



Tick-borne Pathogens in Small Ruminants in Turkey: A Systematic Review

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Abstract

Ticks and tick-borne diseases cause significant problems while raising livestock. Tick-borne diseases have increased in Turkey during recent years because Turkey has suitable climatic conditions and a large-variety animal population. Sheep and goat farming form a substantial part of the national economy. The main tick-transmitted pathogens in small ruminants in Turkey are *Babesia ovis*, *B. motasi*, *B. crassa*, *Babesia* sp., *Theileria ovis*, *T. uilenbergi*, *T. luwenshuni*, *Theileria* sp. MK, *Theileria* sp. OT1, *Theileria* sp. OT3, *Anaplasma ovis*, and *A. phagocytophilum*. The major tick-transmitted pathogens in sheep and goats in terms of geographic region, province, host, number of animals examined, sampling technique, sampling year, and diagnosis method are summarized chronologically in this review, and we present the current situation in Turkey.

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Türkiye'deki Küçük Ruminantlarda Kene ile Bulaşan Patojenler: Sistematik Bir Derleme

Özet

Keneler ve kene kaynaklı hastalıklar hayvan yetiştiriciliği açısından önemli sorunlara neden olmaktadır. Türkiye uygun iklim koşullarına ve çok çeşitli hayvan nüfusuna sahip olduğundan, son yıllarda Türkiye'de kene kaynaklı hastalıklar artmıştır. Koyun ve keçi yetiştiriciliği, ulusal ekonomide önemli bir yer tutmaktadır. Türkiye'deki küçük ruminantlarda kene ile nakledilen başlıca patojenler; *Babesia ovis*, *B. motasi*, *B. crassa*, *Babesia* sp., *Theileria ovis*, *T. uilenbergi*, *T. luwenshuni*, *Theileria* sp. MK, *Theileria* sp. OT1, *Theileria* sp. OT3, *Anaplasma ovis* ve *A. phagocytophilum*'dur. Coğrafik bölge, il, konak, incelenen hayvan sayısı, örnekleme tekniği, örnekleme yılı ve teşhis metodu açısından koyun ve keçilere kene ile bulaşan önemli patojenler kronolojik olarak özetlenmiş ve Türkiye'deki mevcut durum sunulmuştur.

Anahtar Sözcükler: Kene, patojen, koyun, keçi, Türkiye

Introduction

Tick-borne diseases (TBDs) are major factors that restrict the development of animal husbandry worldwide, especially in tropical and subtropical areas where reservoir, pathogen, vector, and host distribution overlap. They have an impact on multifarious domestic and wild animals, and most are considered as neglected and/or emerging zoonosis (Gray et al., 2009). In recent years, as well as across the globe, some tick-borne diseases have increased in Turkey (Inci et al., 2016). Climate change and the migration of birds are the main reasons for this increase (Estrada-Peña et al., 2012).

Turkey, located in Eurasia at 36.42 latitude and 26.45 longitude, has a surface area of 780.576 km² with a population of about 82 million people. According to the Turkish Statistical Institute, there were 17 million cattle, 35 million sheep, and 11 million goats in the country in 2018 (Anonymous, 2018). Agriculture and livestock production activities form a substantial part of the national economy. There are seven geographic regions in the country: Black Sea, Central Anatolia, Eastern Anatolia, Southeastern Anatolia, Aegean, Marmara, and Mediterranean. Because the country is spread across a

wide area, and there are noticeably differing climates for the seven regions. From the coastal regions, Marmara, Aegean, and Mediterranean have a Mediterranean climate, and the Black Sea region has a temperate oceanic climate. In general, a continental climate is predominant in the other regions.

Major TBDs caused by *Theileria*, *Babesia* and *Anaplasma* species in sheep and goats occur across the country (Altay et al., 2007a; 2007b; Aydın et al., 2013; Karagenc, 2017; Bilgic et al., 2017). Because tick infestation in small ruminants is common in all geographic regions of Turkey (Aydın et al., 2012; Dumanlı et al., 2012).

