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A Comprehensive Review on the Common Emerging Diseases in Quails

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ABSTRACT

The poultry industry is considered an important sector that meets the great demand for protein sources all over the world. Now, quails are recognized as promising and important alternative species with many advantages over other poultry species. In many countries around the world, quail meat has achieved great popularity as a good source of protein and other important nutrients. However, there are some limitations and challenges to quails production. One of them is the susceptibility to some viral, bacterial, mycotic and parasitic diseases that can adversely affect quails. Many of the diseases that affect quails cause severe economic losses in quail industry due to a decrease in growth performance, poor feed conversion, reduction in hatchability, increased mortality and treatment costs. There are limited research and literature dealing with different disease and conditions affecting quails. Therefore, the aim of this work was to present a comprehensive review of the most important emerging diseases affecting quails worldwide.

Key words: Bacteria, Virus, Mycosis, Myctoxicosis, Parasites, Quail

INTRODUCTION

The term quail refers to medium-sized birds belonging to various genera of family Phasianidae. There are two important species, the Japanese quails (*Coturnix japonica*) and Bobwhites quails (*Colinus virginianus*) which considered domestic birds since 14th century (Arya et al., 2018).

In recent years, the quail industry has created a huge impact and has been widely distributed in several countries around the world (Murakami, 1991; Redoy et al., 2017). Quails production is more profitable because it requires less investment to start and provides quick returns with a higher cost-benefit ratio. Quail farming is gaining popularity because quails are easy to manage and small in size thus they can be raised within small floor space (Ruskin, 1991; Edris et al., 2004). Moreover, less feed requirements, rapid growth rate, palatable meat, high egg production, high nutritional value of meat and egg, early sexual maturity, short generation interval (3-4 generations per year) and short incubation period are other benefits of quail rearing (Hassan et al., 2017; Yambayamba and Chileshe, 2019).

The advancement in quail production is being hampered by some management factors, infectious and non-infectious diseases (Barnes and Gross, 1997). Infectious diseases are common in quails reared under intensive production system (Paulillo, 1989). As quails are related to poultry, several diseases affecting quails are similar to those in chickens and turkeys (Myint and Carter, 1988).

Accordingly, this review highlighted the most important viral, bacterial, mycotic and parasitic diseases as well as mycotoxicosis affecting quails species worldwide.

Viral diseases

Adenovirus

In Bobwhite quails, adenovirus induced acute respiratory contagious infection called quail bronchitis (Olsen, 1950; DuBose et al., 1958). This disease is more severe in young quails less than 3-week-old and leads to 100% morbidity and 50% mortality (Jack and Reed, 1990). Quail bronchitis virus was recently isolated from 5-day to 8-week old Bobwhite quails raised in Minnesota, USA.

The birds showed respiratory manifestations and high mortality, also histopathological findings included mucus in trachea, congested lungs, caseous airsacculitis, enlarged spleen, urates on internal organs, and necrotic foci on the liver (Singh et al., 2016).

Inclusion Body Hepatitis (IBH), caused by avian adenovirus-1, occurs in Bobwhite quails less than 3-week-old (Jack et al., 1987). However, the outbreak of IBH has been described in adult Japanese quail (Grewal et al., 1994). In a study by Singh et al. (1995), Japanese quails more than 4-week-old inoculated intraperitoneally with IBH adenovirus and showed congested pneumonic lungs, swollen mottled liver and necrotic kidney with intranuclear inclusion bodies. In addition, quail strains of IBH virus were pathogenic for broiler chickens after experimental inoculation.

Egg Drop Syndrome-76 (EDS-76), caused by avian adenovirus-3, was isolated from natural outbreaks in Japanese quail and the virus was serologically indistinguishable from that of chicken (Dash and Pradhan, 1990; Kataria et al., 1991; Dash and Pradhan, 1992). In a large study, the EDS-76 virus caused histopathological changes in the genitalia and spleen, decreased egg quantity and egg quality, increased virus antibody titers and total protein levels in laying Japanese quails (Mohapatra et al., 2014).

Experimental infection of 12-day-old quails with Chicken Embryo Lethal Orphan (CELO) virus and Avian Adeno-Associated Virus (AAAV) significantly increased CELO virus-produced mortality while double infections with high doses of AAAV induced a delay in mortality (Bagshaw et al., 1980).

