International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(12): 622-627
www.biochemjournal.com
Received: 02-11-2025
Accepted: 04-12-2025

Nidhi Patel
Veterinary Officer, Department of Animal Husbandry, Mahisagar, Gujarat, India

Nilesh Gohil
Veterinary Officer, Department of Animal Husbandry, Narmada, Gujarat, India

Khushbu Rana
Veterinary Officer, Department of Animal Husbandry, Panchmahal, Gujarat, India

Corresponding Author:
Nidhi Patel
Veterinary Officer, Department of Animal Husbandry, Mahisagar, Gujarat, India

Study of hemato-biochemical changes in cases of anaplsmosis in cattle

Nidhi Patel, Nilesh Gohil and Khushbu Rana

DOI: https://www.doi.org/10.33545/26174693.2025.v9.i12h.6598

Abstract
Bovine anaplasmosis is one of the economically important haemoprotozoan diseases in India. The disease is a major constraint in dairy industry and causes great economic losses to livestock farmers through mortality and loss of productivity. The present research work was carried out to study haemato-biochemical changes in cattle affected with anaplasmosis. A total of 66 cattle suspected for anaplasmosis were screened based on clinical signs and blood smear examination. Out of them, 22 were found positive for anaplasmosis. Out of them total 18 positive cases of anaplasmosis were selected for study. while group 1 of six healthy cattle was kept for comparison of various haemato-biochemical parameters. The haematological examination revealed that the mean±SE values of haemoglobin, packed cell volume, total erythrocytes count and mean corpuscular haemoglobin concentration (MCHC) were significantly decreased ($p<0.01$) in anaplasmosis affected cattle as compared to healthy cattle, However, lymphocyte and platelets count were decreased non-significantly. Furthermore, there was significant ($p<0.05$) increase in mean corpuscular volume (MCV), while total leucocytes count (TLC), mean corpuscular haemoglobin (MCH), neutrophils, monocytes and eosinophils increase non-significantly. The serum biochemical examinations revealed that the mean±SE values of total protein were decreased non-significantly, while albumin and A/G ratio were decreased highly significantly ($p<0.01$) in anaplasmosis affected cattle as compared to healthy control group. Globulin and alanine aminotranferase were increased significantly ($p<0.05$), whereas aspartate aminotransferase and bilirubin were increased highly significantly ($p<0.01$). However, serum creatinine was increased non-significantly in anaplasmosis affected cattle as compared to healthy cattle.

Keywords: Bovine anaplasmosis, *A. marginale*, *Rhiphicephalus* spp, Haemoglobin, A/G Ratio

1. Introduction
In Indian economy livestock plays an important role and contributes up to 4.11 per cent in Indian GDPA. Total of 20.5 million rural residents depend on cattle for their livelihood. (DAHDF, 19th Livestock Census 2012 report, 2014). Many viral, metabolic, and parasitic diseases concern India due to climate differences in tropical and subtropical countries. The global loss due to Ticks and Tick-Borne Diseases (TTBDs) is estimated to be between US$ 13.90 and 18.70 billion annually (De Castro, 1997) [9], while in India the cost of controlling TTBDs has been estimated as US$ 498.7 million/annum (Minjauw and McLeod, 2003) [16].
The most common haemoprotozoan infections in animals are trypanosomosis, theileriosis, babesiosis, and anaplasmosis. Bovine anaplasmosis is considered as one of the economically important rickettsial diseases affecting ruminants. In India, *A. marginale*, *A. centrale*, and *A. bovis* are the prevalent species in cattle (Nair *et al*., 2013) [17] and they are principally transmitted by a tick of *Rhiphicephalus* spp. (Constable *et al.*, 2017) [7].
Bovine anaplasmosis, formerly known as gall sickness, is an infectious, non- contagious, tick-borne disease of domesticated and wild ruminants caused by *Anaplasma* species characterized by fever, icterus, anorexia, anaemia, constipation, weakness, dehydration, laboured breathing, depression, abortion, and often death (Richey and Palmer, 1990) [20]. Diagnosis can be done by Giemsa stained blood smear examination (Maharana *et al.* 2016) [14]. Diagnosis based on microscopic examination is not reliable for detecting pre-symptomatic or carrier animals. In these cases, the infection is usually detected by presence of antibodies on a serologic test with confirmation by molecular detection methods such as Complement Fixation Test (CFT), Capillary Agglutination Assay, Card Agglutination Test (CAT),

Indirect Fluorescent Antibody (IFA) Enzyme Linked Immunosorbent Assays (ELISA) and PCR (Aubry and Geale, 2011) [5], (Carelli *et al.*, 2007) [6].

