular Volume (MCV) remained within normal parameters or showed only marginal reductions, except in Kétou, where it experienced a significant decrease. The Mean Corpuscular Hemoglobin Content (MCHC) remained constant in all areas. Conversely, the Mean Corpuscular Hemoglobin Concentration (MCHC) experienced a notable drop across all sites. This infection by *C. abortus* leads to non-regenerative anemia that varies in severity depending on the urban centers, with Ifangni being particularly affected (Table 1).

Hematological parameters of erythrocyte lineage of animals infected with *C. Abortus* in various categories

Normocytic normochromic anemia is more severe in sheep than in infected goats, as indicated by the significant decrease in hemoglobin and hematocrit levels. Mean Corpuscular Volume (MCV) remained within normal parameters or suffered only a marginal reduction. The Mean Corpuscular Hemoglobin Content (MCHC) remained unchanged. However, Mean Corpuscular Hemoglobin Concentration (MCHC) appears to be moderately lower in sheep than in goats. In infected young animals, anemia was less pronounced, and Mean Corpuscular Volume (MCV) was preserved. Multiparous animals had more severe anemia than primiparous animals. In essence, *C. abortus* infection results in a non-regenerative anemia of varying intensity, with more pronounced effects observed in multiparous adult ewes, likely due to chronic bone marrow damage (Table 2).

Hematological data from leukocyte lineage of animals positive to *C. abortus* in various municipalities

Leukocytosis presented marked characteristics in Adja-Ouèrè and Pobè,

Table 1. Hematological data of the red blood cell lineage of animals infected with *C. abortus* in different municipalities.

	Parameters					
Sites	**RBC (mm^{3})[c]**	**Hemoglobin (g/dL)[c]**	**Hematocrit (%)[c]**	**MCV (fl)[c]**	**MCH (pg)[c]**	**MCHC (g/dL)[c]**
Adja-Ouèrè	6.3 ± 2.1	15.5 ± 2.3	43.8 ± 11.2	37 ± 13.2	11.0 ± 4.1	37.5 ± 7.0
Ifangni	6.9 ± 1.7	8.1 ± 1.0	42.8 ± 2.6	42.0 ± 11.8	10.4 ± 2.1	33.6 ± 4.0
Ketou	5.7 ± 1.8	10.2 ± 2.8	25.6 ± 4.7	28.4 ± 8.7	11.1 ± 2.3	30.5 ± 4.1[b]
Pobè	6.3 ± 1.6	15.9 ± 0.9	32.7 ± 16.8	45.0 ± 10.4	8.7 ± 1.5	32 ± 7.9
Sakété	5.1 ± 2	12.8 ± 3.6	22.7 ± 4[b]	34.1 ± 12.8	11.5 ± 2.5	32.1 ± 4.2
Reference Values	04-08	8-16	24-45	23-48	08-12	31-38

[c] Mean ± SD, *: p<0.05= significant; RBC: Red Blood Cell; MCV: Mean Corpuscular Volume; MCH: Mean Corpuscular Hemoglobin; MCHC: Mean Corpuscular Hemoglobin Concentration, S: sample, a: above of reference value, b: below of reference value

Table 2. Hematological parameters of the red blood cell lineage of animals infected with *C. abortus* in different categories.

