Chapter

Economic and Health Impact of the Ticks in Production Animals

Oscar Jaime Betancur Hurtado and Cristian Giraldo-Ríos

Abstract

Nowadays there is no doubt about the importance of production animals in the economy and food security of the population throughout the world. For an animal to be productive (cattle, small ruminants, swine or poultry) is needed to be in adequate health conditions. The health of these animals can be altered by the direct and indirect effects of ticks, causing significant losses in the production of meat, milk, eggs, leathers, and in many cases the death of the affected animals. The direct losses are related to the damage produced by the ticks when feeding on the blood of their hosts, while the indirect losses are related to the infectious agents transmitted by the ticks, and the costs associated to the treatment and control. It is important then, to know what are the economic and health impacts of ticks on the main production animals.

Keywords: cattle, diseases, impact, poultry, small ruminants, swine, ticks

1. Introduction

Ticks are external, temporary and obligate parasites of vertebrate animals (birds, mammals and reptiles), which need to feed on blood in order to live. The hot and humid climates favor their survival, while the low temperatures inhibit their development [1]. Ticks belong to two main families, Ixodidae and Argasidae. The most important is the Ixodidae, also called hard ticks, due to the presence of a rigid chitinous shield, which covers the entire dorsal surface of the adult male. In the adult female and in the larva and the nymph it extends only by a small area, which allows the abdomen to swell after feeding. The other family is the Argasidae or soft ticks, so called because they lack of a shield [2]. There is a third family (Nuttalliellidae) to which only one species belongs [3].

Within the hard ticks *Ixodes* is the largest genus, which contains 217 species. Other genera of veterinary importance include *Dermacentor*, *Haemaphysalis*, *Rhipicephalus* (which now includes the genus synonym *Boophilus*), *Hyalomma* and *Amblyomma* (genus synonym *Aponomma*) [2]. On the other hand, the most important soft ticks belong to the genera *Ornithodoros*, *Argas* and *Otobius* [3].

Ticks are one of the biggest public health and veterinary problems in the world [4]. These ectoparasites can impact the production and health of the animals, either directly by the effect of their bites or by the infectious agents they transmit [1], which include viruses, bacteria, rickettsiae and protozoa [2].

Ticks and the pathogens they transmit have co-evolved in equilibrium with wild animals that serve as hosts, and reservoirs at the same time. Normally situations of instability only occur when these reservoirs come into contact with domestic animals, either by the introduction of uninfested animals to infested regions, or by the movement of infested animals to non-infested regions [3].

Ticks are periodically fed with blood, with long intervals between meals. When they bite their hosts, they injure the tissues of animals at their feeding site, causing irritation, inflammation or hypersensitivity [2]. Massive infestations of ticks can cause anemia, as a result of blood loss [5]. Each time a tick bites its host to feed it causes stress and weakens its immune response affecting its productivity, which results in losses in the production of meat and milk, increased morbidity and in many cases mortality, in addition to the indirect economic losses for producers related to prevention and control costs. Affected skin loses its commercial value [1].

Sites bitten by ticks cause lesions that may predispose to localized dermatitis, secondary bacterial infections, or invasion by flies (miasis) that are attracted to bloody areas [6]. Certain ticks contain paralyzing toxins in their saliva (for example *Dermacentor andersoni*, *Ixodes rubicundus*, *I. holocyclus*) that can even cause the death of affected animals. The saliva of *Hyalomma truncatum* can also cause toxicosis that manifests as widespread eczema in African livestock species [3].

The negative impact of ticks is especially important in production animals, and to a lesser extent in equines and companion animals, where pathogens causing tick-borne diseases can limit the international trade and the presence of ticks in sporting events. On the other hand, and not less important, is the role of ticks in the transmission of zoonotic diseases, which cause high morbidity and mortality in people [3]. In this regard, Betancur et al. [7] conducted a literature review highlighting the role of ticks in the transmission of zoonotic agents, and some prevention and control measures to protect the health and well-being of people at risk to get in contact with these ectoparasites.

2. Economic and health impact of the ticks in cattle

2.1 Direct and indirect losses in cattle

Babesiosis, theileriosis and anaplasmosis are the main parasitic diseases transmitted by ticks and that generate important economic losses in cattle production around the world [8], being especially relevant in different countries of Asia, Africa and Latin America [3].

Common signs associated with hemoparasitic disease are: fever, anemia, decreased appetite [9], reduction in milk production [9–11], lower weight gain [12, 13], loss of body condition, reproductive effects in males and females, abortions in the last third of gestation [9], lower pregnancy and birth rate [13], death in some animals [9–12].

Ticks affect 80% of the cattle population of the world. Specifically, *Rhipicephalus microplus* (formerly *Boophilus microplus*) is the tick that has the greatest economic impact [12], due to its wide distribution, vector capacity, blood-sucking habits and the number of cattle that affects [14]. Ticks usually prefer places on the body of animals where the skin is thin and short, and have abundant blood supply, such as the inguinal region and external genitals. Ticks grow and develop best in hot and humid climates [15]. Due to its great capacity for adaptation and propagation, ticks of the genus *Rhipicephalus* have been able to spread in various geographical areas around the world. Approximately 1 billion bovines are in areas at risk of being affected by these parasites [4].

The economic impact is strongly linked to the epidemiology of the disease and can be distributed in direct and indirect losses [9]. Its direct effect on production, results in damage to the skins by biting, especially in highly infested cattle [4, 11, 13, 16]; blood loss associated with high parasitic loads, anemia [4, 13, 16]; severe immunological reactions by the inoculation of toxins (antigens and coagulants in saliva) [4, 13]; permanent stress that affects the behavior and welfare of the animal [9, 13, 16] which also leads to depression of the immune function [17]; loss of energy associated with the constant movement that occurs in response to infestation [13].

Indirect losses are related to the effects of hemoparasites and other diseases that they can transmit [4, 9, 11, 17]. Other indirect losses correspond to the cost of treatment for clinical cases; expenses incurred in the control of ticks; unearned income or inefficiencies in the production system: use of genetically resistant breeds to ticks but less productive; confiscation by acaricide residues in meat or milk; trade restrictions of animals between areas and countries [9]. The economic losses by ticks include not only the price of animals of high genetic value, but the impossibility of these animals to contribute to the genetic improvement (productive potential) of an entire herd or even a region [18].

Betancourt [19], mentions that the losses caused by the infestation with *R. microplus*, the associated diseases and the control of it, have been calculated at USD $13.9–18.7 billion per year worldwide. In Colombia the losses could amount to COP $480,000 million per year (approximately USD $168 million). In Brazil, potential annual losses due to the infestation of *R. microplus* have been estimated in USD $3.24 billion [20]. The same exercise performed in Mexico, indicate losses of USD $573.61 million derived from the potential losses in meat and milk as a result of the infestation by *R. microplus* [21]. Another report estimates that the losses for Mexico are up to USD $942.23, not including the losses produced by the death of animals infected by hemoparasites, nor the expenses in medicines, which could double the annual losses [14]. According to FAO [22], the average total financial losses (production losses plus control cost) per animal per year are USD $7.3.

The effects of ticks on weight gains are quite negative. On average, each engorged female tick is responsible for the loss of 1.37 g of body weight in *Bos taurus* cattle. The comparable value for cattle *B. taurus* × *B. indicus* is 1.18 g per fattened tick [23]. It has been observed that animals infested with ticks reduce their feed intake (4.37 kg) compared to animals not exposed to ticks (5.66 kg). These effects cause losses of several billions of dollars in the global livestock economy [24].