Theileria/Babesia protozoan and *Anaplasma/Ehrlichia* bacteria species are tick-transmitted pathogens, which cause subclinical and clinical infections in a wide range of domestic and wild animals, and also in humans (de la Fuente et al., 2008). Animals become carriers after acute infections, and these animals become a source of infection. There have been several investigations aimed to determine the carrier animals (Altay et al., 2007a; Ekici et al., 2012; Aydın et al., 2013). Furthermore, the detection of agents in ticks can provide significant data for the circulation of the pathogen in the field (Aydın et al., 2015). Ovine and caprine haemoparasite species and isolates comprise *Theileria lestoquardi* (*T. hirci*), *T. uilenbergi* (*Theileria* sp. China 2), *T. luwenshuni* (*Theileria* sp. China 1) (Yin et al., 2007), *T. ovis*, *T. separata*, *T. recondite*, *Theileria* sp. OT1, *Theileria* sp. OT3, *Theileria* sp. MK (Altay et al., 2007a), *Babesia ovis*, *B. motasi*, *B. crassa*, *B. taylori*, *B. foliata*, *Babesia* sp. Xinjiang (Liu et al., 2007; Guan et al., 2009), *Babesia* sp. BQ1, *Babesia* sp. (Ozubek & Aktas, 2017a), *Anaplasma ovis*, *A. phagocytophilum*, *Ehrlichia ruminantium*, *E. ovina*, and *Ehrlichia* sp. Omatjenne until now (Stuen, 2017). From these, *T. lestoquardi*, *T. luwenshuni*, *T. uilenbergi*, *B. ovis*, *B. motasi*, and *A. phagocytophilum* are accepted to be pathogenic. *T. ovis*, *T. separata*, *T. recondite*, *B. crassa*, *Babesia* sp. Xinjiang, and *A. ovis* are considered to be low or non-pathogenic for small ruminants under normal conditions (Liu et al., 2007; Stuen, 2017). *B. foliata* (Ray & Raghavachari, 1941) and *B. taylori* (Sarwar, 1935) were defined nearly a century ago, they have not been reported since so their existence today is questionable (Uilenberg, 2006).

The diagnosis of acute hemoparasitic infections is performed by clinical and microscopic examination (ME) of thin blood and lymph smears (Sevinc et al., 2018). However, species discrimination and determining

low parasitemia is not always possible with ME (Ozubek & Aktas, 2017b). After acute infections, animals become carriers and the detection of the agents with ME is not possible owing to low parasitemia. Serologic tests have been used for this purpose for a long time (Dumanlı et al., 1997; Ekici et al., 2012). However, cross- reactions between species and false-negative results are potential restrictions. Molecular techniques such as polymerase chain reaction (PCR), reverse line blotting (RLB), and sequencing have a broad usage area for TBDs (Bilgic et al., 2017).

Geographic distribution and prevalence

Babesia ovis

According to Goksu (1967), *B. ovis* was first determined in small ruminants in 1889 microscopically by Laveran and Nicolle. Then, it was detected in sheep in Istanbul in 1912 by Hakki, in Bursa in 1930 by Abravanel and Raif, in Ankara in 1931 by Ekrem, again in Bursa in 1931 by Lestoquard and Ekrem, in Central Anatolia region in 1936 by Nevzad through ME and clinical examination. Kurtpinar detected babesiosis using ME and clinical examination in 52 sheep and 11 goats, and Ozcan found it in 11 sheep in Ankara between 1950 and 1951 in the summer months (Goksu, 1967). Goksu (1967) examined 520 suspected and 313 healthy small ruminants from the provinces of Central and Eastern Anatolia regions in 1960-1961. *B. ovis* was detected using ME in suspected and healthy animals at 24.82% and 0.95%, respectively. Hoffmann et al. (1971) detected *B. ovis* as 3.1% in 258 healthy sheep and goats from Adana, Amasya, Ankara, Bursa, Cankiri, Malatya, and Gaziantep provinces using ME between 1967 and 1970. A study performed by Guralp et al. (1975) on 277 healthy sheep from Balikesir, Kırklareli, and Tekirdag provinces of the Marmara region using ME and demonstrated that the prevalence was 0.36%. Tasci (1989) investigated 3878 healthy sheep from the Van province of the Eastern Anatolia region using ME in 1987-1988 and detected babesiosis as 0.85%. It was indicated that some samples were positive for *B. ovis*. Ozer et al. (1993) found *B. ovis* microscopically in healthy sheep and goats as 0.6% in the Malatya, Adiyaman, Sanliurfa, Mardin, and Diyarbakir provinces of the Eastern and Southeastern Anatolia regions in a study of 500 animals in 1988-1989. Inci et al. (1998) found the prevalence as 25.25% using ME on 194 healthy small ruminants in the Cankiri province in 1996. Inci et al. (2002) also stated that the prevalence was 15.48% with ME in small ruminants in the Kayseri province of Central Anatolia