		Parameters					
		RBC (mm^{6})[c]	**Hemoglobin (g/dL) [c]**	**Hematocrit (%)[c]**	**MCV (fl)[c]**	**MCH (pg)[c]**	**MCHC (g/dL)[c]**
Species	Goat	6.1 ± 1.7	13.5 ± 3.5	40.4 ± 12.3*	42.6 ± 11.1	10.6 ± 3.0	35.3 ± 6.5
	Sheep	5.9 ± 1.9	10.8 ± 3.3	27.4 ± 7.8	32.1 ± 10.9	10.9 ± 2.3	31.3 ± 4
Age of animals	<2 years	5.6 ± 1.8	11.1 ± 2.8	23.2 ± 2.9[b]	27.2 ± 6.8	10.3 ± 2.2	31.6 ± 4.4
	2 years and more	6.0 ± 1.8	11.9 ± 3.8	34.3 ± 11.7	38.0 ± 12.1	10.9 ± 2.6	33.1 ± 5.5
Physiological stade	≤ 01 Abortion	5.9 ± 1.8	10.6 ± 2.8	24.7 ± 4.4	26.1 ± 6.6	10.8 ± 2.2	31.0 ± 4.3
	>1 Abortion	5.9 ± 1.9	12.1 ± 3.8	34.4 ± 12.0	38.9 ± 11.7	10.7 ± 2.7	33.4 ± 5.5
Reference Values		04-08	8-16	24-45	23-48	08-12	31-38

[a] Moyenne ± SD, *: p<0.05= significative; RBC: Red Blood Cell; MCV: Mean Corpuscular Volume; MCH: Mean Corpuscular Hemoglobin; MCHC: Mean Corpuscular Hemoglobin Concentration, S: sample, a: above of reference value, b: below of reference value

a moderate manifestation in Kétou, and a less pronounced occurrence in Ifangni and Sakété, indicating varying degrees of systemic inflammatory responses in the different localities. The number of neutrophils increased substantially in Adja-Ouèrè and Pobè, moderately in Kétou and Sakété, and marginally in Ifangni, indicating a more severe acute inflammatory process in certain municipalities. Moderate lymphocytosis was present in all sites studied, indicating an immune response to the infection. This phenomenon was particularly marked in Adja-Ouèrè and Pobè. Monocytes, eosinophils, and basophils did not show significant differences between municipalities. It can be concluded that *C. abortus* infection causes a systemic inflammatory response with immune participation that exhibits geographic variation, with a particularly high response observed in Adja-Ouèrè and Pobè in this particular investigation (Table 3).

Hematological data of white blood cell lineage of animals positive to *C. abortus* in different categories

Leukocytosis was more pronounced in infected goats than in sheep, indicating a systemic inflammatory response. The presence of polymorphonuclear neutrophils was elevated in both species, with a greater increase observed in goats, indicating an acute inflammatory response. Lymphocyte counts were also increased, particularly in adult and multiparous animals, indicating immune stimulation associated with recurrent infections. In addition, a moderate increase in monocytes and eosinophils was observed, suggesting an allergic manifestation of the infection. In summary, it can be stated that *C. abortus* infection triggers a significant inflammatory response in small ruminants, potentially accompanied by an allergic component, which is more pronounced in multiparous adult goats. This highlights the chronic and recurrent nature of this abortive infection (Table 4).

Biochemical parameters of animals infected with *C. abortus* according the municipalities

Hypoglycemia was observed in all municipalities, but it was more pronounced in Ifangni, which is probably attributable to an association with *C. abortus* infection. Uremia showed high levels in all localities, with a pronounced increase in Pobè and Ifangni, indicating renal dysfunction concomitant with this infection. Creatinine levels showed moderate elevation at all study sites, signaling renal involvement. While total protein levels were generally within the normal range, there was a notable increase in globulin levels, particularly pronounced in Ifangni. This increase suggests the presence of a chronic inflammatory process triggered by *C. abortus*. This investigation elucidates the metabolic and renal disturbances associated with *C. abortus* infection in small ruminants in various municipalities of the Plateau, with the severity of the condition varying from one site to another, but being most pronounced in Ifangni.