The adenoviral inclusions were detected in the intestinal epithelia and glandular epithelium of gizzard and conjunctiva in less than 3-week-old quails with depression, ruffled feathers, diarrhea and high mortality (Tsai et al., 1998). Moreover, adenovirus inclusion bodies were observed in the proventriculus of Bobwhite quails and chickens. In wild Bobwhite quails with hepatic inclusion bodies, adenovirus serotype TR-59 was identified in their caeca (King et al., 1981).

Good management practice and biosecurity measures are very important to prevent adenovirus infections. There is no treatment for adenovirus infection. Water treatment with minerals and vitamins is critical to increase quail immunity (Singh et al., 2016).

Avian influenza

Avian Influenza Virus (AIV) was first recorded in Italy in Japanese quail under 3 months of age with respiratory manifestations and high mortalities (Nardelli et al., 1970). In several countries, many subtypes of AIV outbreaks have been detected in quail flocks (Guo et al., 2000; Wee et al., 2006; Lee et al., 2008; Yee et al., 2011; Arya et al., 2018). Japanese quail is considered a vehicle for adaptation of AIV strains in wild birds which is a means to generate new variant strains able to cross species barrier and infect different poultry species and possibly human (Perez et al., 2003; Wan and Perez, 2006; Wang et al., 2008). Chicken and quails were found to be highly susceptible to infection Highly Pathogenic (HP) AIV H5N1; while ducks have higher resistance and served as carriers (Hulse-Post et al., 2005; Tiensin et al., 2005). Moreover, HPAIV H5N1 strains isolated from geese were capable of causing disease in quails, with a longer period of virus shedding than that in chickens (Webster et al., 2002; Jeong et al., 2009; Saito et al., 2009). However, it was found that Japanese quails are resistant to HPAIV H5N3, which is pathogenic for turkeys, thus they could transmit this lethal virus to chickens (Tashiro et al., 1987). A study conducted in Korea revealed that chickens, ducks, and quails experimentally infected with HPAIV H5N1 had various symptoms, mortality, viral titers, and virus shedding. The mentioned study suggested that duck and quail farms should be regularly monitored to prevent virus transmission to another host (Jeong et al., 2009). European quails experimentally infected with HPAIV H7N1 and H5N1 showed severe nervous manifestations with histopathological changes and mortality rates of 67% and 92% in H7N1 and H5N1 challenged birds, respectively. While birds challenged with Low Pathogenic (LP) AIV H7N2 showed no clinical or pathological conditions. However, viral shedding and transmission to naive quail were observed for all types of AIV and drinking water and feathers were possible routes of HPAIV transmission (Bertran et al., 2013). In Egypt, a study on quails detected maternal antibodies against AIV and also evaluated immune responses to inactivated AI vaccines containing H5N1 and H5N2 viruses. The results revealed high to moderate levels of maternal immunity on the first and fifth days of age and low levels on the seventh day. In addition, vaccination at 8-day-old quails induced satisfactory titers at third week of post-vaccination, while the highest titers were detected at fourth and fifth weeks after vaccination (Saad et al., 2010). Moreover, H5N8 strain was detected in only one domestic Egyptian quail farm and it was also isolated from 2 out of 3 wild quail samples (Shehata et al., 2019). Outbreaks of AIV H9N2 revealed stable lineages in chickens and other poultry species such as quails (Naeem et al., 1999). In Hong Kong, 16% of quails in markets were found to be positive for H9N2 viruses (Guan et al., 2000). The amino acid patterns of hemagglutinin of AIV H9 in quails were found to be intermediate between those in duck and in chicken, which explains the susceptibility of quail to duck AIV H9 (Perez et al., 2003). AIV could be detected using indirect immunofluorescent assay in the muscles and internal organs of quails, chickens, and ducks (Antarasena et al., 2006). Prevention of avian influenza in quails mainly occurs through vaccination combined with implementing biosecurity measures by thorough cleaning and disinfecting and restricting the personal movements on the farm. In a study conducted in China, the protective efficacy of inactivated H5N1 (clade 1) influenza vaccine (NIBRG-14) before challenge with heterologous A/Swan/Nagybaracska/01/06 (H5N1 clade 2.2) strain was tested in quails; the results revealed protection of challenged birds and absence of the virus in cloacal swabs, but immunized birds had low antibody titers (Sarkadi et al., 2013). In Indonesia, it was found that vaccination of brown quails with inactivated bivalent H5N1 clades 2.1.3 and 2.3.2 at ages 24 and 45 days induced significant protection, although the virus shedding continued 7 days post-vaccination (Indriani and Dharmayanti, 2016).

