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REVIEW ARTICLE: GLOBAL EVIDENCE OF BOVINE BABESIOSIS

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Abstract:

Babesiosis is frequent global wide spread tick-borne infection which influence different domestic animals in particular cattle causes global enormous economic loss. The global and local endemic of this disease raising several challenges posed by uncontrolled infection and parasite diversity through various risk factors. Due to availability of these challenges concomitant with limited recent prevalence data of various *Babesia* species, thus this review investigated recent available data regarding life cycle, prevalence, method of transmission, clinical signs, diagnosis, treatment and control schedules of bovine babesiosis. Also, highlighted the local and global incidence alongside whether it is foe or friend. The causative agent of bovine babesiosis includes *B. bovis*, *B. bigemina* and *B. divergens*; with a typical signs characterized by high body temperature, severe depression, hemoglobinuria, anemia and high mortality. Microscopic examination of blood smear stained with Giemsa dye represents routine applicable technique to confirm the acute infection. However, advanced diagnostic assays such as serological and molecular assays were employed with more reliable data for confirmation of acute and chronic cases. The major risk factors that are participated in global and local endemic and prevalence of the bovine babesiosis are related to availability of ticks, prevention measurement, existence of ticks in specific region, age and breed of animal, type of babesicidal drugs, general sanitary conditions, and nutrition. Other factors include inactive control schedules on vectors (ticks), evolution of parasitic resistance. This review identified that the disease is challenging and affect agriculture sector particularly cattle management field. Thus, specific qualitative studies that focus on of host with parasite and tick relations, parasite metabolism, and the possible ways of surviving *Babesia* are required. Additionally, specific and precise studies that create predictive measurements of spreading the vector and infection using available regional and epidemiological information are of interest.

Keywords: Cattle, Buffalo, *Babesia* spp., Haemoparasite, Iraq

1.1. Historical view

For centuries, bovine babesiosis is known as threaten illness in both wild and domestic animals including cattle. The responsible agent for this disease was determined in Romania in 1888 by scientist Victor Babes. At the first, the scientist thought it is *Haematococcus bovis* bacteria, and the signs of severe hemolytic disease in sheep and cattle were documented. In 1889, in the United State of America, the Texas cattle fever was occurred due to parasite infection as Smith and Kilborne stated which then termed *Pyrosoma bigeminum*. In 1893, they identified the tick (*Boophilus annulatus*) as the source of transmitting the parasite, and this discovery considered as the earliest information of the transmission of protozoan parasites by arthropods. At the same year, Starcovici is a scientist that named this protozoan as *Babesia bovis, B. ovis* and *B. bigemina,* respectively. *Babesia* is the exact name for the genus instead of the genus name *Pyrosoma* (**Uilenberg, 2006; Schultz, 2008; Alkefari et al., 2017; He et al., 2021**).

1.2. Classification

According to **Sharma *et al.*** (**2013**), *Babesia* classified as following:

Kingdom: Eukaryota
Phylum: Apicomplexa
Class: Sporozea
Order: Piroplasmida
Family: Babesiidae
Genus: *Babesia*
Species: *B. bovis*, *B. bigemina*, *B. divergenis* (**Bock et al., 2004; Kuttler, 2018**).

1.3. Life cycle of parasite

Among various *Babesia* species, life cycle approximately identical with existence of few

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differences existed because, in some species, transovarial transmission occurs while not in other species (**Friedhoff, 2018**). However, *Babesia* species undergo a complex unique life cycle to establish their existence through transmission, sharing of infection between vertebrate mammals and invertebrates (ticks), and forming of different stages. In general, *Babesia* have three stages are gamogony that generated from gametes union in the tick gut, sporogony found in the tick salivary glands of tick which considers as the first phase of asexual reproduction, and finally merogony that occurs in vertebrate host and considers as an asexual reproductive process of apicomplexa (**Figure 1**), (**Jalovecka *et al.,* 2019**).

In vertebrates, *Babesia* species transmit to the vertebrate host by the hard tick biting to pass by transovarial transmission with eggs of the first generation of tick to the next. Infected ticks when attached to host, they transferred sporozoites by their saliva, to invade host's erythrocytes (**Rodriguez *et al*, 2014; Abdela and Jilo, 2016**). Each transferred sporozoite undergoes binary fusion to form two merozoites leading to destruction of host erythrocyte, and initiation of asexual reproduction. Then, each individual merozoite invaded successfully new erythrocytes to complete a merogony. Infective pre-gametocytes stage occurs in the vertebrate host and tick (**Chauvin *et al.*, 2009; Suarez and Noh, 2011; Garg et al., 2013**).

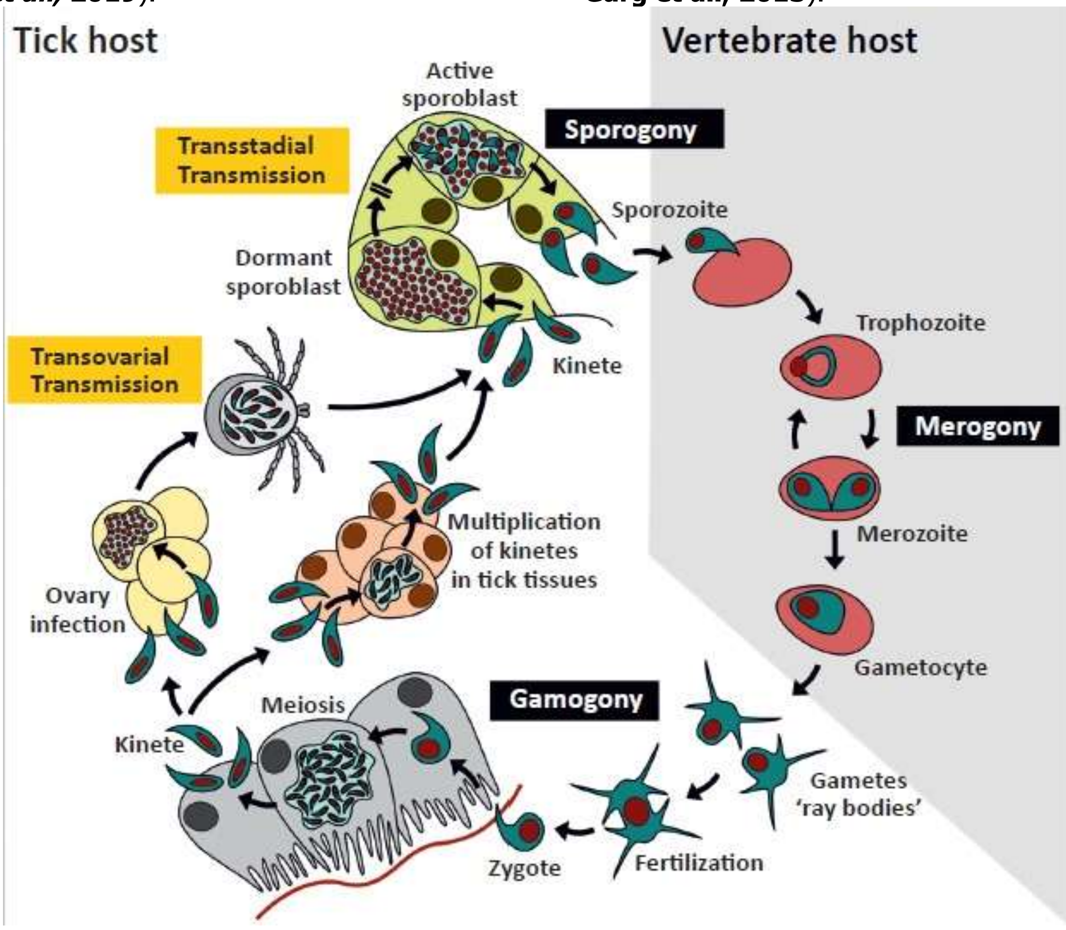

Figure 1: *Babesia* life cycle (Jalovecka *et al.,* 2019)