Biochemical parameters of animals infected with *C. abortus* depending on species, age and physiological state

Hypoglycemia occurred in infected goats and sheep, although with a more pronounced effect in the latter, implying a potential metabolic disturbance associated with the infection. Elevated creatinine levels were evident in both species, indicating concomitant renal dysfunction. Uremia levels were also higher in infected goats and sheep, indicating impaired kidney function. In contrast, total protein and albumin levels remained within the normal range. Only a minor increase in globulin levels was observed, potentially attributed to a chronic inflammatory response triggered by the infection. In the case of young infected animals, hypoglycemia was less pronounced and uremia levels were close to those of adults. In contrast, total protein and albumin levels increased, suggesting a more acute inflammatory response. Infected multiparas had more pronounced hypoglycemia and hyperglobulinemia than primary infections, indicating more severe metabolic and inflammatory damage. These metabolic and renal abnormalities were noticeable in both goats and sheep infected with *C. abortus*, with greater severity observed in multiparous adults (Table 5).

Liver profile of animals infected with *C. abortus* by municipalities

The liver profiles of animals infected with *C. abortus* varied among municipalities. Total bilirubin levels generally fell within expected ranges across all areas. However, a slight elevation was noted in Pobè compared to other localities. Alkaline Phosphatase (ALP) levels surpassed normal limits in all municipalities, indicating hepatic cholestasis. The highest ALP levels were recorded in Adja-Ouèrè and Ifangni. Alanine Aminotransferase (ALT)

Table 3. Hematological data of the white blood cell lineage of animals infected with *C. abortus* in different municipalities.

Localities	Parameters					
	WBC (µL)[a]	Neutrophils (µL)[c]	Lymphocytes (µL)[c]	Monocytes (µL)[c]	Eosinophils (µL)[c]	Basophils (µL)[c]
Adja-Ouèrè	11.4 ± 1.6	54.5 ± 14.0	63.3 ± 14.2	3.7 ± 2.7	6.2 ± 2.2	4.0 ± 1.8a
Ifangni	6.6 ± 1.9	22.8 ± 2.4b	47.6 ± 11.9	3.2 ± 1.9	8.8 ± 1.9	2.2 ± 1.3
Ketou	9.2 ± 2.7	30.8 ± 6.5	39.0 ± 4.8b	4.8 ± 1.9	9.9 ± 3.5	2.1 ± 0.9
Pobè	9.2 ± 3.3	74.3 ± 3.8	61.6 ± 8.1	7.3 ± 2.1a	6.7 ± 3.1	2.7 ± 1.5
Sakété	6.6 ± 3.5	36.8 ± 13.11	49.9 ± 8.2	4.3 ± 1.1	9.1 ± 1.7	2.6 ± 0.8
Reference Values	4-12	25-75	40-70	0-6	0-10	0-3

[c] Mean ± SD, *: p<0.05 = significant; WBC: White Blood Count, S: Sample, a: above of reference value, b: below of reference value

Table 4. Hematological data of the white blood cell lineage of animals infected with *C. abortus* in different categories.

		Parameters					
		WBC (µ L) [c]	Neutrophils (µL) [c]	Lymphocytes (µL) [c]	Monocytes (µL) [c]	Eosinophils (µL) [c]	Basophiles (µL) [c]
Species	Goat	10.0 ± 2.4	54.2 ± 21.6	62.0 ± 10.0	5.1 ± 2.7	6.5 ± 2.1	3.4 ± 1.5[a*]
	Sheep	7.5 ± 3.1	31.5 ± 10.2	43.1 ± 7.8	4.1 ± 1.7	9.6 ± 2.4	2.2 ± 0.9
Age of animals	<2 years	10.1 ± 2.8	31.4 ± 7.9	38.2 ± 5.5[b*]	4.3 ± 2.1	9.0 ± 3.9	2.0 ± 1.1
	2 years and plus	8.0 ± 3.1	41.7 ± 20.0	52.7 ± 12.1	4.5 ± 2.2	8.4 ± 2.5	2.8 ± 1.3
Physiological stade	≤ 01 Abortion	9.5 ± 2.9	31.0 ± 7.1	38.9 ± 5.3[b*]	4.6 ± 1.9	9.5 ± 3.6	2.2 ± 1.0
	>1 Abortion	8.1 ± 3.1	42.4 ± 20.3	55.4 ± 12.2	4.5 ± 2.2	8.2 ± 2.4	2.7 ± 1.4
Reference Values		04-Dec	25-75	40-70	0-6	0-10	0-3