The direct effect of ticks on dairy cattle can reduce total milk production by approximately 90 l/lactation/cow. Each fattened female tick can be responsible for up to 8.9 mL of milk reduction [25]. Other estimates indicate that losses in milk production reach 23% [10].

2.2 Tick-borne pathogens in cattle

2.2.1 Tick fever (babesiosis and anaplasmosis)

Rhipicephalus microplus, is considered the most important tick of cattle in the world, acting in the transmission of pathogens such as *Babesia bigemina*, *B. bovis* and *Anaplasma marginale* [17], developing the clinical disease known as “tick fever” [9]. This disease is endemic in tropical and subtropical areas [16]. These tick-borne hemoparasitic diseases affect the export and import trade of live animals and products of animal origin (meat, milk, leather and skin) [8]. Ticks negatively impact milk production in cattle, both in quantity and quality [1].

Bovine babesiosis is a disease that affects erythrocytes and is characterized by fever, hemolytic anemia, anorexia, lethargy, hemoglobinuria, tachycardia and icterus. In severe cases it can cause seizures, hyperesthesia and paralysis, which can lead to death due to shock and respiratory distress [26]. The two most important species in cattle are *Babesia bovis* and *B. bigemina* [27]. The disease caused by *B. bovis* is usually severe and a large number of sick animals die. The disease caused by *B. bigemina* is usually less severe but can develop very fast [16]. *Rhipicephalus microplus* is the most important and widespread vector, but in southern Africa, a closely related tick, *Rhipicephalus decoloratus*, interferes with its dissemination in drier and colder areas [27]. In Europe there is babesiosis caused by *Babesia divergens* that is transmitted by the *Ixodes ricinus* tick, which is restricted to that continent [9].

Bovine anaplasmosis is caused by *Anaplasma marginale*; affects erythrocytes and causes an acute infection characterized by fever, high levels of bacteremia, anemia, weakness, reduced growth and milk production, abortion and in some cases death [26]. The severity of clinical signs varies considerably, depending on the species and age of the infected animal, with adult cattle being the most severely affected [28]. It is an infectious disease but not contagious. *Anaplasma marginale* can be transmitted by three methods: biological: infected erythrocytes are ingested by ticks; *A. marginale* replicates within the intestine of the tick and the salivary glands and is subsequently transmitted through the saliva of ticks to uninfected ruminants; (ii) mechanical: infected erythrocytes are transferred from infected cattle to susceptible by biting flies or contaminated fomites with blood, including needles or surgical instruments, without this implying the amplification of *A. marginale*; and (iii) transplacental: the infected erythrocytes move through the placenta from the infected cows to their offspring, without the amplification of *A. marginale* [29]. Anaplasmosis is currently classified in List B of the Terrestrial Animal Health Code of the International Office of Epizootics [30] because of its socio-economic importance and its importance in terms of restrictions on the international trade of animals and products of animal origin [31].

It has been reported that at least 20 different species of ticks transmit *A. marginale* throughout the world. In general, tick vectors of *A. marginale* include *Boophilus* spp., *Dermacentor* spp., *Ixodes ricinus* and *Rhipicephalus* spp., while *Amblyomma* spp. they do not seem to transmit *A. marginale* [32]. The soft ticks *Argas persicus*, *Ornithodoros lahorensis* have also been mentioned as capable of transmitting them. The transestadial transmission is the usual mechanism of *Rhipicephalus* species of a single host. Tick males are particularly important as vectors, being able to be permanently infected and serve as reservoirs for infection [30]. Under favorable conditions of adequate vegetation and preserved moisture that protect ticks from drying out, male ticks can persist in the environment for several months to more than 1 year, thus serving as a reservoir of *A. marginale* in the wild [33]. *Rhipicephalus* species are clearly important vectors of anaplasmosis in countries such as Australia and countries in Africa and Latin America [30]. In North America, *A. marginale* can be transmitted by the *Dermacentor* tick species, including the ticks of three hosts as *D. andersoni*, *D. variabilis* and *D. occidentalis*, as well as the single-host tick *D. albipictus* [29].

Animals from childhood that have permanent contact with ticks, usually never develop a clinical episode of tick fever, but become carriers of *Babesia bigemina*, *Babesia bovis* and *Anaplasma marginale* subclinically [9], and therefore, livestock is immune to later challenges as adults. Cattle breeds that are indigenous to endemic regions often have a certain degree of natural resistance to the disease and the consequences of infection are not as severe as when they are exotic breeds of *Bos taurus* [27]. In situations of enzootic stability, when the animals through a natural selection process have become tolerant (but non-refractory) to the infection, as a consequence of the prolonged exposure to the ticks and infectious diseases they transmit, and the number of ticks keeps in balance with the amount of animals, it is possible to find a 100% infection prevalence without clinical evidence of the disease [3]. The problem and the negative effect occur when tick populations increase and when it corresponds to the first contact with the hemoparasite. Thus, in situations of first introduction or enzootic instability and in susceptible animals, direct and indirect economic losses are greater [9].

2.2.2 Theileriosis

Another important disease that derives from the tick bite is theileriosis [10]. *Theileria* species of economic importance that infect cattle and small ruminants are transmitted by ixodid ticks of the genera *Rhipicephalus*, *Amblyomma*, *Hyalomma* and *Haemaphysalis*. The stages of development of the parasite occur in the tick and pass transestadially through the larval, nymph and adult stages, but there is no transovarial transmission. As a result, larvae or nymphs become infected and transmit infections such as nymphs or adults. Adults are more efficient vectors than nymphs [15]. Globally, *Theileria annulata* (cause of tropical theileriosis) and *Theileria parva* (cause of east coast fever) are the most economically important tick-borne pathogens that cause bovine theileriosis [34].

Tropical theileriosis is a risk to approximately 250 million cattle and acts as a major limitation in the production and improvement of livestock in many developing countries [8]. This disease causes high morbidity and mortality in exotic cattle, which inhibits the introduction of improved cattle in endemic areas. The consequence is that the quality of livestock in endemic areas remains low, which prevents the development of the livestock industry. *Theileria annulata* causes serious financial losses due to the decrease in live weight, a decrease in milk production, abortions and in some cases deaths, in addition to the high costs for treatment. The mortality rate in the introduced breeds fluctuates from 40 to 90%, while the mortality rate in native cattle can be only 3% [34]. It has been estimated a decrease in weekly milk production of 2.76 L/day/cow, which corresponds to 31.92% of total milk yield [35].

On the other hand, infection by *T. parva* represents a major threat to the livestock sector in two ways: through the economic impact of the disease due to livestock morbidity and mortality and production losses in all production systems, as well as the cost of measures to control ticks and disease [8]. Morbidity and mortality vary with host susceptibility and parasitic load. The lethality rate in untreated animals can reach 100% in cattle from non-endemic areas. In contrast, the morbidity rate is close to 100% in native cattle, but the mortality rate is usually low [34].

2.3 Control of ticks in cattle

In bovine cattle, the main tool for the control of ticks is still the use of acaricides (chemical control). Chemical control methods have the function of breaking the life cycles of ticks through the application of ixodicides [24]. However, for years it has been suggested that the exclusive strategy of chemical control is inadequate due to the possible development of resistance [36]. The incorrect use of pesticides such as the use of sub-doses, inadequate preparations and erroneous applications cause the failure of the treatment. With this, whenever the ticks survive the applications of the different products used, they transmit to the later generations genetic information about the active principle of the drugs, causing resistance to subsequent generations [37]. The excessive use, the incorrect dosage and the decrease in the interval between the applications, has generated in addition to problems of resistance, the presence of chemical residues, both in the meat and in the milk, as well as the increase in production costs [38].