2. Materials and Methods

The present investigation was carried out at the Department of Veterinary Medicine, College of Veterinary Science and Animal Husbandry, Anand with the objectives to study haemato-biochemical changes in cattle affected with anaplasmosis. Total 66 Giemsa's-stained thin blood smears were examined from cattle suspected for anaplasmosis. Out of them, 22 (33.34%) cattle were found positive by microscopic examination seen as compact spherical masses, inside the red blood cells near the periphery of RBCs wall. Out of 66 samples 34 (51.52%) samples were found positive for anaplasma species by PCR. Out of those 18 animals were selected for hematobiological examination.

2.1 Sample Collection and Storage

Whole blood samples were collected from the jugular veins of the suspected animals in the vacutainers containing an anticoagulant, tripotassium ethylene diamine tetra-acetic acid (K_3EDTA) and serum clot activators on day '0' from selected cases. The similar samples were also collected from cattle under healthy group. These blood samples were kept in ice box, transported to the lab within 2-3 hours, and processed on the same day. Blood samples taken in serum clot activator vials were centrifuged at 3000 rpm for 10 minutes. The sera samples were separated/aspirated with sterile pipette and were stored at -20°C until final use for estimation of various biochemical parameters.

2.2 Haematological Examination

Haematological analysis of samples was performed from the whole blood collected from the jugular vein of healthy and infected cattle in a K_3EDTA vacutainers. Estimation of haematological parameters was done by using auto-haematological analyzer machine (Abacus junior Vet-5) at Veterinary Clinical Complex, which included following parameters.

- Haemoglobin (g/dl)
- Total Erythrocyte Count (10^6/µl)
- Total Leukocyte Count (10^3/µl)
- Differential Leukocyte Count (%)
- Packed Cell Volume (%)
- Platelets count (10^3/µl)
- Mean Corpuscular Volume (fl)
- Mean Corpuscular Haemoglobin (pg)
- Mean Corpuscular Haemoglobin Concentration (g/dl)

2.3 Serum Biochemical Examination

All the biochemical parameters were analyzed by using standard procedures and assay kits on clinical chemistry analyzer (CKK 300) at Veterinary Clinical Complex as per manufacturer's instructions. The serum samples obtained from blood collected on day 0 from cattle affected with anaplasmosis and stored deep frozen were used for the estimation of following biochemical parameters.

- Total Protein (g/dl)
- Albumin (g/dl)
- Bilirubin (mg/dl)
- Creatinine (mg/dl)
- Alanine Aminotransferase (U/L)
- Aspartate Aminotransferase (U/L)
- Globulin (g/dl)
- Albumin/Globulin (A/G) Ratio