In ticks that represent the definitive host, *Babesia* species evolve a novel strategy as a result of needing to adaptation for feeding and molting. In hard tick, the parasite develops a capability for persisting into the next stage of tick development as known as trans-stadially transmission, in addition to trans-ovarially transmission that allows to spreading of *Babesia* from maternal tick for many offspring (**Jalovecka *et al.,* 2018**). Although, many parasites degenerate and destroy during erythrocytes feeding, pre-gametocytes can be survived to undergoing a furthermore develops to elongated gametocytes within the midgut of infected tick (ray bodies). In lumen of digestive tract of tick, gametes will fuse to forming the elongated zygotes, through which, the arrowheads touch the cell membranes of midgut and facilitate cell penetration, when the zygote will be internalized, it will be transform into motile kinetes (**Antunes, 2014; Adzigbe, 2017**). The motile kinetes enter the hemolymph through invasion of intestinal epithelial

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tissues of female ticks and then ovaries as the most notable invaded tissues to be transmitted for their offspring (**Sonenshine and Macaluso, 2017; Ueti *et al.*, 2020**). In sometimes, *Babesia* can be transmitted transstadially throughout developing the tick larvae to nymph then to adult, which represents a more importance adaptation in tick's life cycle (**Friedhoff, 2018**).

1.4. Morphology

It is varied obviously in accordance to *Babesia* species when is large, measures 2.5-3μm such as *B. bigemina* and *B. caballi*, or small when measures 1.5-2μm such as *B. bovis*. Morphology and size of the parasite may be affected by host factors such as immune response, partial treatment and presence of spleen or not, the intra erythrocytic structure of the *Babesia* has pyriform shape which is surrounded by two peripheral membranes within the cytoplasm of a host (**Schuster, 2002; Uilenberg, 2006**). When the parasite enters into erythrocyte, it becomes circle in shape which is developed into trophozoit ring, then molt to merozoites which is characterized by having a tetrad body form. The latter can be clearly spotted microscopically in Giemsa blood smear and serves as a distinguishing feature of bovine Babesiosis (**Herwaldt *et al.*, 2003; Saleh et al., 2015**).

Babesia bovis presents usually in center of erythrocyte as length and width range between 1-1.5μm and 0.5-1.0μm, respectively. Also, the parasite can appear as pair with obtuse angle of each other (**Alvarez et al., 2019**). The typical appearance of *B. bigemina* is like pear-shaped with several single various forms. It is much longer than *B. bovis*, and can be existed as pairs with acute angles and the length and width ranging between 3-3.5μm and 1-1.5μm (**Lempereur et al., 2017**). *Babesia divergens* is measured 1.5μm as long and 0.4μm as wide with a general pairs form that having greater angle between the members; and rarely with circular, pyriform or stout forms with erythrocytes (**Laha et al., 2015**).

1.5. Epidemiology

Babesia parasite founded in parallel with the existing vectors; however, it present in tropical and subtropical region (**Nejash, 2016**). However, epidemiology of bovine babesiosis is based usually on existence of infected tick and sensitive host, in addition to other factors like geographical features and environmental conditions (**Bashir *et al.*, 2009; Abdela and Jilo, 2016**). *Babesia bovis* and *B. bigemina* exist in Asia, Africa, and regions of Southern Europe in addition to Southern and Central America and Australia (**Kuttler, 2018**). Although, *B. bovis* and *B. bigmeina* are usually existed at same geographic region, but there were slightly different groups of ticks which responsible for spreading these species with some variations in their distributions including high incidence of *B. bigemina* in Africa, contrast incidence in Asia, and variation in their vectors in the United States of America, (**Al-Abedi and Al-Amery, 2020; Gharban et al., 2022**). While, **Pohl** (**2013**) mentioned that *B. bovis* and *B. bigemina* were found worldwide, however the high incidence occurs in the regions that occupied by vector, *Boophilus* tick which marked between the latitude of 32° Northern and 30° Southern.

In parts of Europe including UK, Spain and Northern Europe, *Babesia divergens* is considered an important parasite with evidences that the vector of this species of parasite is *Ixodes ricinus* that distributed throughout the Northern Scandinavian to Mediterranean areas (**Calderón et al., 2013; Wodaje et al., 2019**). The type of a host has an important role in epidemiology since more than one hundred of known *Babesia* species were distinguished to be infected numerous kinds of the mammalian host; out of these, eighteen species of this parasite have the ability to induction of infection largely in domesticated animals and rarely humans (**Hamsho *et al.*, 2015; Kumar et al., 2021**). Cattle consider the major reservoir host of *B. bovis* and *B. bigemina* with possibility to infect buffaloes (**Holman et al., 2011; Alkefari et al., 2017**). The epidemiology of *Babesia* parasite is commonly related to the activity and allocation of the vector, the prevalence of vector ticks are reports from April to October while the peak period were reported in May, June, and July because the tick require climate with 80% humidity (**Pohl, 2013**). The introducing of ticks infected with *Babesia* parasite into free regions from ticks results in increasing the prevalence of infection and incidence of babesiosis outbreaks (**De Marco *et al.*, 2017**). Worldwide, *Babesia* has a significant attention due to severe impacts on health status of domestic ruminants in particular cattle (Table 1, 2).