region according to a study conducted on 239 animals between 1998 and 2000.

Ozkoc (1979) investigated *B. ovis* in sheep with serologic tests for the first time in Turkey. According to Duzlu et al. (2012), Ozkoc's study had the characteristic of being the first serologic study for TBDs in small ruminants in Turkey. Deger (1990) investigated 303 healthy sheep from the Van province using ME and serologic tests and its prevalence was 30.6% and 60.3%, respectively. A high prevalence was also found in healthy sheep by Cakmak et al. (1991) in the Samsun province located in the Black Sea region using ME and serologic tests; its prevalence among 141 sheep that were investigated was 67.37% and 71.63% with ME and serologic tests, respectively. Duzgun et al. (1991) investigated 1466 healthy sheep from 16 provinces (Adana, Bursa, Edirne, Istanbul, Samsun, Afyon, Amasya, Ankara, Kirsehir, Sivas, Bingol, Diyarbakir, Elazig, Kars, Sanliurfa, and Van) of all geographic regions of Turkey using serologic tests and they found that the prevalence was 74.4% in total. Sevinc and Dik (1996) examined 723 clinically healthy sheep from the Konya province of the Central Anatolia region and they found the prevalence as 11.47% and 42.14% using ME and serologic tests, respectively. Duzgun (1997) performed a serologic investigation on 360 healthy sheep in the Canakkale province of the Marmara region and found its prevalence ranged between 35% and 63.3% between 1996 and 1997. Sayin et al. (1997) investigated 452 healthy sheep from the Samsun, Izmir, Ankara, Kirsehir, and Erzurum provinces of the Black Sea, Central Anatolia, Aegean, and Eastern Anatolia regions, and they found the seroprevalence as 69.02% in total. According to a study performed by Dumanli et al. (1997) on 331 healthy sheep in the Elazig province of Eastern Anatolia, the seroprevalence was 45.0%. Bicek (2001) examined 156 healthy sheep from the Van province in 1998 and found its prevalence as 16.02% and 45.51% using ME and serologic tests, respectively. Emre et al. (2001) investigated 607 healthy sheep in the Sanliurfa province of the Southeastern Anatolia region between 1997 and 1998 and they found the prevalence as 1.82% and 41.02% using ME and serologic tests, respectively. Aktas et al. (2001) investigated 220 healthy sheep from the Malatya province in 1998 and it was determined that its prevalence was 1.8% and 55.9% using ME and serologic investigations, respectively. Karatepe et al. (2003) examined 1200 healthy sheep in the Nigde province in 1999-2000 and they found the prevalence as 24.75% and 53.75% using ME and the serologic method, respectively. Cicek et al. (2004) found

its prevalence as 0.49% and 51.96%, also with ME and serologic testing in healthy sheep in the Afyon province of the Aegean region according to a study conducted on 204 animals in 2000. Karatepe et al. (2005) investigated 91 healthy sheep in the Amasya province of the Black Sea region in 1999 and its prevalence was 35.16% and 38.46% according to ME and serologic tests. The *B. ovis* seroprevalence was 42.15% in the Konya province of the Central Anatolia region in a study conducted by Ekici et al. (2012) on 2000 healthy sheep in 2010-2011.