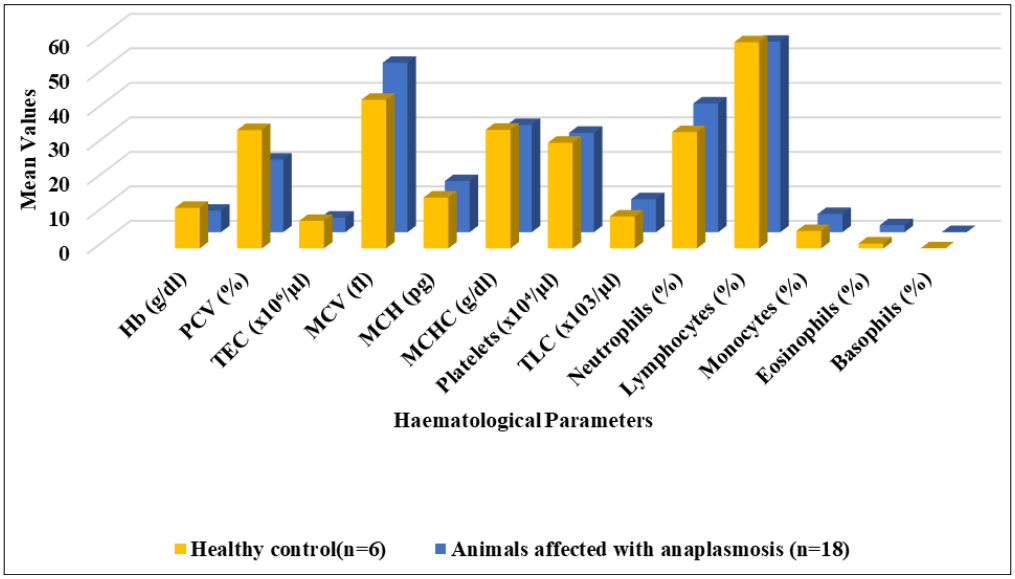
3. Result and Discussions

3.1 Hematological Examination

In present study, whole blood samples were collected from all 18 cattle affected with anaplasmosis and a healthy group (n=6) on day 0 to determine the haematological profile. The mean (±SE) values of various haematological parameters and indices of cattle affected with anaplasmosis are shown in Table 3.1 and Figure 3.2 and are discussed in detail as follows.

Table 3.1: The mean (±SE) values of haematological parameters of healthy and anaplasmosis affected cattle

Parameters	Healthy (n=6)	Anaplasmosis infected animals (n=18)	"p" value
Hb (g/dl)	11.75±0.76	6.23± 0.20**	0.001
PCV (%)	34.30±2.44	21.06±0.77**	0.002
TEC (x10^6/dl)	7.97±0.52	4.23±0.16**	0.000
MCV (fl)	43.07±1.62	49.09±0.97*	0.011
MCH (pg)	14.75±0.31	14.82±0.35	0.870
MCHC (g/dl)	34.37±0.74	31.08±0.55**	0.004
Platelets (x10^3/µl)	306.16 ±22.07	288.16±19.74	0.553
TLC (x10^3/µl)	9.27±0.51	9.59±0.31	0.603
Neutrophils (%)	33.71 ±2.53	37.32±3.05	0.375
Lymphocytes (%)	59.75 ±2.61	55.21±2.96	0.275
Monocytes (%)	5.06±0.69	5.28±0.58	0.810
Eosinophils (%)	1.43±0.20	2.03±0.16*	0.041
Basophils (%)	0.04 ±0.01	0.05±0.01	0.511



*p<0.05= significant, **p<0.01= highly significant

Fig 3.1: Mean values of haematological observations of healthy and anaplasmosis affected cattle

3.1.1 Haemoglobin (Hb; g/dl)

In present study, the mean value of haemoglobin recorded in healthy cattle was 11.75±0.76 g/dl and in cattle with anaplasmosis it was 6.23±0.20 g/dl. The level of haemoglobin was highly significantly (P<0.001) decreased in anaplasmosis affected cattle (Table 3.1, Figure 3.1).

Present findings were in accordance with Shaukat *et al.* (2019) [23]. Similar observations were also reported by Coskun *et al.* (2012) [8], Sharma *et al.* (2013) [22], Singh *et al.* (2014) [24], Meenakshisundaram *et al.* (2014) [15], Maharana *et al.* (2016) [14], Ganguly *et al.* (2018) [11], Subramanian *et al.* (2019) [25], and Ola fadunsin *et al.* (2021) [19].

A significant reduction in the haematological parameters (Hb, PCV, RBC, and MCHC) might be due to the intravascular haemolysis of erythrocytes, increased erythrocyte phagocytosis by the reticuloendothelial system, and restricted erythropoietic activity in the bone marrow, which is a result of *A. marginale* infection (Sharma *et al.*, 2013) [22].

3.1.2 Packed cell volume (PCV;%)

In present study the mean±SE value of PCV recorded in healthy cattle was 34.30±2.44% and in cattle with anaplasmosis 21.06±0.77%. It was highly significantly (P<0.002) decreased in anaplasmosis affected cattle (Table 3.1, Figure 3.1).

Shaukat *et al.* (2019) [23] also reported significantly (P<0.05) decreased packed cell volume in anaplasmosis affected cattle as compared to healthy animals. Similar findings were also reported by many previous workers (Ajayi *et al.*, 1987; Singh *et al.*, 2014; Meenakshisundaram *et al.*, 2014; Szabara *et al.*, 2016; Maharana *et al.*, 2016; Ganguly *et al.*, 2017; Ganguly *et al.*, 2018; Subramanian *et al.*, 2019; Ola fadunsin *et al.*, 2021) [24, 14, 15, 25, 10, 11].