Newcastle disease

The pathogenicity of Newcastle Disease Virus (NDV) in quails depends on the virus strain, dose, and route of administration (Oladele et al., 2008). Quails are considered a susceptible host for NDV and have a non-negligible role in transmission of the virus to chickens. Therefore, quails should be vaccinated against the virus to protect them and prevent transmission to chickens (Sharawi et al., 2015). In Northern India, an outbreak of ND was recorded in Japanese quail aged 22-week-old with central nervous system manifestations, 30% mortality, and 20% morbidity. (Gowthaman et al., 2013). In Iran, loss of appetite, decreased egg production, diarrhea, and nervous symptoms were recorded in quails infected with NDV (Shoushtari et al., 2007). There are several reports on outbreaks of ND in Japanese quail flocks (Kaleta and Baldauf, 1988; Chandrasekaran and Aziz, 1989; Islam et al., 1994). Islam et al. (2016) found that NDV had the highest prevalence rate (11.35%) among the isolated viral diseases (25.21%) from 476 quails in Bangladesh. The experimental infection of quails with NDV revealed that oculo-nasal inoculation of 17-week-old Japanese quails with a velogenic NDV strain resulted in no morbidity or mortality, although broilers chickens that were in contact with infected birds showed clinical signs of ND with 100% mortality. These findings suggest that quails can be NDV carriers (Lima et al., 2004). Inoculation of velogenic strain of NDV in 3-6-week old Japanese quail induced different mortality rates according to route of inoculation, as follows: 13% (Usman et al., 2008) and 100% (Mohamed and Abdel Hafez, 2016) using oculo-nasal route, 25% using intracoelomic route (El-Tarabili et al., 2009), 3% (Oladele et al., 2008) and 40% (Sharawi et al., 2015) using intramuscular. Recently, in a study by Susta et al. (2018), 2-week-old Japanese quails were inoculated through the oculo-nasal route with 4 virulent NDV strains of different genotypes. The results indicated mild to moderate disease with mortality rate ranged from 28% to less than 10%, neurological signs with suppurative encephalitis. In addition, the virus replication was moderate in inoculated birds, but minimal in contact birds. Moreover, inoculated birds with NDV strains originated from quails showed high virus shedding, while high virus transmission occurred in birds inoculated with virus originated from chicken. Mazlan et al. (2017) proved susceptibility of Japanese quail to experimental infection with genotype VII NDV based on the development of specific clinical signs, detection of the virus antigen in the tissues and increase in the titers of haemagglutinating antibodies. The immune response to NDV vaccines in different lines of Japanese quail was studied and the results showed that double vaccination at 4 and 6 weeks of age with inactivated vaccine induced high antibody level in the high line breed that was 24% greater than control one, but in the low line, the antibody level was 37% less than that in the control (Takahashi et al., 1984). Vaccination using both living vaccines like La Sota or Hitchner B1 and inactivated vaccines is very important for efficient eradication of NDV in quails (Lima et al., 2004 and Paulillo et al., 2009).

Poxvirus

Although avian pox has been reported in a wide variety of domestic and wild birds (Bolte et al., 1999), the infection is not common in quails (Rinaldi et al., 1972; Crawford et al., 1979; Davidson et al., 1980; Poonacha and Wilson, 1981). Diphtheritic form of avian pox virus in the respiratory tract was found to induce significant mortality (Tripathy and Reed, 1997). Quail pox virus is a distinct species of the genus *Avipoxviridae*, and the virus had no immunologic relationship to pigeon and fowl poxviruses. Moreover, in areas where poultry is reared in close proximity to quails, cross-infection is possible (Winterfield and Reed, 1985; Ghildyal et al., 1989). Dry pox in quails causes lesions with a gray to yellow or dark brown discoloration and single or multiple nodules with crusts in variable sizes on the comb, eyelids, and the other poorly feathered areas of the body (Singh et al., 1992; Gülbahar et al., 2005). Vaccination of quails is necessary for endemic areas. Quail pox can affect chickens. Fowlpox and pigeon pox vaccines could be considered good vaccines to control poxvirus infection in quails (Promkuntod et al., 2003).