The first molecular study about TBDs in small ruminants in Turkey was performed by Aktas et al. (2005a). They investigated 98 healthy small ruminants from the Elazig province of the Eastern Anatolia region and determined the prevalence as 4.08% and 21.42% with ME and species-specific PCR, respectively. Sarayli et al. (2006) investigated 300 healthy small ruminants from the Kayseri province of the Central Anatolia region and they found its prevalence was 3.0% and 3.7% using ME and RLB. Altay et al. (2007a) also investigated 920 healthy sheep and goats from the Eastern Anatolia region in 2005-2006 and its prevalence was 5.43% with RLB in this study. Also, DNA sequence confirmation was first made for TBDs in small ruminants in Turkey. Aktas et al. (2007) examined 400 healthy small ruminants from eight provinces (Malatya, Mus, Elazig, Erzincan, Erzurum, Igridir, Mardin, and Diyarbakir) of the Eastern and Southeastern Anatolia regions and the prevalence was 1.5% and 8.25% in ME and species-specific PCR. Kocabeyoglu (2009) examined 300 healthy goats from the Kahramanmaraş province of the Mediterranean region and the prevalence was 0.33% and 1.33% with ME and RLB. Inci et al. (2010) performed a study on 573 healthy small ruminants between 2006 and 2008 in the Kayseri, Sivas, and Yozgat provinces of the Central Anatolia region and its prevalence was found as 2.6% using RLB. Sevinc et al. (2013) examined 850 sheep in the Konya province in 2011 and 14.35% were positive in ME. Although all the microscopically positive samples were also positive with PCR, 38.14% of the samples were found to be positive in serologic tests. According to a study conducted on 1128 healthy small ruminants in the Bolu, Kastamonu, Corum, Samsun, Tokat, Giresun and Bayburt provinces of the Black Sea region in 2010-2011 by Aydın et al. (2013), the prevalence of *B. ovis* was found as 0.44% using RLB. Bilgic et al. (2017) performed a study on 1979 healthy small ruminants from 18 provinces (Adana, Afyon, Aksaray, Antalya, Aydın, Burdur, Denizli, Isparta, Izmir, Konya, Kutahya, Manisa, Mugla, Nigde, Sirnak, Sanliurfa, Usak, Van) of the Aegean,

Mediterranean, Central Anatolia, Eastern Anatolia, and Southeastern Anatolia regions between 2011 and 2013, and they found the prevalence was 4.9% with species-specific PCR and 0.4% with RLB. Kose (2017) detected it with RLB at a rate of 0.31% in 630 healthy sheep and goats in the Burdur province of the Mediterranean region in 2015. The prevalence was 5.2% with species-specific PCR in the Konya and Karaman provinces of the Central Anatolia region in a study by Zhou et al. (2017) on 343 healthy sheep and goats in 2010-2011. Ozubek and Aktas examined 200 healthy small ruminants from the Mersin province (2017a) and 590 healthy and suspected small ruminants from the Adana, Gaziantep and Adıyaman provinces (2017b) between 2013 and 2015 and its prevalence was determined as 2.0% and 5.4% using RLB, respectively. Sevinc et al. (2018) investigated 209 sheep with clinical signs suggestive of babesiosis in the Konya and Karaman provinces of the Central Anatolia region in 2015-2016 and the prevalence was 70.81% with species-specific PCR.

Babesia motasi

Babesia motasi was microscopically and molecularly identified in Turkey. According to Goksu (1967) it was detected in Ankara by Nevzat, 1936, in the Mediterranean region by Noyan, 1954, in the Erzurum, Kars, and Agri provinces by Kurtpinar, 1956, in healthy sheep using ME. Its prevalence was found as 12.0% in Ankara using ME in healthy sheep by Ozcan (1961). Goksu (1967) detected it in clinically suspected sheep at a rate of 1.73% in Central and Eastern Anatolia regions. Tasci (1989) also detected it in the Van province using ME.

The presence of *B. motasi* in Turkey was questionable until quite recently because it had not been confirmed molecularly. However, it was defined in small ruminants in Turkey at a rate of 0.1% using RLB in the Mugla province of the Aegean region by Bilgic et al. (2017).