In order to reduce the possibility of resistance, Rodriguez-Vivas et al. [11] recommend an integral control of ticks whose strategies include: rotation of acaricides, with active ingredients that have different mechanisms of action, and without cross-resistance potential; correct application of acaricides, in recommended doses and intervals of time. According to Betancur [39], it is always recommended, to use products with proven effectiveness; in addition, the author recommend to reduce the selection pressure of the toxic compound on the pest species, in other words, the complete elimination of ticks in cattle by the pesticide should be avoided. Knowledge of the biology of the tick, its epidemiology, climatic conditions (such as soil temperature), as well as knowledge of the pesticide to be used, are necessary to understand the effectiveness of the products applied over time, and establish the best application strategies [40].

Different classes of acaricides (organochlorines, organophosphates, carbamates, pyrethroids and amidines) have been used successfully to control ticks in cattle, but some factors such as environmental damage, adverse effects on health (carcinogenic effects), as well as problems of resistance have caused that in some cases its use is limited [41]. The rational use of the traditional and new generation chemical molecules, through the correct dosage and rotation of the active ingredients on the market, allow extending the use of this control alternative, avoiding the resistance on the part of the ticks [38]. In order to improve the effectiveness of tick control, it is now possible to find on the market, products that mix different active ingredients. It is reported that some pesticides such as macrocyclic lactones (ivermectin, doramectin, moxidectin), fipronil, spinosad and fluazuron are very effective in ticks control [41]. Some studies have shown that fluazuron is a molecule with efficiencies greater than 99% in the control of the tick *Rhipicephalus* (*Boophilus*) *microplus*, without resistance problems [37, 42].

Other strategies of an integral control program of ticks are: manual elimination (only practical on farms with small number of infested animals); use of breeds resistant to ticks and the pathogens they transmit; release of sterile male ticks; sowing of plants that are unfavorable for ticks; rotation of pastures with forced breaks in order to interrupt the life cycle of the tick; burning of pastures, exposing the different stages of the ticks at high temperatures, and eliminating the vegetation that protects them; quality animal nutrition to improve resistance to ticks; use of plant extracts and essential oils with acaricidal activity; vaccination; biological control with nematodes, entomopathogenic fungi, ants, birds, among others [11]. The use of chickens as biological controllers of cattle ticks has been suggested, leaving them in the meadows where they consume the ticks that are found in the vegetation [43].

3. Economic and health impact of the ticks in small ruminants

3.1 Direct and indirect losses in small ruminants

Small ruminants are an important source of meat and milk in different countries and play a vital role in food security, in addition to the income earned from the sale of skins and wool. However, as with other species, ticks can limit the production systems of small ruminants, causing direct and indirect losses [44]. Although no tick is a specific host for sheep or goats, both hard and soft ticks parasitize these ruminants [45].

Some species of ticks cause paralysis while others cause toxicosis. Intensive lameness has been noted in the goats, where ticks adhere around the coronary band [46]. Ticks cause substantial financial losses in the livestock industry of some countries such as Ethiopia, for the damage to leathers and skins of sheep, goats and cattle. Lamb skins are particularly susceptible to damage. Secondary bacterial infection after tick bite increases the severity of the damage [47]. Some infestations by ticks such as *Otobius megnini* and *Ornithodoros coriaceus* can generate irritations and injuries at the ear level, which can lead to permanent nerve damage and death from meningitis [45].

Ticks generate indirect damage due to their key role in the transmission of a large number of infectious agents [44]. As mentioned in Bilgic et al. [48], in recent decades, the socioeconomic impact of small ruminants has grown worldwide, and therefore more attention is now being given to the pathogens that affect sheep and goats. As in the case of bovines, the main tick-borne diseases are babesiosis, anaplasmosis, theileriosis and heartwater [3]. Losses attributed to these diseases include mortality, production losses, diagnostic, veterinary treatment and control costs of ticks [48]. In China, it is estimated that *Anaplasma*, *Babesia* and *Theileria* species infect about 35 million of small ruminants. As the per capita economic loss of sheep or goats infected by these tick-borne pathogens is at least 2 USD, the total annual loss of small ruminants due to tick-borne diseases is estimated at around 70 million USD [49].

3.2 Tick-borne pathogens in small ruminants

The etiologic agent of ovine anaplasmosis in most cases is *Anaplasma ovis*. The disease is related to hemolytic anemia in goats and sheep. *A. ovis* is transmitted biologically by ticks of the species *Rhipicephalus bursa*, *Dermacentor silvarum*, *D. marginatus*, *D. andersoni* and *Haemaphysalis sulcata* [50]. In China it has been confirmed that *D. nuttalli*, *Hyalomma asiaticum* and *R. pumilio* are vectors of *A. ovis* [49].

The so-called tick fever in sheep is produced by *Anaplasma phagocytophilum*, whose symptoms include fever, neutropenia (predisposing to secondary bacterial and viral infections), cough, loss of appetite, fatigue, weight reduction and milk production loss. In goats, *A. phagocytophilum* can cause fever and a severe reduction in milk production. Complications often include abortions and alteration of spermatogenesis in rams for at least 2 months. In rare cases it is fatal unless there is a complication with other infections. *A. phagocytophilum* is transmitted by Ixodidae ticks. In Europe, is transmitted mainly by *Ixodes ricinus*, while in the United States the main vectors are *Ixodes scapularis* and *Ixodes pacificus* [50]. It is suggested that *Amblyomma maculatum* has the potential to transmit *Anaplasma* sp. in sheep [51].

Small ruminants are also affected by babesiosis caused by *Babesia ovis*, *B. motasi, B. crassa, B. foliata, B. taylori,* and *Babesia* sp. (China) [52]. *Babesia ovis* is considered highly pathogenic with mortality rates of 30–50% in susceptible sheep. Regarding to babesiosis caused by *B. motasi*, the parasite appears to be of moderate virulence, but it can be fatal. Ticks of the genus *Rhipicephalus* (especially *R. bursa*), *Haemaphysalis*, *Dermacentor* and *Ixoides* are responsible for the transmission of the disease [50].

Theileriosis in sheep and goats is a hemoprotozoan disease transmitted by ticks caused by *Theileria ovis, T. lestoquardi*, *T. luwenshuni*, *T. uilenbergi*, *T. recondita* and *T. separata* [52]. In susceptible sheep, the disease can be highly pathogenic, especially when it is caused by *T. lestoquardi*, causing a lymphoproliferative disease with mortality and high morbidity. *T. lestoquardi* can be transmitted by *Hyalomma* spp., and *Rhipicephalus bursa* [50]. According to Yin et al. [53], *Haemaphysalis qinghaiensis* efficiently transmit *Theileria* sp. to sheep and goats.

Heartwater is a rickettsial disease of domestic and wild ruminants caused by *Ehrlichia* (formerly *Cowdria*) *ruminantium*, which represents a significant obstacle to the improvement of livestock production in the tropics and subtropics with mortality rates ranging from 20–90% in susceptible animals. The organism is transmitted by ticks of *Amblyomma* spp., and small ruminants are particularly at risk of acquiring the disease [54].