[c] Mean ± SD, *: p<0.05 = significant; WBC: White Blood counts, S: Sample, a: above of reference value, b: below of reference value

levels increased in all municipalities, with the most significant rise observed in Ifangni, indicating hepatocyte damage. Aspartate Aminotransferase (AST) levels also exceeded normal ranges in all sites, particularly in Ifangni and Kétou, indicating hepatic cytolysis. This biochemical analysis underscores hepatic imbalances across different cities studied; suggesting mixed liver damage with a predominant presentation of cholestatic disease (Table 6).

Liver profile of animals infected with *C. abortus* according to species, age and physiological stage

Normal bilirubin levels were observed in infected populations of goats and sheep. ALP levels showed a notable increase in both species, with a more pronounced elevation in goats, signifying hepatic cholestasis in the context of *C. abortus* infection. Furthermore, ALT and AST transaminases showed elevated levels in infected individuals from goat and sheep populations, indicating hepatic cytolysis attributed to *C. abortus*. ALT levels were slightly higher in goats. In infected young animals, ALP and transaminases levels were comparatively lower than in adults, implying less severe liver damage. However, among infected multiparous animals, elevated levels of ALP and transaminases were discerned compared to primary-infected animals, likely reflecting deeper liver damage due to recurrent abortive infections caused by *C. abortus* (Table 7).

Ionic profile of animals infected with *C. abortus* according to municipalities

Analysis of Table 8 reveals varying ionic levels in animals infected with *C. abortus* across municipalities. Magnesium and calcium levels remained normal. However, sodium and potassium fell below standard values in Adja-Ouèrè. Additionally, phosphorus (Ifangni and Sakété) and chlorine (Sakété) exceeded usual limits, indicating specific metabolic disturbances linked to this zoonosis in these regions.

Ion profile of animals infected with *C. abortus* by categories

Table 9 details the ion profile of animals infected with *C. abortus* in different categories. Only phosphorus levels exceeded normal ranges in goats, suggesting disruption of phosphorus metabolism. In animals under 2 years old, calcium levels were too low, indicating electrolyte disturbances or appetite problems, while animals over 2 years old had high phosphorus levels, indicating disturbances of phospho-calcium metabolism. In animals having undergone multiple abortions, only phosphorus levels were elevated, highlighting a more pronounced influence on phospho-calcium metabolism than in animals having undergone a single abortion (Table 10).

Discussion

This research concentrated on small ruminants infected with *C. abortus*, the majority of which experienced multiple abortions during their lifespan and were not older than 2 years. The assessment of hematological parameters in these animals revealed variations based on communities, species, age, and particularly, physiological condition. The findings indicated values refers to the reference range suggested by Research Animal Resources [10], except for hematocrit and MCHC values, which exhibited fluctuations depending on the locations. According to Njidda AA, et al. [11] low RBC counts can indicate conditions such as iron shortage, internal bleeding, specific types of anemia, or vitamin deficiencies. This is also confirmed the observation made by Carlos MML, et al. [12] that decreased levels of red blood cells, hematocrit (Ht) and hemoglobin (Hb) are often observed in sick animals these outcomes validate earlier observations by Aba-Adulugba E and Joshua RA [13] and Ndoutamia G and Ganda K [14], regarding the stability of erythrocyte count in ovine species. Additionally, a non-significant decline in hematocrit was noted in small ruminants under 2 years old, deviating from the data provided by Aida A and Rokiya K [15]. This decline suggests the presence of normochromic normocytic anemia or a reduction in erythropoietin induced by *C. abortus*. The bacteria infect the host's blood cells, leading to their lysis, including red blood cells, thereby reducing their count in the bloodstream. No significant variations in white blood cells were observed among different sites, although these values fluctuated within the normal range of Research Animal Resources, [10], notwithstanding some increases. The elevation in white blood cells represents a natural defense response against infection, wherein these cells play a crucial role [16]. *C. abortus* infection in small ruminants triggers an immune response and white blood cell activation [17], elucidating

Table 5. Biochemical parameters of animals infected with *C. abortus* based on municipalities.