The decreased value of PCV might be due to intravascular haemolysis of erythrocytes by *Anaplasma* spp. which invade and cause erythrophagocytosis.

3.1.3 Total erythrocyte count (TEC; x10^6/µl)

In present study, the mean±SE value of TEC recorded in healthy cattle was 7.97±0.52 x10^6/µl and in cattle with anaplasmosis 4.23±0.16 x10^6/µl. It was highly significantly (P<0.001) decreased in anaplasmosis affected cattle (Table 3.1, Figure 3.1).

This observation was in accordance with Shaukat *et al.* (2019) [23]. who also reported that there were significantly (P<0.05) decreased level of total erythrocyte count in anaplasmosis affected cattle as compared to healthy animals. Present findings were also in accordance with Coskun *et al.* (2012) [8], Arunkumar and Nagarajan (2013) [4], Sharma *et al.* (2013) [22], Meenakshisundarm *et al.* (2014), Singh *et al.* (2014) [24], Maharana *et al.* (2016) [14], Szabara *et al.* (2016), Ganguly *et al.* (2017), Ganguly *et al.* (2018), Subramanian *et al.* (2019), and Ola-fadunsin *et al.* (2021) [10, 11, 25].

The decrease level of total erythrocyte might be due to erythrophagocytosis by reticuloendothelial system because of intravascular haemolysis of erythrocyte which was initiated by parasitic damage to erythrocytes and that leads to decrease in total erythrocyte count (Sharma *et al.*, 2013) [22].

3.1.4 Mean corpuscular haemoglobin concentration (MCHC; g/dl)

The mean±SE value of mean corpuscular haemoglobin concentration (MCHC) recorded in healthy cattle was 34.37±0.74 g/dl and in cattle with anaplasmosis it was 31.08±0.55 g/dl. The level of mean corpuscular haemoglobin concentration was decreased highly significantly (P<0.004) in anaplasmosis affected cattle (Table 3.1, Figure 3.1).

The present findings agreed with Ola-Fadunsin *et al.* (2021) [19], who reported significantly decreased mean value of MCHC. Present findings were also in accordance with Arunkumar and Nagrajan (2013), Sharma *et al.* (2013) [22], Maharana *et al.* (2016), and Shaukat *et al.* (2019) [14, 23].

The significant decrease in MCHC might be due to intravascular haemolysis of erythrocytes, increased erythrophagocytosis by reticuloendothelial system and subsequently rapid release of immature erythrocytes into circulation (Ola-fadunsin *et al.*, 2021) [19].

3.1.5 Mean corpuscular volume (MCV; fl)

The mean±SE value of mean corpuscular volume (MCV) recorded in healthy cattle was 43.07±1.62 fl and in cattle

with anaplasmosis it was 49.09±0.97 fl. The level of mean corpuscular volume was increased significantly (P<0.011) in anaplasmosis affected cattle (Table 3.1, Figure 3.1).
The present findings agreed with Shaukat *et al.* (2019) [23], who reported significant (P<0.05) increase in value of MCV in anaplasmosis affected cattle as compared to healthy cattle. Similar observations were also reported by Arunkumar and Nagarajan (2013) [4], Sharma *et al.* (2013) [22], Maharana *et al.* (2016) [14], Ola-Fadunsin *et al.* (2021) [19]. Whereas Ganguly *et al.* (2018) [11] reported a non-significant decrease (MCV of cattle affected with anaplasmosis.
The increase in MCV might be due to rapid haemolysis of erythrocytes which leads to release of immature macrocytic erythrocytes into the circulation.

3.1.6 Eosinophils (%)
The mean ±SE value of eosinophils recorded in healthy cattle was 1.43±0.20% and in cattle with anaplasmosis it was 2.03±0.16%. The level of eosinophils was significantly (P<0.041) increased in anaplasmosis affected cattle as compared to healthy cattle (Table 3.1, Figure 3.1).
Ganguly *et al.* (2018) [11] reported that the mean value of eosinophils was increased non-significantly in anaplasmosis affected cattle as compared to healthy cattle, while Hussain *et al.* (2017) [12] observed a significantly increased mean value of eosinophils in anaplasmosis affected cattle as compared to healthy cattle.
However, lymphocytes and platelets count were decreased non-significantly. Furthermore, total leucocytes count (TLC), mean corpuscular haemoglobin (MCH), neutrophils, monocytes and eosinophils increased non-significantly in anaplasmosis affected cattle.