3.3 Control of ticks in small ruminants

Control strategies against ticks should be aimed at cutting the biological cycle of these [44]. Although there are several useful options for the control of ticks by means of chemical products, it is difficult to achieve a long lasting control, for that reason it is suggested to consider an integrated approach that incorporates cultural, physical and chemical methods [45]. In small grazing units, ticks can be manually removed from the animals. Rotary grazing has been recommended as a means to control tick infestation. Although burning of heavily infested pastures is practiced in some countries, it is not widely recommended due to its damaging effects on the environment. Tillage of the grazing land exposes different stages of the ticks in the soil to sunlight and also buries them in deep layers of the soil thus preventing their development [46]. In most cases, the protection of sheep and goats from ticks still depends mainly on the direct application of acaricides to the animals. The treatment should be scheduled to protect the animals during the peak of tick activity [45].

4. Economic and health impact of the ticks in swine

Domestic pigs are also susceptible to tick infestation, however, under modern production conditions, they hardly come into contact with these ectoparasites. The most important species of ticks in the United States are *Dermacentor*, *Ixodes*, *Amblyomma*, *Ornithodoros* and *Otobius*. Its main economic impact is due to the ability to transmit pathogens, such as the African swine fever virus [55].

4.1 African swine fever

African swine fever is a viral disease that generates large economic losses in swine production, being transmitted by several species of soft ticks of the genus *Ornithodoros* [56]. This is the only known DNA virus that is transmitted by arthropods. The virus is endemic in many parts of the world [57], mainly spread in sub-Saharan Africa, Eastern Europe and the Caucasus and the Italian island of Sardinia [58]. African swine fever is a highly deadly and contagious hemorrhagic disease that restricts the international trade of pigs and their derivatives [59].

The virus is very well adapted to survive and persist in the tick, with minimal harmful effects on this host. The virus enters the tick when it feeds on an infected animal, then reaches the middle intestine where it replicates, then enters the hemocele and infects the major secretory gland, the salivary and coxal glands; finally when the tick feeds the virus is transmitted by means of the fluids of these glands [60]. Tick populations can remain infected and infectious for long periods due to transestadial, venereal and transovarial transmission of the virus in the tick population, which allows the virus to persist even in the absence of viraemic hosts. Infected ticks play an important role in the long-term maintenance of the disease, surviving for months in burrows and up to several years after feeding from an infected host [58].

All members of the pig family (Suidae) are susceptible to infection, but clinical disease is only observed in domestic and wild pigs, as well as in the closely related European wild boar. It affects pigs of all ages and induces a hemorrhagic fever. It can appear in a variety of forms ranging from peracute, acute, subacute, chronic and non-apparent. It is recognized more frequently in the acute form with an associated lethality of up to 100 percent [58]. The high lethality in domestic pigs, the introduction of mass slaughter campaigns and restrictions on swine movement contribute to the high socio-economic impact of the disease on swine production, global trade and livelihoods of the people. The impact is usually greatest for low-income farmers in developing countries, who depend on pigs as an additional source of income and a relatively cheap source of protein [61].

It is difficult to find global data on the economic costs of African swine fever and, therefore, estimates can vary substantially. As a result of outbreaks of African swine fever in 2014 and 2015 in Poland, Lithuania, Latvia and Estonia, the value of exports of pork and pork products was reduced by USD $961 million, which represents up to 50% of exports [61]. The introduction of African swine fever in Denmark could generate losses of USD $12 million in direct costs and USD $349 million in exports [62]. In Russia, it was estimated that African swine fever had cost USD $267 million in 2011. The further spread of African swine fever to China could have disastrous consequences, recognizing that China contains more than half of the world population of pigs [61].

When the populations of ticks are very low, they can be eliminated manually, removing the animals from the infected zone, and in other cases acaricides can be used [55]. In the case of African swine fever, as there is currently no vaccine or effective treatment, the best strategy for countries or areas that are still free of the disease is to prevent the entry of the virus through improved border control, adequate awareness and better biosecurity. For infected countries, improved awareness and biosecurity are also applied, along with rapid control of outbreaks through movement restrictions and sanitary slaughter policies [58]. According to Fasina et al. [63], a full implementation of biosecurity will result in a reduction of 9.70% in the total annual benefit, but is justified in view of the substantial costs incurred in the event of an outbreak of African swine fever.

4.2 Tularemia

Another disease that can be transmitted to pigs through tick bites is tularemia. This disease is caused by a bacterium (*Francisella tularensis*) and is zoonotic in nature. Ticks are true reservoirs, as well as vectors, and can transmit the bacterium to their offspring (transovarial and transestadial) or horizontally to other healthy hosts. Multiple species are included, particularly *Amblyomma americanum*, *Dermacentor andersoni*, *D. variabilis*, *Ixodes* spp. Repeated isolations of *F. tularensis* from ticks have been reported in the United States, Europe, Asia and Japan. In adult pigs the disease is usually subclinical, while in young, fever, dyspnea and depression are observed [64]. However, this disease may be unimportant in domestic pigs, while wild pigs behave as reservoirs of the bacteria, putting hunters and consumers of infected pork at risk [65]. Prevalence has been found in wild pigs of 1.3% [66].

5. Economic and health impact of the ticks in poultry

Ticks are associated with bird production systems. In modern poultry production, there are not many cases of tick infestation. The two most common species considered as pests of poultry are the ticks *Argas persicus* and *Argas radiatus*. Wild birds are usually the source of infestation [67]. Most infestations occur in backyard birds, where the environment is more compatible with ticks. Adult soft ticks spend most of their lives in cracks and other hiding places outside the bird; their feeding habits on the bird are nocturnal, so that an infestation can be easily overlooked, and only a nocturnal inspection can make them noticeable [68]. At the opposite, larvae of *Argas persicus* adhere to poultry and feed for a few days [69].

The most important tick in poultry is *Argas persicus*, known as bird tick (sometimes called "blue bug"), although many species of hard ticks feed intermittently on poultry [68]. It is widely distributed in tropical and subtropical areas [70]. It affects poultry, turkeys, ducks, pigeons and canaries [71]. In commercial birds, infestations by *Argas persicus* occur with irritation, drowsiness, ruffled feathers, weight loss, decreased egg production, and anemia that can be fatal in heavy infestations [6, 70, 72]. The larval forms of these ticks also cause paralysis [73].

Insertion of the tick hypostoma into the skin of the host causes damage to the epidermis and rupture of the blood vessels. Tick bite causes skin damage consisting of edema, cell infiltration, and extensive hemorrhage. These injuries predispose the animals to decrease the absorption of food and lose body weight. In addition, the poor appearance of the carcass reduces marketability and this is a point that must be carefully considered in the poultry industry [74]. Soft ticks have many nymphal instars, each of which must be fed with blood, so repeated feeding by large populations of soft ticks can cause blood loss, wasting and deadly anemia [68]. Khan et al. [75], quantified up to 3.5 *Argas persicus* per bird, each sucking an amount of 18.57 mg of blood per day and 0.06 g per bird, which translates into huge economic losses due to production losses.