Localities	Parameters					
	Blood sugar (mg/dL)[c]	Creatinine (mg/dL)[c]	Urea Level (mg/dL)[c]	Protein (g/dL)[c]	Albumin (g/dL)[c]	Globulin (g/dL)[c]
Adja-Ouèrè	60.7 ± 16.3	0.8 ± 0.5	16.8 ± 2.2	5.3 ± 2.2	1.9 ± 0.2b	3.5 ± 1.3
Ifangni	38.2 ± 23.9	1.5 ± 0.3	39.0 ± 10.7	4.4 ± 2.1b	4.3 ± 0.3	6.0 ± 1.6a
Ketou	47.3 ± 24.8	1.0 ± 0.7	29.1 ± 15.7	8.8 ± 3.0a	3.6 ± 0.7	2.5 ± 0.9
Pobè	63.3 ± 21.4	0.4 ± 0.3b	40.3 ± 7.2	8.7 ± 1.5a	3.1 ± 0.5	3.9 ± 2.3
Sakété	50.2 ± 21.8	1.3 ± 0.5	24.7 ± 14.2	5.8 ± 2.5	2.7 ± 0.9	3.4 ± 1.0
Reference Values	30-80	0.6-1.6	15-45	5-8	2.5-4.5	02-04

[c] Mean ± SD, *: p<0.05= significant, S: Sample, a: above of reference value, b: below of reference value

Table 6. Biochemical parameters of animals infected with *C. abortus* based on species, age, and physiological status.

		Parameters					
		Blood Sugar (mg/dL)[c]	Creatinine (mg/dL)[c]	Urea Level (mg/dL)[c]	Protein (g/dL)[c]	Albumin (g/dL)[c]	Globulin (g/dL)[c]
Species	Goats	54.4 ± 20.8	0.8 ± 0.6	29.2 ± 13.2	6.0 ± 2.6	2.8 ± 1.0	3.8 ± 1.7
	Sheep	47.9 ± 23.3	1.2 ± 0.5	29.5 ± 14.7	7.0 ± 3.0	3.4 ± 0.9	3.7 ± 1.9
Age of animals	<2 years	41.0 ± 24.3	1.0 ± 0.5	27.6 ± 18.4 *	8.2 ± 3.3a	3.9 ± 0.7	2.8 ± 0.9
	2 years and more	52.5 ± 21.7	1.1 ± 0.6	29.9 ± 13.1	6.2 ± 2.8	3.0 ± 1.0	4.0 ± 1.9
Physiological stade	≤ 01 abortion	47.7 ± 27.2	0.9 ± 0.5	29.5 ± 17.1	8.5 ± 3.0a	3.6 ± 0.8	2.7 ± 0.9
	>1 abortion	51.1 ± 21.2	1.1 ± 0.6	29.4 ± 13.3	6.0 ± 2.7	3.1 ± 1.0	4.1 ± 1.9a
Reference Values		30-80	0.6-1.6	15-45	05-08	2.5-4.5	02-04

[c] Mean ± SD, *: p<0.05= significant, S: Sample, a: above of reference value, b: below of reference value

Table 7. Hepatic profile of animals infected with *C. abortus* by municipalities.