Table (1): Iraqi incidence of bovine babesiosis

Governorates	Animal	Species	Diagnostic assay	%	References
Erbil	Cattles	*B. bigemina*	ELISA	27.27	Ameen et al., 2012
Duhok, Erbil and Sulaymaniyah	Cattle	*Babesia* spp.	Light microscopy ELISA	11.7 12.4	Omer et al., 2012
Al-Qadisiya	Cattle	*B. bovis*	PCR	47.91	A'aiz, and Sabbar, 2016
Diyala	Cattle	*Babesia* spp.	Light microscopy	82.1-86.7	Minnat et al., 2016

Wasit	Buffalo	*B. bigemina*	Light microscopy ELISA PCR	1.68 25.7 11.73	Alkefari et al., 2017
Al-Najaf	Buffalo	*B. ovis* *B. bigemina*	Light microscopy PCR	38.30 7.45	Ateaa and Alkhaled, 2019
Wasit	Cattle	*Babesia* spp. *B. bovis* *B. bigemina* *B. divergens*	Light microscopy PCR PCR PCR	12.78 24.44 8.89 1.11	Al-Abedi, and Al-Amery, 2020
Basrah	Cattle	*Babesia* spp.	PCR	27.14	AL-Mayah and Abdul-Karim, 2020

Table (2): Global incidence of bovine babesiosis

Country	**Animal**	**Species**	**Diagnostic assay**	**%**	**References**
Ethiopia	Cattle	*Babesia* spp. *B. bigemina* *B. bovis*	Light microscopy	21.7 15.53 6.17	Fesseha et al., 2022
Saudi Arabia	Cattle	*Babesia* spp.	Light microscopy	2.49	Alanazi et al., 2020
Turkey	Cattle	*B. bovis* *B. bigemina* *B. divergens*	Light microscopy	0.08-0.9 2.5-15.4 7.4	Aktas and Ozubek, 2015
Iran	Cattle	*Babesia* spp.	PCR	7.1	Khamesipour et al., 2015
China	Cattle	*B. bovis* *B. bigemina* *B. ovata*	PCR	20.7 9.3 1.5	Niu et al., 2015
India	Cattle Buffalo	*B. bigemina*	Light microscopy PCR	2.17 3.96	Kaur et al., 2021
Egypt	Cattle	*B. bigemina*	PCR	19.33	El-Dakhly et al., 2020
Ethiopia	Cattle	*Babesia* spp.	Light microscopy	0.6-23	Wodaje et al., 2019
Bolivia		*Babesia* spp. *B. bovis* *B. bigemina*	PCR	8.65 0.96 7.69	Ogata et al., 2021
Spain	Cattle	*Babesia* spp.	PCR	2.2	Calleja-Bueno et al., 2022
Malawi	Cattle	*B. bigemina*	PCR	2.6	Chatanga et al., 2022
Sweden	Cattle	*B. divergens*	PCR	53.5	Andersson et al., 2017
Italy	Cattle	*B. bovis* *B. bigemina* *B. divergens*	Serology	45.4 17.4 34.9	Cassini et al., 2012
France	Cattle	*B. divergens*	Serology PCR	7 20	Devos and Geysen, 2004
Tanzania	Cattle	*B. bigemina*	Serology	34.9	Swai et al., 2007
Norway	Cattle	*B. divergens*	Serology	27	Hasle et al., 2010
Germany	Cattle	*Babesia* spp. *B. divergens*	PCR Serology	5.8 43.37	Springer et al., 2020
Brazil	Cattle	*B. bovis* *B. bigemina*	Serology	56.4-95.5 54.8-91.3	Barros et al., 2005

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1.6. Transmission

All *Babesia* species are naturally transported between animals through the tick bites. Infection within the ticks was transmitted through the eggs from mother ticks (trans-ovarian transmission), and from egg to larvae to nymph and finally to adult (transtadial transmission) (**Ghosh *et al*., 2007**). Transmission of *B. bigemina* occurs usually by one host ticks such as *Rhipicephalus annulatus* (formerly known as *Boophilus annulatus*), *Rhipicephalus microplus* (formerly known as *Boophilus microplus*), *Rhipicephalus geigyi*, *Rhipicephalus decoloratus* and *Rhipicephalus evertsi*. For *B. bovis*, transmission occurs by *R. annulatus* and *R. microplus* (**Friedhoff, 2018**). Also, babesial transmission can occur between animals through biting flies and contaminated fomites by infected blood (**Belimenko et al., 2019**).

1.7. Pathogenesis

In vertebrates, *Babesia* species can cause a disease through the effects of both direct damage and immune mediated since some infected cases appear an immune-mediated hemolytic anemia as one of the most common disease indicators (**Rauf *et al.,* 2020**). Gimenez et al. (2010) mentioned that during acute infection, pathology of *B. bovis* resulted by over releasing of proinflammatory cytokine and destruction of erythrocytes in addition to parasiticidal molecules which cause activation of macrophages (**Gallego-Lopez et al., 2019**). Subsequently, many studies referred that *B. bovis* has great pathogenicity than other *Babesia* species during acute stage of disease (**Alvarez et al., 2019; Cavani et al., 2020**). Parasitemia can induce the micro circulation by accumulation of infected erythrocytes in capillaries as the most harmful patho-physiological lesion for renal and cerebral regions to result in respiratory distresses syndrome and cerebral babesiosis with increasing of vascular permeability, infiltration of neutrophils and edema (**Li et al., 2018; De Niz et al., 2019; Schetters, 2019**). The first defense mechanism against parasitemia is incidence of intravascular hemolysis that leads to hemoglobinemia in addition to hypoxia, anemia and secondary inflammatory lesion. While, the second mechanism is activation of complements that lead to electrolyte imbalance, coagulation disturbance, releasing of pharmacological active substance, degeneration of centrilobular liver, degeneration in the epithelium of kidney tubule which could be due immune pathologic reaction and hypoxia. Damage in kidney tubule epithelium causes disturbance in the ion exchanges leading to hydrogen ion retentions and acidosis (**Mahmoud et al., 2015; Osman, 2019; Goodman *et al*., 2021**). When animal becomes infected with acute cases, multiplication of parasite initiated in visceral vessels (*B. bovis*) or in peripheral vessels (*B. bigemina*) reaching a top with evolution of hemolysis that is clinically detectable (**Gunn and Pitt, 2022**). There are ischemic alterations in affected heart and skeletal muscles in animals that surviving for long time, vasodilation and hypotension due to stimulation of vasoactive substances production and increasing of vascular permeability (**Das *et al*, 2022**). With *B. bovis* infection, circulatory stasis and shock resulting in disseminated intravascular coagulation associated with fatal pulmonary thrombosis and possibly cerebral babesiosis (**Akel and Mobarakai, 2017**). It is well known that *B. bigemina* is an un-complicated hemolytic agent and doesn't cause vascular and coagulation effects (**Kumar *et al*., 2014**).

1.8. Clinical signs

In cattle, *Babesia* species can cause acute to persistent subclinical disease. The status is based on age and immune state of infected host, *Babesia* species, strain virulence, and the numbers of infected ticks. Although, coffee like colored urine (hemoglobinuria) which is the specific sign of clinical diagnosed of babesiosis. In addition to remarkable elevated body temperature, increases in heart and respiratory rates, inappetence, cessation of ruminal contractions, icterus, emaciation, progressive hemolytic anemia. Furthermore, labored breathing, decline in milk production, ocular problems, abortion, and decline bulls fertility are seen clinically (**Constable et al., 2016; Almazán et al., 2022**). However, there is remarkable variation in severity of clinical signs between the main *Babesia* species. For instance, aggregation of erythrocytes in extra-vascular and cerebral capillary can be observed in *B. bovis* infections; while in *B. bigemina* infections, intravascular aggregation of infected erythrocyte doesn't occur. Subsequently, parasitemia in acute stage of *B. bovis* is represented <1%; while infections of *B. bigemina* and *B. divergens* ranged from 10% to 30% (**Goff et al., 1998; Beckley, 2013; Mtshali and Mtshali, 2013; Constable et al., 2016**).