5.1 Tick-borne pathogens in poultry

It has been shown that the avian tick has the potential to transmit a significant number of pathogens in many parts of the world [68]. *Borrelia anserina*, *Staphylococcus aureus*, *Salmonella* Pullorum and *Escherichia coli* have been isolated from *Argas persicus*, and it is considered that they may play an important role in the epidemiology of these diseases [76]. Other microorganisms isolated include *Pseudomonas pyocyanea*, *Bacillus subtilis*, *Salmonella* Gallinarum, *Streptococcus gallinarum*, *Sporosarcina lutea*, *Serratia marcescens*, *Flavobacterium indothefcum*, *Bacillus anthracis*, *Aerobacter cloacae*, *Proteus vulgaris*, *Proteus rettgeri*, *Aerobacter aerogenes*, *Staphylococcus albus*, *Streptococcus zooepidemicus*, *Streptococcus pyogenes*, *Vibrio cholerae*, *Clostridium botulinum*, *Klebsiella aerogenes* and *Flavobacterium* spp. However, even when different pathogens can be isolated from ticks, not all are capable of promoting clinical disease in birds [77]. Different reports of literature mention that the ticks that transmit certain pathogens that cause diseases such as salmonellosis, mycoplasmosis, leukocytozoonosis, aegyptianellosis, pasteurellosis, avian encephalomyelitis, borreliosis and avian cholera [72, 75, 78].

Although salmonellosis is a disease of great impact in the poultry industry, and there are reports that indicate that *Argas persicus* has the possibility of transmitting at least experimentally *Salmonella* Pullorum [79], and *Salmonella* Gallinarum [80], vector role for ticks with respect to *Salmonella* remains speculative [81]. In any case, it is suggested to take sanitation measures that aim to eliminate ticks in poultry farms, since ticks are able to harbor these viable bacteria for 8 months, excreting it through the feces [79].

Argas persicus transmits *Borrelia anserina*, an important avian pathogen that causes spirochetosis [3, 69]. Spirochetosis has an important economic impact, since it causes a high mortality among birds that can reach up to 100%, in addition to its effect on the reduction of egg production in layers and the reduction of production in broilers. The clinical signs of spirochetosis vary according to the virulence of the strain, but it is characterized by weight loss, drop in egg production, drowsiness, ruffled feathers, pyrexia, greenish diarrhea, pallor of the crest and chins, paralysis of the wings and lateral desquamation that is observed in the last stage of the disease [82]. The bird can also become infected as a result of ingestion of ticks, their eggs, contaminated droppings and cannibalism [83].

The adult argasides are highly resistant to starvation, which allows them to survive without feeding for more than 1 year in the absence of a host, which confuses the eradication of the infested facilities. All cracks and crevices that can harbor ticks should be thoroughly treated with an appropriate acaricide to successfully eliminate a tick infestation, and it may be necessary to repeat the treatment to suppress ticks that are born from the remaining eggs [68].

6. Economic and health impact of the ticks in equines and companion animals

Pets, particularly dogs, suffer the consequences of tick-borne diseases. Babesiosis and ehrlichiosis are the most important, being the infection by *Ehrlichia canis* frequently fatal [3].

As in cattle, ticks are an ectoparasite of sanitary importance in equines, due to their potential role in the transmission of pathogens. The *Dermacentor*, *Ixodes* and *Amblyomma* species are the most common hard ticks in horses. The severity of the symptoms will depend on the level of infestation, being able to develop a localized or generalized hypersensitivity reaction, in addition, at the bite site appear nodules, erosions, papules, scabs, ulcers and hair loss [84]. Two of the main diseases derived from tick infestation in horses are equine granulocytic anaplasmosis and equine piroplasmosis. The first has its origin in the bacterium *Anaplasma phagocytophilum*, while the second is caused by the hemoparasites *Theileria equi* and *Babesia caballi*. These pathogens have been detected in various parts of the world by molecular techniques [85]. The presentation of piroplasmosis generates a restriction in the international mobilization of horses, preventing their participation in sporting events [3].

6.1 Control of ticks in equines and companion animals

Tick control on dogs in particular is advocated by the use of acaricide-impregnated collars, whereas individual treatment for horses usually consists of synthetic pyrethroid pour-on compounds [3]. Numerous studies have been conducted to evaluate the efficacy of various acaricides such as amitraz, fipronil and permethrin against ticks infesting dogs. While product efficacy is often excellent in most studies, significant variation in efficacy can occur and 100% control is rarely achieved [86]. In recent years, some last-generation acaricides have come on the market, such as the lotilaner, which has been shown to be highly effective (up to 100%) and with excellent residuality for the control of ticks in dogs [87] and cats [88]. However, for best results, it is suggested restricting pet access towards tick infested environments [86].

7. Conclusions

Ticks are important ectoparasites that cause great economic and health losses in production animals, such as cattle, small ruminants, swine and poultry. The feeding habits of ticks cause stress in animals affected by bites, blood losses that can lead to anemia and even death. Animals that are severely affected by ticks, or that do not have immunity against them or the infectious agents they transmit, decline in their capacity to produce meat, milk, eggs or leathers. The economic importance of ticks in equines and companion animals is relatively "minor", but its health impact is very relevant. Different tick control methods have been proposed, and the best approach is always an integral management that considers physical, chemical and biological controls. The present literature review can help professionals and producers to know, in a general way, what are the direct and indirect effects of ticks in animals, as well as the main infectious agents they transmit. It is recommended to deepen in each of the animals and ticks species, according to the needs of the interested people.

Conflict of interest

The authors declare that they have no conflicts of interest that may have inappropriately influenced them in writing this chapter.

Author details

Oscar Jaime Betancur Hurtado[1*] and Cristian Giraldo-Ríos[2]

1 Elanco Animal Health, Bogotá D.C., Colombia

2 Independent Researcher, Santa Rosa de Osos, Colombia

*Address all correspondence to: betancur_oscar_jaime@elanco.com

References

[1] Eskezia B, Desta A. Review on the impact of ticks on livestock health and productivity. Journal of Biology, Agriculture and Healthcare. 2016; **6**(22):1-7

[2] Taylor M, Coop R, Wall R. Veterinary entomology. In: Taylor M, Coop R, Wall R, editors. Veterinary Parasitology. 4th ed. UK: Wiley-Blackwell; 2016. pp. 161-258

[3] Jongejan F, Uilenberg G. The global importance of ticks. Parasitology. 2004; **129**:4S3-S14. DOI: 10.1017/S0031182004005967

[4] Rodríguez R, Ojeda M, Pérez L, Rosado J. Epidemiología y control de *Rhipicephalus* (*Boophilus*) *microplus* en México. In: Quiroz H, Figueroa J, Ibarra F, López M, editors. Epidemiología de enfermedades parasitarias en animales domésticos. México: UNAM; 2011. pp. 477-504

[5] Manzano-Román R, Díaz-Martín V, Pérez-Sánchez R. Garrapatas: Características anatómicas, epidemiológicas y ciclo vital. Detalles de la influencia de las garrapatas sobre la producción y sanidad animal. Sitio Argentino de Producción Animal. 2012: 1–8. Available from: http://www.produccion-animal.com.ar/sanidad_intoxicaciones_metabolicos/parasitarias/Bovinos_garrapatas_tristeza/160-garrapatas.pdf [Accessed: April 15, 2018]

[6] Taylor M, Coop R, Wall R. Facultative ectoparasites and arthropod vectors. In: Taylor M, Coop R, Wall R, editors. Veterinary Parasitology. 4th ed. UK: Wiley-Blackwell; 2016. pp. 921-973

[7] Betancur O, Betancourt A, Giraldo C. Importance of ticks in the transmission of zoonotic agents. Revista MVZ Córdoba. 2015;**20**(Suppl):5053-5067