Localities	Parameters			
	Bilirubin Total (mg/dL)[c]	ALP (U/L)[c]	ALT (U/L)[c]	AST (U/L)[c]
Adja-Ouèrè	0.4 ± 0.3	167.75 ± 27.0	14.3 ± 5.7	34.0 ± 15.6
Ifangni	0.4 ± 0.2	170.6 ± 21.7	33.4 ± 6.9	50.8 ± 16.9
Ketou	0.4 ± 0.3	87.9 ± 56.4	27.1 ± 16.2	48.3 ± 26.3
Pobè	0.7 ± 0.2[a]	161.3 ± 78.2	33.7 ± 6.6	35.0 ± 5.2
Sakété	0.2 ± 0.1	139.5 ± 62.6	27.2 ± 16.5	45.7 ± 14.6
Reference Values	0.1-0.6	50-200	10-40	20-70

[c] Mean ± SD, *: p<0.05= significant; ALP: Alkaline Phosphatase; ALT: Alanine aminotransferase; AST: Aspartate aminotransferase, S: Sample, a: above of reference value, b: below of reference value

Table 8. Hepatic profile of animals infected with *C. abortus* based on species, age, and physiological stage.

		Parameters			
		Bilirubin Total (mg/dL)[c]	ALP (U/L)[c]	ALT (U/L)[c]	AST (U/L)[c]
Species	Goats	0.5 ± 0.3	165 ± 42.8	26.3 ± 12.7	39.7 ± 15.4
	Sheep	0.3 ± 0.3	123.4 ± 62.3	27.6 ± 14.2	46.9 ± 19.9
Age of animals	<2 years	0.3 ± 0.2	68.8 ± 21.9	23.6 ± 17.3	41.6 ± 28.5
	2 years et plus	0.4 ± 0.3	155.8 ± 51.6	28.0 ± 12.6	44.9 ± 16.0
Physiological stade	≤ 01 abortion	0.3 ± 0.3	92.2 ± 60.5	24.2 ± 15.6	44.3 ± 26.4
	>1 abortion	0.4 ± 0.3	153.0 ± 51.5	28.0 ± 13.0	44.3 ± 16.1
Reference Values		0.1-0.6	50-200	10-40	20-70

[c] Mean ± SD, *: p<0,05= significant; PAL: Alkaline Phosphatase; ALT: Alanine aminotransferase; AST: Aspartate aminotransferase, S: Sample, a: above of reference value, b: below of reference value

Table 9. Ionic profile of animals infected with *C. abortus* by municipalities.

Localities	Parameters					
	Calcium (g)[c]	Phosphor(g)[c]	Magnesium (g)[c]	Sodium (g)[c]	Potassium (g)[c]	Chlorine (g)[c]
Adja-Ouèrè	8.5 ± 1.3	5.0 ± 1.8	1.6 ± 0.4	134.2 ± 5.6[b]	2.5 ± 1.5[b]	100.7 ± 10.8
Ifangni	10.4 ± 3.6	6.2 ± 2.8[a]	2.9 ± 0.2	141.8 ± 10.9	4.6 ± 0.4	97.0 ± 3.8
Ketou	9.7 ± 3.6	4.1 ± 3.1	1.8 ± 0.7	138 ± 22.3	3.6 ± 1.1	99.6 ± 9.2
Pobè	11.0 ± 1.0	4.3 ± 0.6	2.3 ± 0.6	155.0 ± 2.6	4.5 ± 1.2	101.7 ± 11.1
Sakété	9.7 ± 3.8	5.3 ± 1.8[a]	2.0 ± 0.5	139.3 ± 20.6	4.4 ± 0.5	110.5 ± 12.8[a]
Reference Values	09-Nov	03-May	1.5-2.5	135-155	3.5-5	95-110

[c] Mean ± SD, *: p<0.05= significant, S: Sample, a: above of reference value, b: below of reference value

Table 10. Ionic profile of animals infected with *C. abortus* by categories.