1.9. Diagnosis

Considerable different techniques have developed for diagnostic and epidemiological aims, babesiosis is generally distinguished based on clinical signs, individual history and seasons. However, doubtful babesiosis in cattle can be further diagnosed through direct identification of the parasite in blood smears by direct microscopic examination method or indirectly through molecular technique and serological tests (**Bari et al., 2015; Alvarez et al., 2019**).

1.9.1 Blood smear Examination

Microscopic method still the standard fastest and cheapest technique which applied widely for direct identification of a parasite in host blood smears and tick tissue of acutely cases (**Sharma et al., 2020**). In chronic cases, this test has limited sensitivity and

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specificity values due to decreased the percentage of erythrocytes infected with *Babesia* which reduced ability to screening organisms and can simply be false for an artifact (**Mosqueda et al., 2012**). Species differentiation was perfect in thin film but poor in case of thick film (**Pritt, 2015**). Also, thin films are usually suitable to detect the acute infections, but unsuitable for carrier cases where the parasitemias are generally too much low, so differentiation and identification of parasite can be done throughout fluorescent dyes (**Zintl *et al.*, 2003; Nejash, 2016**). Thick blood film was more sensitive than thin blood film in about 10 to 20 times; therefore, it is so useful to detect the low level of *Babesia* spp. infections (**Pritt, 2015**).

Infection of ticks by *Babesia* species can clearly checked by staining of the salivary glands of the tick, but the foremost disadvantages of this technique are inability to identify the species, low sensitivity, and thus time-consuming (**Becker et al., 2009**). In carrier animals, the blood smear is undependable for detection of the parasite, so the molecular and / or the serological diagnostic methods to prove specific the antibodies are required (**Menshawy, 2020**). However, microscopic and cultural methods are time-consuming, laborious, give highly variable results, and need for extensive expertise to be performed (**Farhan et al., 2012; Parija *et al.,* 2015**).

1.9.2. Serological tests

Among different serological techniques, indirect-fluorescent antibody technique (IFAT), enzyme linked immunosorbent assay (ELISA), and complement fixation test (CFT) are the most crucial methods due to their ability for detection of specific antibodies in chronic infected cases. Hence, these assays can be applied successfully in research purposes, export certification, epidemiological studies, or when vaccine inactivity is suspected (**Sparagano et al., 2000; Salih *et al.*, 2015; Alkefari et al., 2017**). ELISAs have developed to detect a number of *Babesia* spp. with more advantages than CFT, IFAT and agglutination techniques; however, drawbacks of low true positive results (sensitivity) due to past infections, and cross reactions can complicated the differentiation between some species were described (**Spickler et al., 2010; Li *et al.,* 2014**).

1.9.3. Molecular techniques

Diagnostic serological tests are frequently used in determination of subclinical infections; however, serology has drawbacks such as cross reactivity of the antibodies between species and inadequate sensitivity in animals with decline parasitaemia levels. For these reasons, using specific and sensitive molecular techniques becomes necessary for the epidemiological investigations **(Bilgiç *et al.*, 2013**). Based on *18SrRNA* gene, molecular diagnosis using polymerase chain reaction (PCR) assay is method of choice for detection of the parasite genomic DNA, and to confirm of infection in different samples due to higher sensitivity and specificity (**Sudan *et al.,* 2017**). Either multiplex or simple amplification PCR *18SrRNA* gene fragment were the most common methods used for detection *Babesia* parasite in both vertebrate hosts and ticks as well as for differentiation between species particularly in carrier animals (**Shayan and Rahbari, 2005; Adjou Moumouni et al., 2015**). Also, *18SrRNA* considers as a reference gene and widely used for molecularly phylogenetic classification of *Babesia* parasite (**Zobba *et al.*, 2011**). Accordingly, accumulated evidence pointed out that the PCR is precise method that recommended in diagnosing *B. bigemina* in host and carrier animals(**Ganzinelli *et al.*, 2020**).

1.10. Treatment

When the disease is diagnosed earlier, cure is likely most successful but with possibly failure if infected animals have weakened by anemia (**Gohil et al., 2013**). Earlier therapeutic approaches are with great efficiency in removing and elimination of parasite from circulation in acutely cases within 3-4 days (**Ord and Lobo, 2015**). Imidocarb and amicarbalide compounds represent the most active therapies for cattle infection with different *Babesia* species (Wodaje et al., 2019). Administration of oxytetracycline can significantly reduce the destruction of erythrocytes and parasitemia without inhibition development of immunity (**Yunta and Dietrich, 2019**). Vitamins, fluid replacements, blood transfusion and purgatives are highly recommended supportive therapeutics which aid recovery in acute anemic cattle. Anti-inflammatory medications (non-steroid) could be applied to reduce negative impacts of inflammatory process and its associated changes resulting from releasing of chemical mediators (**Bártíková *et al.*, 2016**).

1.11. Prevention and control methods

The active programs that exclusively could be applied to control and prevent spreading bovine babesiosis can be precisely established by three specific methods include immunization program, chemoprophylaxis and specific vector control program. However, the greatest useful and commonly applied way to control of babesiosis is the treatment of infected animals and chemical control of ticks with acaricides drugs but these methods of control are not every time completely active, therefore using of immunization is the best viable choice (**Rajput et al., 2006; Almazan et al., 2018**). In Iraq, acaricides are commonly used for controlling tick infestation; however, incorrectly use in almost cases allows developing strong resistance to these products in addition to their severe economic consequences for cattle producers. Globally, it is found that the applied vaccination program to prevent disease spreading and

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ticks control can reduced environmental contaminations, expenditure cost, and prevents selective drugs resistance to ticks due to over using acaricide (**Canales et al., 2009; Rodríguez-Mallon, 2016**). Cattle developed a firm immunity followed a single infection; therefore, this characteristic has been utilized to immunize cattle with the using of live attenuated vaccines (**Jonsson et al., 2012; Marcelino et al., 2021**).

1.12. CONCLUSIONS

Despite it is dangerous and invasive disease for cattle and other domestic animals, babesiosis represent one of the most neglected diseases in Iraq with unknown significant medical and economic impacts. Therefore, specific and precise qualitative and quantitative studies that imply the relation and interaction between the host, tick, and parasite, also the metabolism process of the parasite are immediately required. Furthermore, identify the possible explanation of survival Babesia in erythrocytes. Moreover, specific and wide demographic and epidemiological information availability could be used to design predictive program in order to detect the spreading and existing way of ticks.