Babesia crassa

It has been suggested that this species is present in Turkey in a study conducted using molecular methods (Schnittger et al., 2003) and it was recently identified in small ruminants in the Aegean, Mediterranean, Central, East, and Southeastern Anatolia regions of Turkey by Bilgic et al. (2017) and by Kose (2017) at rates of 4.0% and 6.19%, respectively, using RLB.

Theileria ovis

The first evidence for *T. recondita* (syn: *T. ovis*) in Turkey comes from the study performed by Lestoquard

and Ekrem, 1931, on sheep in the Bursa province of the Marmara region by ME. It was also detected microscopically on clinically suspected and healthy small ruminants with rates of 18.26% and 52.71% in Central and Eastern Anatolia regions according to Goksu (1967). Hoffmann et al. (1971) determined *T. ovis* with ME in healthy small ruminants from the Adana, Amasya, Ankara, and Bursa provinces at a rate of 3.1%. *T. recondita* (syn: *T. ovis*) was also detected microscopically in healthy sheep from the Marmara region at a rate of 1.44% by Guralp et al. (1975).

Between 1993 and 2005, limited articles were published in which *Theileria* spp. was diagnosed using ME (Ozer et al., 1993; Inci et al., 1998; 2003; Aktas et al., 2005b), and with genus-specific PCR (Aktas et al., 2005b); however, species discrimination was not performed. The microscopic prevalence of *Theileria* spp. was between 7.4% and 18.4% in these studies, and the molecular prevalence was 41.2%.

There was only one study aimed at determining *T. ovis* using serologic tests in Turkey (Sayin et al., 2009). The authors investigated 776 healthy small ruminants from the Ankara, Aksaray, Cankiri, Elazig, Van, Bingol and Mersin provinces between 1997 and 1999 and its prevalence was found as 33.89% and 54.38% in ME and serological investigations.

The first molecular study for *T. ovis* in small ruminants in Turkey was conducted by Altay et al. (2005) on 124 healthy sheep from the Eastern Anatolia region. Its prevalence was 19.35% and 54.03% using ME and species-specific PCR in this study. Aktas et al. (2005b) examined 164 healthy small ruminants from the Elazig province of the Eastern Anatolia region in 2004 and they found the prevalence as 24.39% and 43.29% using ME and species-specific PCR, respectively. Altay et al. (2007b) also found that the prevalence was 15.60% and 50.55% using the same methods in a study conducted on 819 small ruminants from the Malatya, Mus, Erzincan, Erzurum, Iğdir, Diyarbakir, and Mardin provinces. The prevalence with RLB was 37.6% in sheep and goats in the Kayseri province of the Central Anatolia region (Sarayli et al., 2006); 34.56% in sheep and goats in the Eastern Anatolia region (Altay et al., 2007a); 0.33% in goats in the Kahramanmaraş province of the Mediterranean region (Kocabeyoglu, 2009); 33.9% in sheep and goats in the Kayseri, Sivas and Yozgat provinces of the Central Anatolia region (Inci et al., 2010); 18.90% (Altay et al., 2012) and 28.99% (Aydın et al., 2013) in sheep and goats in the Black Sea region; 60.00% in a total 18 provinces of the Aegean,

Mediterranean, Central, Eastern and Southeastern Anatolia regions (Bilgic et al., 2017); 41.90% in sheep and goats in the Burdur province of the Mediterranean region (Kose, 2017); 39.16% in sheep and goats in the Sivas province of the Central Anatolia region (Altay et al., 2017); 17.0% in sheep and goats in the Mersin province of the Mediterranean region (Ozubek & Aktas, 2017a); and 35.4% in sheep and goats in the Adana, Gaziantep, and Adiyaman provinces (Ozubek & Aktas 2017b). According to recent articles, its prevalence with species-specific PCR in healthy small ruminants was 61.4% (Bilgic et al., 2017) in 18 provinces of Turkey and 35.9% (Zhou et al., 2017) in the Konya and Karaman provinces.