		Parameters					
		Calcium (g)[c]	Phosphor (g)[c]	Magnesium (g)[c]	Sodium (g)[c]	Potassium (g)[c]	Chlore (g)[c]
Species	Goats	9.8 ± 2.3	5.1 ± 1.6[a]	2.1 ± 0.6	144.2 ± 11.1	3.7 ± 1.5	100.2 ± 8.9
	Sheep	9.8 ± 3.5	4.9 ± 2.7	2.0 ± 0.6	138.4 ± 18.9	4.1 ± 0.9	103.2 ± 11.3
Age of Animals	<2 years	8.2 ± 3.1[b]	3.2 ± 2.8	2.1 ± 0.6	140.0 ± 26.7	3.5 ± 0.5	98.0 ± 10.1
	2 years et plus	10.2 ± 3.0	5.5 ± 2.0[a*]	2.1 ± 0.6	140.6 ± 14.0	4.1 ± 1.2	103.2 ± 10.4
Physiological Stade	≤ 01 abortion	9.0 ± 3.4	4.2 ± 3.4	1.9 ± 0.7	138.0 ± 24.4	3.3 ± 0.7	99.8 ± 10.1
	>1 abortion	10.1 ± 3.0	5.3 ± 1.9[a]	2.1 ± 0.6	141.3 ± 14.0	4.2 ± 1.2	102.8 ± 10.6
Reference Values		09-Nov	03-May	1.5-2.5	135-155	3.5-5	95-110

[c] Mean ± SD, *: p<0.05= significant, S: Sample, a: above of reference value, b: below of reference value

the decrease in neutrophils and lymphocytes, and the increase in monocytes and basophils, underlying the alteration in this immune response.

Regarding animal age, a notable decline in hematocrit (23,2 ± 2,9) and lymphocytes (38,2 ± 5,5) was observed in animals younger than 2 years. This decrease is less compared to that reported by Alain TK, et al. [18] (28 to 45%, averaging 35.55% in non-pregnant goats in Lubumbashi). *Chlamydia abortus* invasion might be responsible for the immune response triggered by infected animals' organisms, justifying the erythropoietin decrease [17]. Average hematocrit values increase with age, consistent with Sidi's study [19]. Concerning hematocrit levels, goats exhibit an average of 40.4 ±

12.3%, surpassing the findings of Alian TK, et al. [18] (35.55 ± 5.23% for non-pregnant goats). This is confirmed the observation made by Habibu B, et al. [20]. In contrast, sheep demonstrate an average hematocrit of 27.4%, lower than the value reported by Faye D, et al. [21] (30.1 ± 0.3% for Djallonké sheep from Senegal). Regarding mean corpuscular hemoglobin (MCH), the values observed in Djallonké sheep in this study are inferior to those documented by Alain TK, et al. [18] in Arab sheep (22 ± 2.3 pg), Fulani sheep (23.22 ± 0.8 pg), and Kirdimi sheep (24.37 ± 0.03 pg). They also fall short of the levels recorded by Ndoutamia G [14] in Sahelian goats (202.0 ± 2.25 g/L) and Arab sheep (274.7 ± 1.4 g/L), as well as those reported by Brun-Hansen et al., [22] concerning Mean Corpuscular Hemoglobin Concentration (MCHC). The Djallonké breed, specific to our study, presents MCV values lower than those reported by Delabesse, et al. [23] for the Arab race (80.2 ± 0.3 fl) and by Ndoutamia G and Ganda K [14] for the Peulh race. This decrease can be explained by the presence of *C. abortus* causing microcytic anemia in infected animals [24]. Pitel M [25] also reported a difference in this parameter depending on the race. All values obtained fluctuated within the normal range in both red and white lines, except for basophils, which experienced significant variation. This variation justifies the specific immune response against *C. abortus*. Regarding the physiological state of the infected animals, no notable variations were observed in the red line, but a significant decrease in lymphocytes was noted in animals that had undergone only one abortion during their career. This value is lower than that observed by Kahn [26]. Early infection by *C. abortus* could be responsible for the indifference observed in the red line, and this decrease in lymphocytes could be due to a late inflammatory response of the organism of these animals to the infection [27]. All these results can be justified by the fact that when a sheep or goat is infected with *C. abortus*, the bacteria multiply in the cells of the uterine lining, causing inflammation and necrosis of the tissues. This can lead to abortion or the birth of weak offspring [28].