REFERENCES

1. A'aiz, N.N., and Sabbar, K.H. (2016). Sabbar, K. H. (2016). Molecular detection of Babesia bovis in cattle in AL-Qadisiyah Province. *The Iraqi Journal of Veterinary Medicine*, 40(2), 155-158.
2. Abdela, N., and Jilo, K. (2016). Bovine Babesiosis and its Current Status in Ethiopia: A Systemic Review. *Advances in Biological Research*, *10*(3), 138-146.
3. Adjou Moumouni, P.F., Aboge, G.O., Terkawi, M.A., Masatani, T., Cao, S., Kamyingkird, K., and Xuan, X. (2015). Molecular detection and characterization of Babesia bovis, Babesia bigemina, Theileria species and Anaplasma marginale isolated from cattle in Kenya. *Parasites and vectors*, *8*(1), 1-14.
4. Adzigbe, J.E. (2017). *Molecular Characterization Of Tick-Borne Parasites In Naturally Infected Cattle In Accra And Adidome, Ghana* (Doctoral dissertation, University of Ghana).
5. Akel, T., and Mobarakai, N. (2017). Hematologic manifestations of babesiosis. *Annals of clinical microbiology and antimicrobials*, *16*(1), 1-7.
6. Aktas, M., and Ozubek, S. (2015). Molecular and parasitological survey of bovine piroplasms in the Black Sea region, including the first report of babesiosis associated with Babesia divergens in Turkey. *Journal of medical entomology*, *52*(6), 1344-1350.
7. Al-Abedi, G.J.K., and Al-Amery, A.M. (2020b). Microscopic and Molecular Diagnostic Study of *Babesia* species in Cattle in Wasit Province, Iraq. *Biochem Cell Arch*, 20 (Suppl 2), 3569-3577.
8. Al-Abedi, G.J.K., and Al-Amery, A.M.A. (2020a). Molecular Diagnosis and Phylogenetic Analysis of Babesia Species Isolated from Ticks of Infested Cattle in Wasit Governorate, Iraq. *Iraqi Journal of Agricultural Sciences*, *51*(5), 1249-1260.
9. Alanazi, A.D., Alouffi, A.S., Alshahrani, M.Y., Alyousif, M.S., Abdullah, H.H., Allam, A.M., and Alsulami, M. (2020). Molecular detection of tick-borne pathogens in cattle from Saudi Arabia. King Abdullah University of Science and Technology, 1-18.
10. Alkefari, O.A., Al-Gharban, H.A., and Ahmed, T.H. (2017). Microscopic, serological and molecular detection of Babesia bigemina in buffaloes (Bubalus bubalis) in Wasit Province, Iraq. *Al-Qadisiyah Journal of Veterinary Medicine Sciences*, *16*(1), 123-130.
11. AL-Mayah, S.H., and Abdul-Karim, A.T. (2020). Epidemiology and Seasonal Variation of Ixodid Ticks and Piroplasmida Detection in Cattle of Basrah Province, Iraq. *Indian Journal of Forensic Medicine and Toxicology*, *14*(3), 671-677.
12. Almazán, C., Scimeca, R.C., Reichard, M.V., and Mosqueda, J. (2022). Babesiosis and Theileriosis in North America. *Pathogens*, *11*(2), 168.
13. Almazan, C., Tipacamu, G.A., Rodriguez, S., Mosqueda, J., and de Leon, A.P. (2018). Immunological control of ticks and tick-borne diseases that impact cattle health and production. *Frontiers in Bioscience-Landmark*, *23*(8), 1535-1551.
14. Alvarez, J.A., Rojas, C., and Figueroa, J. V. (2019). Diagnostic tools for the identification of Babesia sp. in persistently infected cattle. *Pathogens*, *8*(3), 143.
15. Ameen, K.A.H., Abdullah, B.A., and Abdul-Razaq, R.A. (2012). Seroprevalence of Babesia bigemina and Anaplasma marginale in domestic animals in Erbil, Iraq. *Iraqi Journal of Veterinary Sciences*, *26*, 109-114.
16. Andersson, M.O., Víchová, B., Tolf, C., Krzyzanowska, S., Waldenström, J., and Karlsson, M. E. (2017). Co-infection with Babesia divergens and Anaplasma phagocytophilum in cattle (Bos taurus), Sweden. *Ticks and Tick-borne Diseases*, *8*(6), 933-935.

17. Antunes, S.I.D.C. (2014). Differential expression and functional characterization of cattle tick genes in response to pathogen infection (Babesia bigemina). *Universidade Nova de Lisboa, Instituto de Higiene e Medicina Tropical*. Pp: 47.
18. Ateaa, R., and Alkhaled, M. (2019). Microscopic identification, molecular and phylogenetic analysis of Babesia species in buffalo from slaughter house in Al-Najaf city of Iraq. *Iraqi Journal of Veterinary Sciences*, *33*(2), 251-258.
19. Bari, A., Saleem, G., and Khan, I. (2015). Pathological Effects of Natural Babesiosis Infection: A Review. *Scholar's Advances in Animal and Veterinary Research*, 2 (1),7-14
20. Barros, S.L., Madruga, C.R., Araújo, F.R., Menk, C.F., de Almeida, M.A.O., Melo, E.P., and Kessler, R.H. (2005). Serological survey of Babesia bovis, Babesia bigemina, and Anaplasma marginale antibodies in cattle from the semi-arid region of the state of Bahia, Brazil, by enzyme-linked immunosorbent assays. *Memórias do Instituto Oswaldo Cruz*, *100*, 513-517.
21. Bártíková, H., Podlipná, R., and Skálová, L. (2016). Veterinary drugs in the environment and their toxicity to plants. *Chemosphere*, *144*, 2290-2301.
22. Bashir, I.N., Chaudhry, Z.I., Ahmed, S., and Saeed, M.A. (2009). Epidemiological and vector identification studies on canine babesiosis. *Pakistan Veterinary Journal*, *29*(2).
23. Becker, C.A., Bouju-Albert, A., Jouglin, M., Chauvin, A., and Malandrin, L. (2009). Natural transmission of zoonotic Babesia spp. by Ixodes ricinus ticks. *Emerging infectious diseases*, *15*(2), 320.
24. Belimenko, V.V., Gulyukin, A.M., Khristianovsky, P.I., Novosad, E.V., and Shabeykin, A.A. (2019). Effect of Enrofloxacin for treatment of bovine anaplasmosis and canine babesiosis. In *IOP Conference Series: Earth and Environmental Science*. *IOP Publishing*, 315 (4), 42-56.
25. Bilgiç, H.B., Karagenç, T., Simuunza, M., Shiels, B., Tait, A., Eren, H., and Weir, W. (2013). Development of a multiplex PCR assay for simultaneous detection of Theileria annulata, Babesia bovis and Anaplasma marginale in cattle. *Experimental parasitology*, *133*(2), 222-229.
26. Calderón, A., Cardona, J., and Vergara, Ó. (2013). Frequency of Babesia spp. in horses of Monteria, Cordoba (Colombia). *Revista UDCA Actualidad and Divulgación Científica*, *16*(2), 451-458.
27. Calleja-Bueno, L., Sainz, Á., García-Sancho, M., González-Martín, J.V., Díaz-Regañón, D., Rodríguez-Franco, F., and Villaescusa, A. (2022). First detection of Anaplasma phagocytophilum and Babesia divergens and high infection rates of Anaplasma marginale and Babesia bigemina in cattle in extensive grazing systems of Central Spain. *Transboundary and Emerging Diseases*, *69*(4), e1090-e1100.
28. Canales, M., Almazán, C., Naranjo, V., Jongejan, F., and De la Fuente, J. (2009). Vaccination with recombinant Boophilus annulatus Bm86 ortholog protein, Ba86, protects cattle against B. annulatus and B. microplus infestations. *BMC biotechnology*, *9*(1), 1-8.
29. Cassini, R., Marcer, F., di Regalbono, A.F., Cancrini, G., Gabrielli, S., Moretti, A., and Pietrobelli, M. (2012). New insights into the epidemiology of bovine piroplasmoses in Italy. *Veterinary parasitology*, *184*(1), 77-82.
30. Cavani, L., Braz, C.U., Giglioti, R., Okino, C.H., Gulias-Gomes, C.C., Caetano, A.R., and Oliveira, H.N.D. (2020). Genomic Study of Babesia bovis Infection Level and Its Association With Tick Count in Hereford and Braford Cattle. *Frontiers in Immunology*, *11*, 1905.
31. Chatanga, E., Maganga, E., Mohamed, W.M.A., Ogata, S., Pandey, G.S., Abdelbaset, A.E., and Nakao, R. (2022). High infection rate of tick-borne protozoan and rickettsial pathogens of cattle in Malawi and the development of a multiplex PCR for Babesia and Theileria species identification. *Acta Tropica*, *231*, 106413.
32. Chauvin, A., Moreau, E., Bonnet, S., Plantard, O., and Malandrin, L. (2009). Babesia and its hosts: adaptation to long-lasting interactions as a way to achieve efficient transmission. *Veterinary research*, *40*(2), 1-18.
33. Constable, P.D., Hinchcliff, K.W., Done, S.H., and Grünberg, W. (2016). *Veterinary medicine: a textbook of the diseases of cattle, horses, sheep, pigs and goats*. Elsevier Health Sciences.
34. Das, D., Sarma, K., Eregowda, C.G., Roychoudhury, P., Rajesh, J.B., Behera, P., and Tolenkhomba, T.C. (2022). Naturally occurring Anaplasma marginale infection in cattle: Molecular prevalence and associated risk factors, haemato-biochemical alterations, oxidant/antioxidant status and serum trace