3.2 Serum Biochemical Profile
In present study, whole blood samples were collected from all 18 cattle affected with anaplasmosis and a healthy group (n=6) for estimation of various serum biochemical constituents. The mean (±SE) values of different serum biochemical parameters studied are shown in Table 3.2 and Figure 3.2, and are discussed in detail as follows

Table 3.2: The mean (±SE) serum biochemical profile of healthy and anaplasmosis affected cattle

Parameters	Healthy	Anaplasmosis infected animals (N=18)	"p" Value
Total protein (g/dl)	7.30±0.23	7.21±0.07	0.356
Albumin (g/dl)	3.73±0.19	2.56 ±0.10**	0.001
Globulin (g/dl)	3.57±0.15	4.65±0.14**	0.000
A/G Ratio	1.05±0.085	0.56±0.03**	0.001
Bilirubin (mg/dl)	0.89±0.04	1.84 ±0.08**	0.000
Creatinine (mg/dl)	1.20±0.11	1.40 ±0.08	0.185
AST (U/L)	91.31±3.38	122.72±2.76**	0.000
ALT (U/L)	35.94±4.24	51.92±2.15**	0.010

*p<0.05= significant, **p<0.01= highly significant

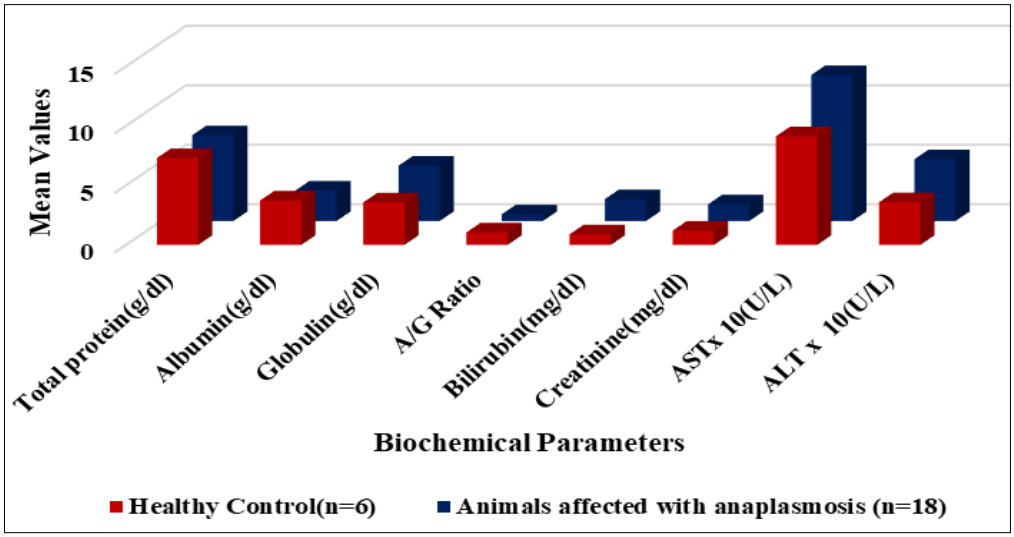


Fig 3.2: Mean values of serum-biochemical observations of healthy and anaplasmosis affected cattle

3.2.1 Albumin (g/dl)
The mean ±SE value of serum albumin recorded in healthy cattle was 3.73±0.19 g/dl and in cattle with anaplasmosis 2.56±0.10 g/dl. It was highly significantly (P<0.001) decreased in anaplasmosis affected cattle (Table 3.2 and Figure 3.2).
The present findings were in accordance with Ganguly *et al.* (2018) [11] and Ola-Fadunsin *et al.* (2021) [19] who observed significantly decreased albumin level of cattle affected with anaplasmosis. However, Szabara *et al.* (2016) observed mild hypoalbuminemia in cattle affected with anaplasmosis as compared to healthy group. Furthermore, Hussain *et al.* (2017) [12] reported no changes in biochemistry in cattle affected with anaplasmosis.