***Theileria lestoquardi* (*Theileria hirci*)**

This species was only reported in goats as assessed using ME from the Cankiri, Malatya, and Gaziantep provinces in October/November as 16.9% by Hoffmann et al. (1971). However, according to the results of many studies made with molecular techniques, this species has not been found in Turkey.

Theileria luwenshuni* and *Theileria uilenbergi

T. luwenshuni and *T. uilenbergi* were recently detected in healthy small ruminants via PCR and RLB by Bilgic et al. (2017). The prevalence of *T. luwenshuni* was detected as 7.52% and 0.05% with PCR and RLB respectively, and 6.46% and 0.5% of the animals were found to be positive in terms of *T. uilenbergi* with PCR and RLB.

Unidentified *Theileria* and *Babesia* species or isolates

In 2007 a new *Theileria* isolate was discovered in small ruminants in Turkey according to 18 S rRNA gene analysis by Altay et al. (2007a). It was named as *Theileria* sp. MK and its prevalence was 1.30% in the Eastern Anatolia region. This new genotype was detected in healthy small ruminants in the Black Sea region at a rate of 0.99% (Altay et al., 2012) and 0.62% (Aydın et al., 2013) in RLB. *Theileria* sp. MK was also determined in sheep and goats by Bilgic et al. (2017), Altay et al. (2017) and Ozubek and Aktas (2017b) at rates of 0.4%, 2.59%, and 0.3%, respectively, using RLB. *Theileria* sp. OT1 (Bilgic et al., 2017) and *Theileria* sp. OT3 (Altay et al., 2007a; Altay et al., 2012; Aydın et al., 2013; Bilgic et al., 2017; Altay et al., 2017) are the other identified isolates in healthy sheep and goats in the Eastern Anatolia, Black Sea, and Central Anatolia regions.

In a recent study by Ozubek and Aktas (2017a), a new *Babesia* isolate, which was provisionally designated

Babesia sp., showing the highest diversity with other *Babesia* species according to 18S rRNA gene analysis, was detected in goats at a rate of 5.74% in the Mersin province.

Theileria annulata

T. annulata was detected in sheep and goats from the Adana, Gaziantep, and Adiyaman provinces using RLB and nested PCR-restriction fragment length polymorphism (RFLP) at a total rate of 3.9% (Ozubek & Aktas, 2017b).

Anaplasma ovis

A. ovis was first determined in Turkey using ME in sheep by Ekrem in 1931, and in sheep from Bursa by Lestoquard and Ekrem in 1931 (Goksu, 1967). Goksu (1967) detected it in clinically suspected and healthy sheep and goats at rates of 1.34% and 2.23% in the Central Anatolia and Eastern Anatolia regions using ME. Hoffmann et al. (1971) reported that two goats were infected with *Anaplasma* spp. as assessed using ME in the Mediterranean region. According to Guralp et al. (1975), its microscopic prevalence in healthy sheep from the Balikesir, Kirklareli, and Tekirdag provinces was 0.72%. Ozer et al. (1993) also microscopically detected it in healthy sheep and goats from the Malatya, Adiyaman, Sanliurfa, Mardin, and Diyarbakir provinces at a rate of 0.2%.

After 2013, molecular based studies were conducted to determine the actual prevalence of *A. ovis* in small ruminants. According to an investigation of 830 healthy sheep from the Aydin, Mugla, Denizli, Burdur, Usak, Aksaray, Konya, Van, and Sanliurfa provinces using species-specific PCR, the prevalence was 31.4% in total (Renneker et al., 2013). Altay et al. (2014) examined 422 healthy sheep and goats from the Bingol, Elazig, Malatya, and Mus provinces using PCR and they found that 67.06% of samples were positive. Its molecular prevalence was 50.83% in sheep and goats in the Marmara region according to a study conducted on 423 animals from Istanbul, Tekirdag, Edirne, and Kirklareli provinces (Oter et al., 2016).

Ekici (2016) performed a serologic survey on 832 healthy sheep and goats from Konya and Karaman provinces, and the prevalence was determined as 10.0% and 75.12% using ME and serologic tests.