[8] Demessie Y, Derso S. Tick borne hemoparasitic diseases of ruminants: A review. Advances in Biological Research. 2015;**9**(4):210-224. DOI: 10.5829/idosi.abr.2015.9.4.9516

[9] Benavides E, Romero J, Villamil L. Las garrapatas del ganado bovino y los agentes de enfermedad que transmiten en escenarios epidemiológicos de cambio climático. In: Guía para el manejo de garrapatas y adaptación al cambio climático. San José, Costa Rica: Universidad de la Salle; Instituto Interamericano de Cooperación para la Agricultura (IICA); 2016. p. 93

[10] Regitano L, Prayaga K. Ticks and tick-borne diseases in cattle. In: Bishop S, Axford R, Nicholas F, Owen J, editors. Breeding for Disease Resistance in Farm Animals. 3rd ed. London, UK: CAB International; 2011. pp. 295-314

[11] Rodriguez-Vivas RI, Jonsson NN, Bhushan C. Strategies for the control of *Rhipicephalus microplus* ticks in a world of conventional acaricide and macrocyclic lactone resistance. Parasitology Research. 2018;**117**(1):3-29. DOI: 10.1007/s00436-017-5677-6

[12] Benavides E, Romero N. Consideraciones para el control integral de parásitos externos del ganado. Revista Carta Fedegán. 2001;**70**:64-86

[13] Polanco-Echeverry D, Ríos-Osorio L. Aspectos biológicos y ecológicos de las garrapatas duras. Corpoica Ciencia y Tecnología Agropecuaria. 2016;**17**(1): 81-95

[14] Domínguez D, Torres F, Rosario-Cruz R. Evaluación económica del control de garrapatas *Rhipicephalus microplus* en México. Revista Iberoamericana de las Ciencias Biológicas y Agropecuarias. 2016;**5**(9)

[15] Nejash A, Tilahun B. Epidemiology and control of bovine theileriosis in Ethiopia: Review. Journal of Medicine, Physiology and Biophysics. 2016;**23**: 32-44

[16] García Z. Garrapatas que afectan al ganado bovino y enfermedades que trasmiten en México. 1er Simposium de salud y producción de bovinos de carne en la zona Norte-Centro de México Aguascalientes. 2010. Available from: http://biblioteca.inifap.gob.mx:8080/jspui/bitstream/handle/123456789/3281/Garrapatasqueafectanalganadobovinoyenfermedades.pdf?sequence=1 [Accessed: June 18, 2018]

[17] Abbas RZ, Zaman MA, Colwell DD, Gilleard J, Iqbal Z. Acaricide resistance in cattle ticks and approaches to its management: The state of play. Veterinary Parasitology. 2014;**203**(1–2): 6-20. DOI: 10.1016/j.vetpar.2014.03.006

[18] Kariuki D. Tick-borne diseases of livestock. International Laboratory for Research on Animal Diseases. 1991;**9**:3

[19] Betancourt J. Nueva vacuna para prevención y control de garrapatas en ganado. Períodico El Agro. 2017;**92**:6

[20] Grisi L, Leite RC, Martins JR, Barros AT, Andreotti R, Cancado PH, et al. Reassessment of the potential economic impact of cattle parasites in Brazil. Brazilian Journal of Veterinary Parasitology. 2014;**23**(2):150-156. DOI: 10.1590/S1984-29612014042

[21] Rodríguez-Vivas R, Grisi L, Pérez A, Silva H, Torres-Acosta J, Fragoso H, et al. Potential economic impact assessment for cattle parasites in Mexico. Review. Revista Mexicana de Ciencias Pecuarias. 2017;**8**(1):61-74. DOI: 10.22319/rmcp.v8i1.4305

[22] FAO (Food and Agriculture Organization). Module 1. Ticks: Acaricide resistance: Diagnosis, management and prevention. In: FAO, editor. Guidelines Resistance Management and Integrated Parasite Control in Ruminants. Rome: FAO Animal Production and Health Division; 2004. pp. 25-77. Available from: http://www.fao.org/tempref/docrep/fao/010/ag014e/ag014e05.pdf [Accessed: June 16, 2018]

[23] Jonsson NN. The productivity effects of cattle tick (*Boophilus microplus*) infestation on cattle, with particular reference to *Bos indicus* cattle and their crosses. Veterinary Parasitology. 2006;**137**(1–2):1-10. DOI: 10.1016/j.vetpar.2006.01.010

[24] Rodríguez-Vivas R, Rosado-Aguilar J, Ojeda-Chi M, Pérez-Cogollo L, Trinidad-Martínez I, Bolio-González M. Control integrado de garrapatas en la ganadería bovina. Ecosistemas y Recursos Agropecuarios. 2014;**1**(3): 295-308

[25] Rodrigues D, Leite R. Impacto econômico de *Rhipicephalus* (*Boophilus*) *microplus*: estimativa de redução de produção de leite. Arquivo Brasileiro de Medicina Veterinária e Zootecnia. 2013; **65**(5):1570-1572

[26] Suarez CE, Noh S. Emerging perspectives in the research of bovine babesiosis and anaplasmosis. Veterinary Parasitology. 2011;**180**(1–2):109-125. DOI: 10.1016/j.vetpar.2011.05.032

[27] Bock R, Jackson L, de Vos A, Jorgensen W. Babesiosis of cattle. Parasitology. 2004;**129**(Suppl): S247-S269. DOI: 10.1017/S0031182004005190

[28] Howden KJ, Geale DW, Pare J, Golsteyn-Thomas EJ, Gajadhar AA. An update on bovine anaplasmosis (*Anaplasma marginale*) in Canada. The Canadian Veterinary Journal. 2010; **51**(8):837-840

[29] Aubry P, Geale DW. A review of bovine anaplasmosis. Transboundary and Emerging Diseases. 2011;**58**(1):1-30. DOI: 10.1111/j.1865-1682.2010.01173.x

[30] OIE (World Organisation for Animal Health). Anaplasmosis bovina. In: OIE, editor. Manual de las pruebas de diagnóstico y vacunas para los animales terrestres. París: Francia; 2015. pp. 1-16. Available from: http://www.oie.int/fileadmin/Home/esp/Health_standards/tahm/2.04.01_Anaplasmosis_bovina.pdf [Accessed: May 13, 2018]

[31] Živković Z. Tick-pathogen interactions in bovine anaplasmosis [doctoral thesis]. Atalanta Drukwerkbemiddeling, Houten. Nederlands: Universiteit Utrecht; 2010. Available from: https://dspace.library.uu.nl/bitstream/1874/40493/2/zivkovic.pdf [Accessed: April 19, 2018]

[32] Kocan KM, de la Fuente J, Blouin EF, Garcia-Garcia JC. *Anaplasma marginale* (Rickettsiales: Anaplasmataceae): Recent advances in defining host-pathogen adaptations of a tick-borne rickettsia. Parasitology. 2004;**129**(Suppl):S285-S300. DOI: 10.1017/S0031182003004700

[33] Kocan K, de la Fuente J, Step D, Blouin E, Coetzee J, Simpson K, et al. Current challenges of the management and epidemiology of bovine anaplasmosis. The Bovine Practitioner. 2010;**44**(2):93-102

[34] Abdela N, Bekele T. Bovine theileriosis and its control: A review. Advances in Biological Research. 2016; **10**(4):200-212. DOI: 10.5829/idosi.abr.2016.10.4.103107