3.2.2 Globulin (g/dl)
In present study, the mean ±SE value of serum globulin recorded in healthy cattle was 3.57±0.15 g/dl and in cattle with anaplasmosis it was 4.65±0.14 g/dl. The level of globulin was highly significantly increased (P<0.000) in anaplasmosis affected cattle as compared to healthy ones (Table 3.2 and Figure 3.2).

The present findings were in accordance with Nasreldin *et al.* (2020) [18], who observed significant increase in the level of globulin in cattle affected with anaplasmosis. Similar finding was also reported by Sharma *et al.* (2013) [22]. The elevated serum globulin level observed in the *A. marginale* infected animals could be due to activation of a defensive immune response that leads to an increase in circulating immunoglobulin in the serum (Sharma *et al.*, 2013) [22].

3.2.3 Albumin/Globulin (A/G) ratio

The mean ±SE value of serum A/G ratio recorded in healthy cattle was 1.05±0.085 and in cattle with anaplasmosis 0.56±0.03 It was highly significantly decreased ($P<0.001$) in anaplasmosis affected cattle (Table 3.2 and Figure 3.2).

The present findings are in accordance with Nasreldin *et al.* (2020) [18] who observed significantly decreased level of A/G ratio in female cattle affected with anaplasmosis.

3.2.4 Bilirubin (mg/dl)

In present study, the mean ±SE value of serum bilirubin recorded in healthy cattle was 0.89±0.04 mg/dl and in cattle with anaplasmosis it was 1.84 ±0.08 mg/dl. The level of bilirubin was highly significantly ($P<0.000$) increased in anaplasmosis affected cattle than in healthy cattle (Table 3.2 and Figure 3.2).

The present findings are in consistent with Nasreldin *et al.* (2020) [18] who reported significant increase in the level of total bilirubin in the anaplasmosis affected cattle in comparison to healthy group. Similar observations were also reported by Coskun *et al.* (2012) [8], Sharma *et al.* (2013) [22], Jaseem *et al.* (2015), Sazabara *et al.* (2016), Ganguly *et al.* (2018) [11], and Ola-Fadunsin *et al.* (2021) [19].

The elevated serum bilirubin levels could be due to haemolysis of parasitized erythrocytes. Additionally, higher serum bilirubin levels have been linked to haemolytic anaemia and hepatic dysfunction (Coskun *et al.*, 2012) [8].

3.2.5 Aspartate aminotransferase (AST; U/L)

In present study, the mean ±SE value of serum aspartate aminotransferase activity recorded in healthy cattle was 91.31±3.38 U/L and in cattle with anaplasmosis it was 122.72±2.76 U/L. The level of aspartate aminotransferase was highly significantly ($P<0.000$) increased in anaplasmosis affected cattle (Table 3.2 and Figure 3.2).

Similar findings were reported by Alekish and Iamail (2019) in cattle affected with anaplasmosis. Our findings were also in conconance with those reported by Riond *et al.* (2008), Coskun *et al.* (2012) [8], Jaseem *et al.* (2015), Szabara *et al.* (2016), Ganguly *et al.* (2017), Ganguly *et al.* (2018) and Nasreldin *et al.* (2020) [10, 11, 18].

The increase in AST is related to a hepatic damage or muscular trauma induced by prolonged clinical recumbency in animals. Massive haemolysis may also occur, which when combined with hypoxia, can result in hepatic cell degeneration and glomerular dysfunction, resulting in a rise in AST and ALT enzymes.

3.2.6 Alanine Aminotransferase (ALT; U/L)

The mean±SE value of serum alanine aminotransferase activity recorded in healthy cattle was 35.94±4.24 U/L and in cattle with anaplasmosis it was 51.92±2.15 U/L. The level of alanine aminotransferase was significantly ($P<0.010$) increased in anaplasmosis affected cattle (Table 3.2 and Figure 3.2).

`Our findings were in accordance with Jaseem *et al.* (2015), Szabara *et al.* (2016), Ganguly *et al.* (2017) [10] and Ganguly *et al.* (2018) [11] and Nasreldin *et al.* (2020) [18], who reported significant ($P<0.05$) increase in the serum alanine aminotransferase in cattle affected with anaplasmosis. However, Alekish and Iamail (2019) observed non-significantly increased alanine aminotransferase in anaplasmosis affected cattle.