Bilgic et al. (2017) stated that its prevalence was 63.3% in healthy small ruminants in species-specific PCR, this rate was 60.0% in the Konya and Karaman provinces (Zhou et al., 2017), and 18.0% in the Adana, Mersin,

Table 1. Tick-borne pathogens (TBPs) in small ruminants in Turkey; the prevalence, the diagnostic methods and the references.

<i>Species</i>	<i>Method</i>	<i>Prevalence (%)</i>	<i>Reference</i>
<i>Babesia ovis</i>	ME	0.36-67.37	Goksu, 1967; Hoffmann et al., 1971; Guralp et al., 1975; Tasci, 1989; Ozer et al., 1993; Inci et al., 1998; 2002; Deger, 1990; Cakmak et al., 1991; Sevinc & Dik, 1996; Bicek, 2001; Emre et al., 2001; Aktas et al., 2001; 2005a; 2007; Karatepe et al., 2003; 2005; Cicek et al., 2004; Sarayli et al., 2006; ; Kocabeyoglu, 2009; Sevinc et al., 2013
	SM	38.46-74.4	Ozkoc, 1979; Deger, 1990; Cakmak et al., 1991; Duzgun et al., 1991; Sevinc & Dik, 1996; Duzgun, 1997; Sayin et al., 1997; Dumanli et al., 1997; Bicek, 2001; Emre et al., 2001; Aktas et al., 2001; Karatepe et al., 2003; 2005; Cicek et al., 2004; Ekici et al., 2012; Sevinc et al., 2013
	MT	0.31-21.42	Aktas et al., 2005a; 2007; Sarayli et al., 2006; Altay et al., 2007a; Kocabeyoglu, 2009; Inci et al., 2010; Sevinc et al., 2013; 2018; Aydın et al., 2013; Bilgic et al., 2017; Kose, 2017; Zhou et al., 2017; Ozubek & Aktas, 2017a; 2017b
<i>Babesia motasi</i>	ME	1.73-12.0	Goksu, 1967; Ozcan, 1961; Tasci, 1989
	MT	0.1	Bilgic et al., 2017
<i>Babesia crassa</i>	MT	4.0-6.19	Schnittger et al., 2003; Bilgic et al., 2017; Kose, 2017
<i>Babesia sp.</i>	MT	5.74	Ozubek & Aktas, 2017a
<i>Theileria ovis</i>	ME	1.44-52.71	Goksu, 1967; Hoffmann et al., 1971; Guralp et al., 1975; Sayin et al., 2009; Altay et al., 2005; 2007b; Aktas et al., 2005b
	SM	54.38	Sayin et al., 2009
	MT	0.33-61.4	Altay et al., 2005; 2007a; 2007b; 2012; 2017; Aktas et al., 2005b; Sarayli et al., 2006; Kocabeyoglu, 2009; Inci et al., 2010; Aydın et al., 2013; Bilgic et al., 2017; Kose, 2017; Ozubek & Aktas, 2017a; 2017b; Zhou et al., 2017
<i>Theileria lestoquardi</i>	ME	16.9	Hoffmann et al., 1971
<i>Theileria uilenbergi</i>	MT	6.46	Bilgic et al., 2017
<i>Theileria luwenshuni</i>	MT	7.52	Bilgic et al., 2017
<i>Theileria annulata</i>	MT	3.9	Ozubek & Aktas, 2017b
<i>Theileria sp. MK</i>	MT	0.3-2.59	Altay et al., 2007a; 2012; 2017; Aydın et al., 2013; Bilgic et al., 2017; Ozubek & Aktas, 2017b
<i>Theileria sp. OT1</i>	MT	2.6	Bilgic et al., 2017
<i>Theileria sp. OT3</i>	MT	0.2-3.24	Altay et al., 2007a; 2012; 2017; Aydın et al., 2013; Bilgic et al., 2017
<i>Anaplasma ovis</i>	ME	0.2-10.0	Goksu, 1967; Hoffmann et al., 1971; Guralp et al., 1975; Ozer et al., 1993; Ekici, 2016
	SM	75.12	Ekici, 2016
<i>Anaplasma phagocytophilum</i>	MT	18.0-67.06	Renneker et al., 2013; Altay et al., 2014; Oter et al., 2016; Bilgic et al., 2017; Zhou et al., 2017; Aktas & Ozubek, 2018; Sevinc et al., 2018
	ME	9.86	Gokce et al., 2008
	SM	14.86-21.3	Unver et al., 2005; Gokce et al., 2008; Ekici, 2016
	MT	1.56-19.66	Gokce et al., 2008; Altay et al., 2014; Atas et al., 2016; Oter et al., 2016; Bilgic et al., 2017; Sevinc et al., 2018