[35] Ayadi O, Gharbi M, Elfegoun M. Milk losses due to bovine tropical theileriosis (*Theileria annulata* infection) in Algeria. Asian Pacific Journal of Tropical Biomedicine. 2016; **6**(9):801-802. DOI: 10.1016/j.apjtb.2016.06.014

[36] Ugurlu S. Insecticide resistance. In: Perveen F, editor. Insecticides—Advances in Integrated Pest Management. Rijeka, Croatia: InTech; 2012. pp. 469-478. DOI: 10.5772/28086

[37] Couto M, Gonçalves G, Marino P. Eficácia do controle químico de carrapatos *Rhipicephalus* (*Boophilus*) *microplus* em bovinos leiteiros com uso de fluazuron: relato de caso. Revista Uningá. 2017;**53**(2):113-115

[38] Rodríguez-Durán A. Control estratégico de garrapatas en el ganado bovino: énfasis departamento de Arauca. In: Salamanca A, editor. Avances de investigación en medicina veterinaria y producción animal. Bogotá, Colombia: Universidad Cooperativa de Colombia; 2016. pp. 195-197

[39] Betancur O. Insecticide resistance management: A long term strategy to ensure effective pest control in the future. Journal of Animal Science and Research. 2018;**2**(1). DOI: 10.16966/2576-6457.111

[40] Benavides E, Jiménez P, Betancur O, Vélez G, Polanco N, Morales J. Effect of the use of fluazuron for control of *Rhipicephalus* (*Boophilus*) *microplus* in cattle. Revista MVZ Córdoba. 2017;**22** (Suppl):6050-6061. DOI: 10.21897/rmvz.1075

[41] George JE, Pound JM, Davey RB. Chemical control of ticks on cattle and the resistance of these parasites to acaricides. Parasitology. 2004;**129** (Suppl):S353-S366. DOI: 10.1017/S0031182003004682

[42] Puerta JM, Chaparro JJ, Lopez-Arias A, Arroyave SA, Villar D. Loss of *in vitro* efficacy of topical commercial acaricides on *Rhipicephalus microplus* (Ixodida: *Ixodidae*) from Antioquian farms. Colombia. Journal of Medical Entomology. 2015;**52**(6):1309-1314. DOI: 10.1093/jme/tjv129

[43] Sahito H, Sanjrani S, Arain M, Ujjan N, Soomro H. Biological control of animal ticks by poultry birds through IPM techniques. Research Journal of Agricultural and Environmental Management. 2013;**2**(10):289-294

[44] Habela M, Fruto JM, Moreno A, Gragera-Slikker A. Infestación por garrapatas. Repercuciones y planes de lucha y control en las explotaciones de pequeños rumiantes. Mundo Ganadero. 2003;**156**:44-50

[45] Gnad DP, Mock DE. Ectoparasite control in small ruminants. The veterinary clinics of North America food animal. Practice. 2001;**17**(2):245-263

[46] Kusiluka L, Kambarage D. Diseases caused by arthropods. In: Kusiluka L, Kambarage D, editors. Diseases of Small Ruminants: A Handbook; Common Diseases of Sheep and Goats in Sub-Saharan Africa. Scotland: VETAID; 1996. pp. 102-108

[47] Mohammed K, Admasu P. Prevalence of Ixodid ticks in small ruminants in selected districts of Fafen zone, Eastern Ethiopia. European Journal of Applied Sciences. 2015;**7**(2): 50-55. DOI: 10.5829/idosi.ejas.2015.7.2.9471

[48] Bilgic HB, Bakirci S, Kose O, Unlu AH, Hacilarlioglu S, Eren H, et al. Prevalence of tick-borne haemoparasites in small ruminants in Turkey and diagnostic sensitivity of single-PCR and RLB. Parasites & Vectors. 2017;**10**(1):211. DOI: 10.1186/s13071-017-2151-3

[49] Yin H, Luo J. Ticks of small ruminants in China. Parasitology Research. 2007;**101**(Supp. 2):S187-S189. DOI: 10.1007/s00436-007-0688-3

[50] Alessandra T, Santo C. Tick-borne diseases in sheep and goats: Clinical and diagnostic aspects. Small Ruminant Research. 2012;**106S**:S6-S11. DOI: 106S: S6–S11. 10.1016/j.smallrumres.2012.04.026

[51] Lira-Amaya J, Ojeda-Robertos N, Álvarez-Martínez J, Rojas-Martínez C, Bautista-Garfias C, Figueroa-Millán J. Identificación de garrapatas en una explotación de ovinos. Entomología Mexicana. 2015;**2**:721-726

[52] Aouadi A, Leulmi H, Boucheikhchoukh M, Benakhla A, Raoult D, Parola P. Molecular evidence of tick-borne hemoprotozoan-parasites (*Theileria ovis* and *Babesia ovis*) and bacteria in ticks and blood from small ruminants in Northern Algeria. Comparative Immunology, Microbiology and Infectious Diseases. 2017;**50**:34-39. DOI: 10.1016/j.cimid.2016.11.008

[53] Yin H, Luo J, Guan G, Gao Y, Lu B, Zhang Q, et al. Transmission of an unidentified *Theileria* species to small ruminants by *Haemaphysalis qinghaiensis* ticks collected in the field. Parasitology Research. 2002;**88**(Supp. 1):S25-S27. DOI: 10.1007/s00436-001-0565-4

[54] Faburay B, Jongejan F, Taoufik A, Ceesay A, Geysen D. Genetic diversity of *Ehrlichia ruminantium* in *Amblyomma variegatum* ticks and small ruminants in The Gambia determined by restriction fragment profile analysis. Veterinary Microbiology. 2008;**126**(1–3):189-199. DOI: 10.1016/j.vetmic.2007.06.010

[55] Greve J, Davies P. External parasites. In: Zimmerman J, Karriker L, Ramirez A, Schwartz K, Stevenson G, editors. Diseases of Swine. 10th ed. UK: John Wiley & Sons, Inc; 2012. pp. 885-894

[56] Bernard J, Hutet E, Paboeuf F, Randriamparany T, Holzmuller P, Lancelot R, et al. Effect of *O. porcinus* tick salivary gland extract on the African swine fever virus infection in domestic pig. PLoS One. 2016;**11**(2):

e0147869. DOI: 10.1371/journal.pone.0147869

[57] Brown V, Bevins S. A review of African swine fever and the potential for introduction into the United States and the possibility of subsequent establishment in feral swine and native ticks. Frontiers in Veterinary Science. 2018;**5**(11). DOI: 10.3389/fvets.2018.00011

[58] Beltrán-Alcrudo D, Arias M, Gallardo C, Kramer S, Penrith M. African swine fever: Detection and diagnosis—A manual for veterinarians. FAO Animal Production and Health Manual No. 19. Rome: Food and Agriculture Organization of the United Nations (FAO); 2017. Available from: http://www.fao.org/3/a-i7228e.pdf [Accessed: May 11, 2018]

[59] Chenais E, Boqvist S, Emanuelson U, von Bromssen C, Ouma E, Aliro T, et al. Quantitative assessment of social and economic impact of African swine fever outbreaks in northern Uganda. Preventive Veterinary Medicine. 2017; **144**:134-148. DOI: 10.1016/j.prevetmed.2017.06.002

[60] Burrage TG. African swine fever virus infection in *Ornithodoros* ticks. Virus Research. 2013;**173**(1):131-139. DOI: 10.1016/j.virusres.2012.10.010