This research revealed a decline in creatinine, protein, and albumin levels across various study sites. These values deviate from the established normal range [10] and are notably lower than those documented by Kramer JW [29]. Additionally, there was an elevation in protein and globulin levels, surpassing the normal range. This elevation might indicate partial impairment of renal function in animals infected with *C. abortus* in these regions, although other factors could contribute. The average protein level in this study seems to be elevated in aborted animals and those under 2 years old. This level exceeds the normal range, potentially due to *C. abortus*-induced abortions during the last trimester of gestation [30] or toward the end of gestation [31]. Bilirubin levels in infected animals remained high regardless of physiological stage, age, or species, varying only by site. This finding contradicts the significant influence observed in Ouled-Djellal sheep in Algeria by Deghnouche K, et al. [30]. In our study, physiological stage, age, and species did not affect the albumin level in infected animals. However, an increase in globulin level was observed, especially in animals experiencing multiple abortions. These values deviate from the normal range and could be attributed to a pre-existing increase before the abortion process triggered by *C. abortus* infection. Regarding the ionogram of infected small ruminants, a decrease in calcium levels was noted in animals under 2 years old, remaining within the normal range of Research Animal Resources, (2009), but lower than that reported by Kahn [26]. This decline may result from *C. abortus* invasion causing electrolyte disturbances and subsequently increasing appetite in young animals. Phosphorus exhibited significant variation depending on sites, species, and physiological stages of infected animals, contradicting the normal ranges of Research Animal Resources and Kahn [10,26]. The elevated phosphorus levels in our study suggest a severe impact of *C. abortus* on the phosphor-calcium metabolism of infected animals. Sodium, potassium, and chloride showed nonsignificant variations across sites but remained consistent across species, age (121 ± 5.13 for sodium and 85 ± 7.55 for Chlore), and physiological stage (119 ± 4.73 for sodium and 80 ± 9.07 for Chlore). These variations were bellowed the normal ranges of Research Animal Resources and Kahn [10,26]. The fluctuations in sodium, potassium, phosphorus, and chloride levels in animals infected with *C. abortus* may stem from electrolyte disturbances induced by infection and an inflammatory response. Infections can disrupt electrolyte balance and alter electrolyte regulation, including sodium, potassium, and chloride. These changes may also be influenced by specific interactions between the microorganism and the host organism. These findings confirmed our hypothesis which based on the fact that the infection induced by *C. abortus* had an impact on blood complete cell and biochemical among small ruminants.

Conclusion

In Benin, *C. abortus* significantly impacts small ruminant productivity and poses health risks to pregnant women, with this study being the first to report the prevalence of enzootic ovine abortion in the country. Hematological and biochemical analyses revealed severe anemia, renal dysfunction, and phospho-calcium imbalances in infected animals, directly correlating with reproductive losses and bacterial contamination. The findings underscore the need for improved disease management, screening programs, and increased awareness and preventive measures to mitigate the impact of *C. abortus* on animals' health.

Acknowledgement

The authors want to thanks the Pan African Life and Earth Sciences Institute (Including Health and Agriculture) (PAULESI) at the University of Ibadan, Oyo State, Nigeria, for funded this study and also the Veterinary Laboratory in Bohicon for their collaboration in the analysis of this samples.

Contributions of Authors

AHK: Writing – original draft, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. GA & PC: Writing – review & editing, Formal analysis, Data curation. ET & JD: Writing – review & editing, Formal analysis, Data curation. GCA & FZ: Writing – review & editing, Methodology, Funding acquisition, Conceptualization. CKB: Writing – review & editing, Methodology, Conceptualization.

Conflict of Interest

The authors declared they were no conflict of interest.

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How to cite this article: Kifouly, Aboudou Habirou, Géorcelin Alowanou, Pierre Challaton and Esaïe Tchetan, et al. "Effect of *Chlamydia abortus* on Hematological and Biochemical Parameters of Infected Small Ruminants in Plateau Department (Southern East) of Benin Republic." *J Vet Sci Technol* 15 (2024): 253.