The present finding is conceivable since it is related to a hepatic damage or muscular trauma induced by prolonged clinical recumbency. These tissues might contain a large amount of enzymes that could be released into the bloodstream. (Coskun *et al.* 2012) [8]. According to the researchers, the rise in enzyme activity might be due to severe anaemia, which causes hypoxia and liver damage. Massive haemolysis may also occur, which, when combined with hypoxia, can result in hepatic cell degeneration and glomerular dysfunction, resulting in a rise in AST and ALT enzymes (Sharma *et al.* (2013) [22].

However non-significant changes were observed in the level of total protein and creatinine.

4. Conclusion

The haematological examinations revealed that the Mean±SE values of haemoglobin, packed cell volume, and total erythrocytes count were decreased highly significantly ($p<0.01$) and mean corpuscular haemoglobin concentration (MCHC) was decreased significantly ($p<0.05$) in anaplasmosis affected cattle as compared to healthy cattle. The serum biochemical examinations revealed that the Mean±SE values of total protein were decreased non-significantly, while albumin and A/G ratio were decreased highly significantly ($p<0.01$) in anaplasmosis affected cattle as compared to healthy control group. Globulin and alanine aminotransferase were increased significantly ($p<0.05$), whereas aspartate aminotransferase and bilirubin were increased highly significantly ($p<0.01$).

5. Acknowledgement

The authors are grateful to the Dean of Collage of Veterinary Science and Animal Husbundary, and authorities of Kamdhenu Universirty for the facilities and encouragement provided for this work.

Conflict of Interest: Not available

Financial Support Not available

References

1. Department of Animal Husbandry, Dairying and Fisheries. 20th Livestock Census (2019). Ministry of Agriculture and Farmers Welfare, Government of India; New Delhi, India.
2. Ajayi SA, Oyetunde IL, Ogbonna GA, Dipeolu OO. Bovine anaplasmosis: clinical, haematological and blood biochemical changes in experimentally infected Nigerian cattle. Journal of Animal Husbandry and Veterinary Medicine in Tropical Countries. 1987;40(1):41-47.
3. Alekish MO, Ismail ZB. Relationship between certain serum biochemical values and serostatus against *Anaplasma marginale* in dairy cows. Veterinary World. 2019;12(11):1858-1861.
4. Arunkumar S, Nagarajan K. Prevalence of *Anaplasma marginale* infection among cattle population of Kancheepuram and Chennai districts of Tamil Nadu.