[61] Sanchez-Cordon PJ, Montoya M, Reis AL, Dixon LK. African swine fever: A re-emerging viral disease threatening the global pig industry. Veterinary Journal. 2018;**233**:41-48. DOI: 10.1016/j.tvjl.2017.12.025

[62] Halasa T, Botner A, Mortensen S, Christensen H, Toft N, Boklund A. Simulating the epidemiological and economic effects of an African swine fever epidemic in industrialized swine populations. Veterinary Microbiology. 2016;**193**:7-16. DOI: 10.1016/j.vetmic.2016.08.004

[63] Fasina FO, Lazarus DD, Spencer BT, Makinde AA, Bastos AD. Cost implications of African swine fever in smallholder farrow-to-finish units: Economic benefits of disease prevention through biosecurity. Transboundary and Emerging Diseases. 2012;**59**(3): 244-255. DOI: 10.1111/j.1865-1682.2011.01261.x

[64] Rodríguez E. Tularemia, brote nuevo en Castilla y León en 2007. Profesión Veterinaria. 2007;**16**(67): 74-86

[65] Al Dahouk S, Nockler K, Tomaso H, Splettstoesser WD, Jungersen G, Riber U, et al. Seroprevalence of brucellosis, tularemia, and yersiniosis in wild boars (Sus scrofa) from North-Eastern Germany. Journal of Veterinary Medicine B, Infectious Diseases and Veterinary Public Health. 2005;**52**(10): 444-455. DOI: 10.1111/j.1439-0450.2005.00898.x

[66] Hartin R, Ryan M, Campbell T. Distribution and disease prevalence of feral hogs in Missouri. Human–Wildlife Conflicts. 2007;**1**(2):186-191

[67] Yang H, Dey S, Buchanan R, Biswas D. Pests in poultry, poultry product-borne infection and future precautions. In: Bhat R, Gómez-López V, editors. Practical Food Safety: Contemporary Issues and Future Directions. 1st ed. UK: John Wiley & Sons, Ltd; 2014. pp. 535-552. DOI: 10.1002/9781118474563.ch26

[68] Hinkle N, Corrigan R. External parasites and poultry pests. In: Swayne D, editor. Diseases of Poultry. 13th ed. UK: John Wiley & Sons, Inc; 2013. pp. 1099-1116. DOI: 10.1002/9781119421481.ch26

[69] Aslam B, Hussain I, Zahoor M, Mahmood M, Rasool M. Prevalence of *Borrelia anserina* in *Argas* ticks. Pakistan Journal of Zoology. 2015;**47**(4): 1125-1131

[70] Trees A. Parasitic diseases. In: Pattison M, McMullin P, Bradbury J, Alexander D, editors. Poultry Diseases. 6th ed. China: Elsevier Limited; 2008. pp. 444-467. DOI: 10.1016/B978-0-7020-2862-5.50044-1

[71] Mallesh P, Kumar M, Murthy G, Lakshman M. Occurrence of *Argas persicus* infestation in poultry farms in and around Hyderabad, Telangana. The Pharma Innovation Journal. 2018;**7**(4): 118-120

[72] Shah A, Khan M, Iqbal Z, Sajid M. Tick infestation in poultry. International Journal of Agriculture & Biology. 2004; **6**(6):1162-1165

[73] Rosenstein M. Paralysis in chickens caused by larvae of the poultry tick, *Argas persicus*. Avian Diseases. 1976; **20**(2):407-409. DOI: 10.2307/1589281

[74] Hobbenaghi R, Tavassoli M, Alimehr M, Nasiri S, Pashaie B. Pathological study of experimentally induced tick bitten (*Argas persicus*) in poultry skin. Iranian Journal of Veterinary Science and Technology. 2015;**7**(2):1-8. DOI: 10.22067/veterinary.v7i2.36208

[75] Khan M, Khan L, Mahmood S, Qudoos A. *Argas persicus* infestation: Prevalence and economic significance in poultry. Pakistan Journal of Agricultural Sciences. 2001;**38**(3–4):32-34

[76] Shah A, Khan M, Iqbal Z, Sajid M, Akhtar M. Some epidemiological aspects and vector role of tick infestation on layers in the Faisalabad district (Pakistan). World's. Poultry Science Journal. 2006;**62**:145-157. DOI: 10.1079/WPS200591

[77] Buriro S. Experimental inoculation of bacterial isolates obtained from *Argas* (*Persicargas*) *persicus* in poultry. Zeitschrift Fur Angewandte Entomologie. 1980;**89**:324-330. DOI: 10.1111/j.1439-0418.1980.tb03474.x

[78] Petney TN, Andrews RH, McDiarmid LA, Dixon BR. *Argas persicus* sensu stricto does occur in Australia. Parasitology Research. 2004;**93**(4): 296-299. DOI: 10.1007/s00436-004-1141-5

[79] Stefanov V, Matev I, Balimezov I. Role of ticks of the species *Argas persicus* Oken, 1818, in the epizootiology of pullorum disease in birds. Veterinarno-Meditsinski Nauki. 1975;**12**(5):45-50

[80] Glukhov V. Transmission of *Salmonella* gallinarum-pullorum by the tick *Argas persicus*. Veterinariya. 1970;**9** (Abstract):60-61

[81] Wales AD, Carrique-Mas JJ, Rankin M, Bell B, Thind BB, Davies RH. Review of the carriage of zoonotic bacteria by arthropods, with special reference to *Salmonella* in mites, flies and litter beetles. Zoonoses and Public Health. 2010;**57**(5):299-314. DOI: 10.1111/j.1863-2378.2008.01222.x

[82] El Nasri I, Shigidi M, Mohammed A. Pathology of domestic fowl spirochaetosis in different age groups of chicken experimentally infected with *Borrelia anserina*. The Sudan Journal of Veterinary Research. 2010;**25**:23-28

[83] El Nasri I. Studies on fowl spirochetosis in Khartoum state [doctoral thesis]. Sudan: University of Khartoum; 2008. Available from: https://core.ac.uk/download/pdf/71670766.pdf [Accessed: April 22, 2018]

[84] Rees C. Disorders of the skin. In: Reed S, Bayly W, Sellon D, editors. Equine Internal Medicine. 2nd ed. USA: Elsevier; 2004. pp. 667-720

[85] Agudelo-Ruíz Y, Acevedo-Gutiérrez L, Montoya-Sanchéz A, Paternina L, Rodas J. Molecular identification of tick-borne hemoparasites in equines from northwestern Colombia. Revista MVZ Córdoba. 2017;**22**(Suppl):6004-6013. DOI: 10.21897/rmvz.1070

[86] Dryden MW. Flea and tick control in the 21st century: Challenges and opportunities. Veterinary Dermatology. 2009;**20**(5–6):435-440. DOI: 10.1111/j.1365-3164.2009.00838.x

[87] Cavalleri D, Murphy M, Seewald W, Drake J, Nanchen S. A randomized, controlled study to assess the efficacy and safety of lotilaner (Credelio) in controlling ticks in client-owned dogs in Europe. Parasites & Vectors. 2017;**10**(1):531. DOI: 10.1186/s13071-017-2478-9

[88] Cavalleri D, Murphy M, Seewald W, Drake J, Nanchen S. Laboratory evaluation of the efficacy and speed of kill of lotilaner (Credelio(TM)) against Ixodes ricinus ticks on cats. Parasites & Vectors. 2018;**11**(1):413. DOI: 10.1186/s13071-018-2968-4