Abbreviations: ME, microscopic examination; SM, serologic method; MT, molecular techniques.

Gaziantep, and Adiyaman provinces (Aktas & Ozubek 2018). Sevinc et al. (2018) also found that *A. ovis* was present at a rate of 56.94% in sheep with clinical signs suggestive of babesiosis in the Konya and Karaman provinces.

Anaplasma phagocytophilum

Preliminary data for *A. phagocytophilum* in small ruminants was provided from a serologic survey conducted on 104 healthy sheep from the Kars province by Unver et al. (2005). The seroprevalence was 19.2% in that study. Gokce et al. (2008) investigated its prevalence with ME, serologic tests, and PCR in 750 healthy sheep from the Artvin, Rize, Trabzon, Giresun, Ordu, and Samsun provinces, and the prevalence was 9.86%, 14.86%, and 12.35% with these methods respectively. Its prevalence in species-specific PCR varied between 1.56% and 19.66% in Turkey. Altay et al. (2014) found it as 19.66% in Bingol, Elazig, Malatya, and Mus, whereas its prevalence was 4.33% in Sanliurfa (Atas et al., 2016), 8.51% in Istanbul, Tekirdag, Edirne, and Kirklareli (Oter et al., 2016), 1.56% in 18 provinces of Turkey (Bilgic et al., 2017), and 2.39% in Konya and Karaman (Sevinc et al., 2018). According to a recent serologic investigation in Konya and Karaman, its prevalence was 21.3% (Ekici, 2016).

Conclusion

Studies about tick-borne protozoan and bacterial infections in sheep and goats in Turkey were summarized with this review (Table 1). The prevalence of tick-transmitted pathogens in healthy sheep and goats was 0.36-67.37% (ME), 38.46-74.4% (serologic methods), 0.31-21.42% (molecular techniques) for *B. ovis*; 1.73-12.0% (ME), and 0.1% (molecular techniques) for *B. motasi*; 4.0-6.19% (molecular techniques) for *B. crassa*; 5.74% (molecular techniques) for *Babesia* sp.; 1.44-52.71% (ME), 54.38% (serologic method), 0.33-61.4% (molecular techniques) for *T. ovis*; 7.52% (molecular techniques) for *T. luwenshuni*; 6.46% (molecular techniques) for *T. uilenbergi*; 0.3-2.59% (molecular techniques) for *Theileria* sp. MK.; 2.6% (molecular techniques) for *Theileria* sp. OT1; 0.2-3.24% (molecular techniques) for *Theileria* sp. OT3; 3.9% (molecular techniques) for *T. annulata*, 0.2-10.0% (ME); 75.12% (serologic method); 18.0-67.06% (molecular techniques) for *A. ovis*; and 9.86% (ME), 14.86-21.3% (serologic method), 1.56-19.66% (molecular techniques) for *A. phagocytophilum*.

As a conclusion, *B. ovis* has a broad range of distribution and low prevalence, *T. ovis* has a broad

range of distribution and also a high prevalence. Presence of *B. motasi*, *B. crassa*, *T. luwenshuni* and *T. uilenbergi* were recently molecularly confirmed, but need to be investigated in detail. Further investigations should be performed related with the newly identified species / isolates (*Theileria* sp. MK, *Theileria* sp. OT1, *Theileria* sp. OT3, *Babesia* sp. and *T. annulata*) in sheep and goats. According to the limited number of studies about sheep and goat *Anaplasma* infections, *A. ovis* has high prevalence, and *A. phagocytophilum* has low prevalence in sheep and goats in Turkey.

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