International Journal of Food, Agriculture and Veterinary Sciences. 2013;3(1):155-157.
5. Aubry P, Geale DW. A review of bovine anaplasmosis. Transboundary and Emerging Diseases. 2011;58(1):1-30.
6. Carelli G, Decaro N, Lorusso A, Elia G, Lorusso E, Mari V, Ceci L, Buonavoglia C. Detection and quantification of *Anaplasma marginale* DNA in blood samples of cattle by real-time PCR. *Veterinary Microbiology*. 2007;124(1-2):107-114.
7. Constable PD, Hinchcliff KW, Done SH, Grünberg W. Veterinary Medicine: A Textbook of the Diseases of Cattle, Horses, Sheep, Pigs and Goats. 11th ed. St. Louis: Elsevier; 2017. p. 769-775.
8. Coşkun A, Derinbay Ekici Z, Güzelbekteş H, Aydoğdu U, Şen S. Acute phase proteins, clinical, hematological and biochemical parameters in dairy cows naturally infected with *Anaplasma marginale*. Journal of the Faculty of Veterinary Medicine, Kafkas University. 2012;18(3):497-502.
9. De Castro JJ. Sustainable tick and tick-borne disease control in livestock improvement in developing countries. Veterinary Parasitology. 1997;71(2-3):77-97.
10. Ganguly A, Bisla RS, Singh H, Bhanot V, Kumar A, Kumari S, Ganguly I. Prevalence and haemato-biochemical changes of tick-borne haemoparasitic diseases in crossbred cattle of Haryana, India. *Indian Journal of Animal Sciences*. 2017;87(5):552-557.
11. Ganguly A, Maharana BR, Ganguly IK, Potliya A, Arora D, Bisla RS. Molecular diagnosis and haemato-biochemical changes in *Anaplasma marginale*-infected dairy cattle. Indian Journal of Animal Sciences. 2018;88(9):989-993.
12. Hussain MF, Qamar M, Malik MI, Hussain M, Saeed Z, Shaikh RS, Iqbal F. Molecular detection of anaplasma in apparently healthy Cholistan breed of cattle from Bahawalpur district, Pakistan. *Tropical Biomedicine*. 2017;34(1):37-44.
13. Jassem GA, Agaar OA. Molecular and biochemical study of *Anaplasma marginale* in cattle in Wassit Province of Iraq. African Journal of Bacteriology Research. 2015;7(4):36-41.
14. Maharana BR, Kumar B, Prasad A, Patbandha TK, Sudhakar NR, Joseph JP, Patel BR. Prevalence and risk factors of haemoprotozoan infections in cattle and buffaloes of South-West Gujarat, India. *Indian Journal of Animal Research*. 2016;50(6):1-7.
15. Meenakshisundaram A, Anna T, Malmarugan S. Concomitant *Theileria annulata* and *Anaplasma marginale* infections in a crossbred dairy herd. Indian Journal of Veterinary and Animal Sciences Research. 2014;10(6):422-425.
16. Minjauw B, McLeod A. Tick-borne diseases and poverty: The impact of ticks and tick-borne diseases on the livelihood of small-scale and marginal livestock owners. Research Report. Edinburgh: Centre for Tropical Veterinary Medicine, University of Edinburgh; 2003. p. 1-116.
17. Nair AS, Ravindran R, Lakshmanan B, Sreekumar C, Kumar SS, Raju R, Saseendranath MR. Bovine carriers of *Anaplasma marginale* and *Anaplasma bovis* in South India. *Tropical Biomedicine*. 2013;30(1):105-112.
18. Nasreldin N, Ewida RM, Hamdon H, Elnaker YF. Molecular diagnosis and biochemical studies of tick-borne diseases in Aberdeen Angus cattle in Egypt. *Veterinary World*. 2020;13(9):1884-1891.
19. Ola-Fadunsin S, Ademola IO, Adejinmi JO, Okediran BS. Haemoparasites and haemato-biochemical profiles associated with *Anaplasma marginale* infections of cattle in Ilorin, Nigeria. *Veterinaria*. 2021;70(3):335-349.
20. Richey EJ, Palmer GH. Bovine anaplasmosis. *Compendium on Continuing Education for the Practising Veterinarian*. 1990;12:1661-1688.
21. Riond B, Meli ML, Braun U, Deplazes P, Joerger K, Thoma R, Hofmann-Lehmann R. Concurrent infections with vector-borne pathogens associated with fatal anaemia in cattle. Comparative Clinical Pathology. 2008;17(3):171-177.
22. Sharma A, Singla LD, Kaur P, Bal MS, Batth BK, Juyal PD. Prevalence and haemato-biochemical profile of *Anaplasma marginale* infection in dairy animals of Punjab, India. Asian Pacific Journal of Tropical Medicine. 2013;6(2):139-144.
23. Shaukat A, Mehmood K, Shaukat I, Rehman TU, Naeem MA, Mehfooz A, Saleem MI, Sindhu ZUD, Rajput SA, Hassan M, Umar S, Jamil MA, Abbas RZ, Qureshi AS. Prevalence, haematological alterations and chemotherapy of bovine anaplasmosis in cattle of Faisalabad, Pakistan. *Pakistan Journal of Zoology*. 2019;51(6):2023-2032.
24. Singh ND, Banga HS, Gadhave PD, Chougule AA, Goyal A, Brar RS. Clinico-pathological alterations in bovine anaplasmosis. Indian Journal of Animal Research. 2014;48(3):295-297.
25. Subramanian B, Vijayalakshmi P, Perumal SV, Selvi D. Clinical and haemato-biochemical changes in cattle with *Anaplasma marginale* infection. *International Journal of Chemical Studies*. 2019;7(5):4373-4376.
26. Szabára A, Majer J, Ózsvári L, Jakab C, Baumgartner W. Co-infection with bovine viral diarrhoea virus and *Anaplasma marginale* in a dairy herd. *Veterinární Medicína*. 2016;61(9):504-515.