mineral levels. *Microbial Pathogenesis*, 105575.

35. De Marco, M.F., Hernández-Triana, L.M., Phipps, L.P., Hansford, K., Mitchell, E.S., Cull, B., and Johnson, N. (2017). Emergence of Babesia canis in southern England. *Parasites and vectors*, *10*(1), 1-9.
36. De Niz, M., Meehan, G.R., Brancucci, N.M., Marti, M., Rotureau, B., Figueiredo, L.M., and Frischknecht, F. (2019). Intravital imaging of host–parasite interactions in skin and adipose tissues. *Cellular microbiology*, *21*(5), e13023.
37. El-Dakhly, K.M., Arafa, W.M., Soliman, S., Abdel-Fatah, O.R., Wahba, A.A., Esteve-Gasent, M.D., and Holman, P.J. (2020). Molecular detection, phylogenetic analysis, and genetic diversity of Theileria annulata, Babesia bigemina, and Anaplasma marginale in cattle in three districts of Egypt. *Acta Parasitologica*, *65*(3), 620-627.
38. Farhan, A.A., Muhammad, S.K., Hafiz, J.I., Ghulam, M.A., Ejaz, A., and Sami, U. (2012). Prevalence of Anaplasma marginale, Babesia bigemina and Theileria annulata infections among cattle in Sargodha District, Pakistan. *African Journal of Agricultural Research*, *7*(22), 302-3307.
39. Fesseha, H., Mathewos, M., Eshetu, E., and Tefera, B. (2022). Babesiosis in cattle and ixodid tick distribution in Dasenech and Salamago Districts, southern Ethiopia. *Scientific Reports*, *12*(1), 1-11.
40. Friedhoff, K.T. (2018). Transmission of babesia. In Babesiosis of domestic animals and man. *CRC Press*. Pp: 23-52.
41. Gallego-Lopez, G.M., Cooke, B.M., and Suarez, C.E. (2019). Interplay between Attenuation- and Virulence-Factors of Babesia bovis and Their Contribution to the Establishment of Persistent Infections in Cattle. *Pathogens*, *8*(3), 97.
42. Ganzinelli, S., Benitez, D., Gantuya, S., Guswanto, A., Florin-Christensen, M., Schnittger, L., and Igarashi, I. (2020). Highly sensitive nested PCR and rapid immunochromatographic detection of Babesia bovis and Babesia bigemina infection in a cattle herd with acute clinical and fatal cases in Argentina. *Transboundary and Emerging Diseases*, *67*, 159-164.
43. Garg, S., Agarwal, S., Kumar, S., Shams Yazdani, S., Chitnis, C.E., and Singh, S. (2013). Calcium-dependent permeabilization of erythrocytes by a perforin-like protein during egress of malaria parasites. *Nature communications*, *4*(1), 1-12.
44. Gharban, A.J., Al-Shaeli, S.J., Al-Abedi, G.J., Abbas, Z.R., and Jassim, A.F. (2022). Microscopic Investigation of Bovine Haemoparasites in Wasit Province, Iraq. *Annals of the Romanian Society for Cell Biology*, *26*(01), 1143-1159.
45. Ghosh, S., Bansal, G.C., Gupta, S.C., Ray, D., Khan, M.Q., Irshad, H., and Ahmed, J.S. (2007). Status of tick distribution in Bangladesh, India and Pakistan. *Parasitology research*, *101*(2), 207-216.
46. Gimenez, G., Magalhães, K.G., Belaunzarán, M.L., Poncini, C.V., Lammel, E.M., Cappa, S.G., and Isola, E.L.D. (2010). Lipids from attenuated and virulent Babesia bovis strains induce differential TLR2-mediated macrophage activation. *Molecular Immunology*, *47*(4), 747-755.
47. Goff, W.L., Johnson, W.C., and Cluff, C.W. (1998). Babesia bovis Immunity: In Vitro and in Vivo Evidence for IL-10 Regulation of IFN-γ and iNOS a. *Annals of the New York Academy of Sciences*, *849*(1), 161-180.
48. Gohil, S., Herrmann, S., Günther, S., and Cooke, B.M. (2013). Bovine babesiosis in the 21st century: advances in biology and functional genomics. *International journal for parasitology*, *43*(2), 125-132.
49. Goodman, A., Bilal, M., Amarnath, S., Gentile, T., and Shepherd, Z. (2021). The unusual case of babesiosis causing disseminated intravascular coagulation with hemophagocytic lymphohistiocytosis. *Clinical Case Reports*, *9*(9), e04744.
50. Gunn, A., and Pitt, S.J. (2022). *Parasitology: an integrated approach*. John Wiley and Sons. Pp: 92-151.
51. Hamsho, A., Tesfamarym, G., Megersa, G., and Megersa, M. (2015). A cross-sectional study of bovine babesiosis in Teltele District, Borena Zone, Southern Ethiopia. *J Veterinar Sci Technol*, *6*(230), 2.
52. He, L., Bastos, R.G., Sun, Y., Hua, G., Guan, G., Zhao, J., and Suarez, C.E. (2021). Babesiosis as a potential threat for bovine production in China. *Parasites and Vectors*, *14*(1), 1-12
53. Holman, P.J., Carroll, J.E., Pugh, R., and Davis, D.S. (2011). Molecular detection of Babesia bovis and Babesia bigemina in white-tailed deer (Odocoileus virginianus) from Tom Green County in central Texas. *Veterinary parasitology*, *177*(3-4), 298-304.
54. Jalovecka, M., Sojka, D., Ascencio, M., and Schnittger, L. (2019). Babesia life cycle–when

phylogeny meets biology. *Trends in parasitology*, *35*(5), 356-368.
55. Jameel, H.G.H. (2016). Determination of complication decrease the risk factor in cattle infected by lumph skin disease virus in Diyala province, Iraq. *International Journal of Micro Biology*, 2: 1-9.
56. Jonsson, N.N., Bock, R.E., Jorgensen, W.K., Morton, J.M., and Stear, M.J. (2012). Is endemic stability of tick-borne disease in cattle a useful concept?. *Trends in parasitology*, *28*(3), 85-89.
57. Kaur, P., Sharma, A., Juyal, P.D., Bal, M.S., Singh, C., and Singla, L.D. (2021). Comparative epidemiology and pathophysiology of patent and latent babesiosis caused by Babesia bigemina in buffaloes and cattle from different agroclimatic zones of Punjab State, India. *Tropical Animal Health and Production*, *53*(2), 1-9.
58. Khamesipour, F., Doosti, A., Koohi, A., Chehelgerdi, M., Mokhtari-Farsani, A., and Chengula, A. A. (2015). Determination of the presence of Babesia species in blood samples of cattle, camel and sheep in Iran by PCR. *Archives of Biological Sciences*, *67*(1), 83-90.
59. Kim, C., Iseki, H., Herbas, M. S., Yokoyama, N., Suzuki, H., Xuan, X., and Igarashi, I. (2007). Development of TaqMan-based real-time PCR assays for diagnostic detection of Babesia bovis and Babesia bigemina. *The American journal of tropical medicine and hygiene*, *77*(5), 837-841.
60. Kumar, A., O'Bryan, J., and Krause, P. J. (2021). The global emergence of human babesiosis. *Pathogens*, *10*(11), 1447.
61. Kumar, S., Mondal, M., Kumar, R., and Samantaray, S. (2014). Occurrence of Babesia bigemina infection in crossbred calf. *Journal of Veterinary Parasitology*, *28*(1), 84-85.
62. Kuttler, K.L. (2018). World-wide impact of babesiosis. In *Babesiosis of domestic animals and man*. CRC Press. Pp: 1-22.
63. Laha, R., Das, M., and Sen, A. (2015). Morphology, epidemiology, and phylogeny of Babesia: An overview. *Tropical parasitology*, *5*(2), 94.
64. Lempereur, L., Beck, R., Fonseca, I., Marques, C., Duarte, A., Santos, M., and Zintl, A. (2017). Guidelines for the detection of Babesia and Theileria parasites. *Vector-Borne and Zoonotic Diseases*, *17*(1), 51-65.
65. Li, S., Goyal, B., Cooper, J. D., Abdelbaki, A., Gupta, N., and Kumar, Y. (2018). Splenic rupture from babesiosis, an emerging concern? A systematic review of current literature. *Ticks and tick-borne diseases*, *9*(6), 1377-1382.
66. Li, Y., Luo, Y., Cao, S., Terkawi, M.A., Lan, D.T., Long, P.T., and Xuan, X. (2014). Molecular and seroepidemiological survey of Babesia bovis and Babesia bigemina infections in cattle and water buffaloes in the central region of Vietnam. *Trop Biomed*, *31*(3), 406-413.
67. Mahmoud, M.S., Kandil, O.M., Nasr, S.M., Hendawy, S.H., Habeeb, S.M., Mabrouk, D.M., and Suarez, C.E. (2015). Serological and molecular diagnostic surveys combined with examining hematological profiles suggests increased levels of infection and hematological response of cattle to babesiosis infections compared to native buffaloes in Egypt. *Parasites and Vectors*, *8*(1), 1-15.
68. Marcelino, I., Chavez, A., Gharbi, M., Farber, M., Holzmuller, P., Martinez, D., and Vachiéry, N. (2021). Protozoal and Rickettsial Vaccines. *Veterinary Vaccines: Principles and Applications*, 77-99.
69. Menshawy, S.M. (2020). A Review on Bovine Babesiosis in Egypt. *Egyptian Veterinary Medical Society of Parasitology Journal (EVMSPJ)*, *16*(1), 8-19.
70. Minnat, T.R., Al-Zuhairi, A.H., and Jalil, W. I. (2016). Study of clinical, epidemiological and heamatological changes of heamoparasites infection in cattle of Diyala province-Iraq. *RESEARCH JOURNAL OF PHARMACEUTICAL BIOLOGICAL AND CHEMICAL SCIENCES*, *7*(4), 3094-3102.
71. Mosqueda, J., Olvera-Ramirez, A., Aguilar-Tipacamu, G., and J Canto, G. (2012). Current advances in detection and treatment of babesiosis. *Current medicinal chemistry*, *19*(10), 1504-1518.
72. Mtshali, M.S., and Mtshali, P.S. (2013). Molecular diagnosis and phylogenetic analysis of Babesia bigemina and Babesia bovishemoparasites from cattle in South Africa. *BMC veterinary research*, *9*(1), 1-7.
73. Nejash, A.A. (2016). Bovine Babesiosis and its current status in Ethiopia: A review. *Journal of Medicine, Physiology and Biophysics*, *23*, 15-23.
74. Niu, Q., Liu, Z., Yu, P., Yang, J., Abdallah, M.O., Guan, G., and Yin, H. (2015). Genetic characterization and molecular survey of Babesia bovis, Babesia bigemina and Babesia ovata in cattle, dairy cattle and yaks in China. *Parasites and vectors*, *8*(1), 1-13.
75. Ogata, S., Pereira, J.A.C., Jhonny, L.V.A., Carolina, H.P.G., Matsuno, K., Orba, Y., and

Nakao, R. (2021). Molecular Survey of Babesia and Anaplasma Infection in Cattle in Bolivia. *Veterinary sciences*, *8*(9), 188.
76. Omer, L.T., Kadir, M.A., and Ahmed, J.S. (2012). Seroprevalence of piroplasmosis with tick distribution in northern Iraq. *Iraqi Journal of Veterinary Sciences*, *26*, 105-108.
77. Ord, R.L., and Lobo, C.A. (2015). Human babesiosis: Pathogens, prevalence, diagnosis, and treatment. *Current clinical microbiology reports*, *2*(4), 173-181.
78. Osman, H.T.A.E.M. (2019). *A Study of Bovine Babesiosis in El-fasher-North North Darfur State-Sudan* (Doctoral dissertation, Sudan University of Science and Technology).
79. Parija, S.C., Dinoop, K.P., and Venugopal, H. (2015). Diagnosis and management of human babesiosis. *Tropical Parasitology*, *5*(2), 88.
80. Pohl, A.E. (2013). *Epidemiology study of tick-borne diseases in cattle in Minas Gerais, Brazil* (Doctoral dissertation, lmu).
81. Pritt, B.S. (2015). Plasmodium and babesia. *Manual of clinical microbiology*, 2338-2356.
82. Rajput, Z.I., Hu, S.H., Chen, W.J., Arijo, A.G., and Xiao, C.W. (2006). Importance of ticks and their chemical and immunological control in livestock. *Journal of Zhejiang University Science B*, *7*(11), 912-921.
83. Rauf, U., Suleman, M., Abid, A., Jamil, H., Menghwar, H., Durrani, A.Z., and Akbar, H. (2020). Humoral and cell-mediated immune response validation in calves after a live attenuated vaccine of Babesia bigemina. *Pathogens*, *9*(11), 936.
84. Rodriguez, A.E., Florin-Christensen, M., Flores, D.A., Echaide, I., Suarez, C.E., and Schnittger, L. (2014). The glycosylphosphatidylinositol-anchored protein repertoire of Babesia bovis and its significance for erythrocyte invasion. *Ticks and tick-borne diseases*, *5*(3), 343-348.
85. Rodríguez-Mallon, A. (2016). Developing anti-tick vaccines. In *Vaccine Design*. Humana, New York, NY. Pp: 243-259.
86. Saleh, A.M.A., Adam, S.M., Abdel-Motagaly, A.M., Ibrahim, A.M.A., and Morsy, T.A. (2015). Human babesiosis: a general review with special reference to Egypt. *Journal of the Egyptian Society of Parasitology*, *45*(3), 493-510.
87. Salih, D.A., El Hussein, A.M., and Singla, L.D. (2015). Diagnostic approaches for tick-borne haemoparasitic diseases in livestock. *Journal of Veterinary Medicine and Animal Health*, *7*(2), 45-56.
88. Schetters, T. (2019). Mechanisms involved in the persistence of Babesia canis infection in dogs. *Pathogens*, *8*(3), 94.
89. Schuster, F.L. (2002). Cultivation of Babesia and Babesia-like blood parasites: agents of an emerging zoonotic disease. *Clinical microbiology reviews*, *15*(3), 365-373.
90. Sharma, M., Sindhu, N., Kumar, T., and Jain, V.K. (2020). Diagnosis and Therapeutic Management of Babesiosis in a Murrah buffalo. *Intas Polivet*, *21*(1), 136-138.
91. Shayan, P., and Rahbari, S. (2005). Simultaneous differentiation between Theileria spp. and Babesia spp. on stained blood smear using PCR. *Parasitology Research*, *97*(4), 281-286.
92. Sonenshine, D.E., and Macaluso, K.R. (2017). Microbial invasion vs. tick immune regulation. *Frontiers in Cellular and Infection Microbiology*, *7*, 390.
93. Sparagano, O., Loria, G. R., GUBBELS, M.J., De Vos, A.P., Caracappa, S., and Jongejan, F. (2000). Integrated molecular diagnosis of Theileria and Babesia species of cattle in Italy. *Annals of the New York Academy of Sciences*, *916*(1), 533-539.
94. Spickler, A.R., Galyon, J., and Roth, J.A. (2010). Descriptions of recent incursions of exotic animal diseases. In *Emerging and exotic diseases of animals. 4th edition, 2nd printing* (pp. 52-76). CFSPH/IICAB, Iowa State University, Ames (IA).
95. Springer, A., Höltershinken, M., Lienhart, F., Ermel, S., Rehage, J., Hülskötter, K., and Strube, C. (2020). Emergence and epidemiology of bovine babesiosis due to Babesia divergens on a northern German beef production farm. *Frontiers in veterinary science*, *7*, 649.
96. Suarez, C.E., and Noh, S. (2011). Emerging perspectives in the research of bovine babesiosis and anaplasmosis. *Veterinary parasitology*, *180*(1-2), 109-125.
97. Sudan, V.T., Shanker, D., Sharma, B., Jaiswal, A.K., and Singh, A.T. (2017). Molecular characterization and sequence phylogenetic analysis of Babesia bigemina cattle isolate from Mathura based on 18S ribosomal DNA gene. *Indian Journal of Animal Sciences*, *87*(8), 977-979.
98. Swai, E.S., Karimuribo, E.D., French, N.P., Fitzpatrick, J.L., Bryant, M.J., Kambarage, D.M., and Ogden, N.H. (2007). Seroprevalence of Babesia bigeminain smallholder dairy cattle in Tanzania and associated risk factors.

Journal of the South African Veterinary Association, *78*(1), 15-20.

99. Terkawi, M.A., Huyen, N.X., Shinuo, C., Inpankaew, T., Maklon, K., Aboulaila, M., and Igarashi, I. (2011). Molecular and serological prevalence of Babesia bovis and Babesia bigemina in water buffaloes in the northeast region of Thailand. *Veterinary Parasitology*, *178*(3-4), 201-207.
100. Ueti, M.W., Johnson, W.C., Kappmeyer, L.S., Herndon, D.R., Mousel, M.R., Reif, K.E., and Brayton, K.A. (2020). Transcriptome dataset of Babesia bovis life stages within vertebrate and invertebrate hosts. *Data in Brief*, *33*, 106533.
101. Uilenberg, G. (2006). Babesia-a historical overview. *Veterinary parasitology*, *138*(1-2), 3-10.
102. Wodaje, A., Adudna, B., and Hamid, M. (2019). A review on bovine babesiosis. *Int. J. Adv. Res. Biol. Sci*, *6*(1), 63-70.
103. Yunta, M.J., and Dietrich, R.C. (2019). Tropical and Subtropical Parasitic Diseases: Targets for a New Approach to Virtual Screening. *Molecular Informatics*, *38*(11-12), 1900052.
104. Zintl, A., Mulcahy, G., Skerrett, H.E., Taylor, S.M., and Gray, J.S. (2003). Babesia divergens, a bovine blood parasite of veterinary and zoonotic importance. *Clinical microbiology reviews*, *16*(4), 622-636.
105. Zobba, R., Parpaglia, M.L.P., Spezzigu, A., Pittau, M., and Alberti, A. (2011). First molecular identification and phylogeny of a Babesia sp. from a symptomatic sow (Sus scrofa Linnaeus 1758). *Journal of clinical microbiology*, *49*(6), 2321-2324.