Tumors

There are few reports on naturally occurring lymphoproliferative disease or Marek's Disease (MD) in Japanese quails. The MD Virus (MDV) is a causative agent of spontaneous tumor disease in quails (Pradhan et al., 1985; Adedeji et al., 2019) and can be transmitted to chickens by contact exposure (Kenzy and Cho, 1969). A study found a positive association between the incidence of lymphomatous changes and the presence of MDV-specific antigen on a quail flock (Kobayushi and Mikami, 1986). It has been reported that JM strain of MDV could be isolated by cell culture from quails at 7-8 days post-inoculation. (Khare et al., 1975), however, the same strain was not recovered from quail by direct culture of kidney tissue (Mikami et al., 1975). Quails inoculated with HPRS-16 strain of MDV showed lower viremia than that of chickens inoculated with the same strain (Powell and Rennie, 1984). Quails could be experimentally infected with MDV of chicken origin (Dutton et al., 1973; Fujimoto et al., 1975). The MDV was detected in natural lymphoproliferative outbreaks in eight flocks of Japanese quails. (Imai et al., 1990). Avian Leukosis Virus (ALV) could induce tumors in Japanese quails (Wight, 1963) and quails with lymphoproliferative disease had antibodies against ALV subgroup A (Schat et al., 1976). Recently, it was observed that intraperitoneal inoculation of quails with ALV subgroup A induced transient viremia, intermittent cloacal shedding and mild lesions in infected quails (Zhang et al., 2019). Quails are susceptible to experimental infection with reticuloendotheliosis virus (Theilen et al., 1966). A malignant tumor resembling reticuloendotheliosis was reported under natural conditions in quails (Carlson et al., 1974; Schat et al., 1976). In Japanese quail, avian myeloblastosis virus was able to produce a wide spectrum of neoplasms similar to that observed in chickens; however, contrary to what is observed in chickens, acute myeloblastic leukemia was not found in Japanese quail (Moscovici and Macintyre, 1966). Genetic selection of tumors-resistant breeds is very important to prevent tumor development in quails.

Bacterial diseases

Salmonellosis

Today, avian salmonellosis is still a major problem facing quail production and needs to be solved. Many reports demonstrated the isolation of different *Salmonella* spp. from quails (Erdogrul et al., 2002; Takata et al., 2003; Aarestrup et al., 2005). Sander et al. (2001) and Bacci et al. (2012) isolated *Salmonella enterica* in quail's carcasses. The frequency of salmonellosis in young quails of two flocks in Bangladesh was 6.73% and 11.97% (Islam et al., 2003, 2016). Al-Nakhli (2005) isolated different types of *Salmonella* spp. causing paratyphoid infection among Japanese quails in Saudi Arabia. In Brazilian quail flocks, Freitas et al. (2013) identified *S. enterica* subspecies Enterica; *S. Corvalis, S. Give, S. Lexington, S. Minnesota, S. Schwarzengrund, S. Rissen,* and *S. Typhimurium* from meconium samples of one-day-old quail chicks. In addition, *Salmonella* spp. were isolated from cloacal swabs of Kelantan quails in Malaysia (Palanisamy and Bamaiyi, 2015). Udhayavel et al. (2016) confirmed the identification of *S. enterica* from heart blood swabs, liver and spleen samples collected from 8-day-old Japanese quails in India. Recently, in Nigeria, a total of 19 out of 200 quail's eggs swabs were identified as *Salmonella* spp. (Mera et al., 2017). Moreover, it was found that 10 out of 75 (13.33%) quail samples from three farms in Bangladesh were positive for *Salmonella* spp. of which seven isolates were motile *Salmonella* (Jahan et al., 2018). Barde (2014) demonstrated that *S. Gallinarum* in Japanese quails causes septicemic disease with distribution of the organism in major organs, greenish-yellow diarrhea, high mortality, marked drop in egg production and congestion with enlargement of internal organs, which is similar to that in chickens. Hamed and Hassan (2013) proved that water supplementation with acetic acids, organic acids mixture, and hydrochloric acid reduced *S.* Enteritidis colonization in the gut and internal organs as well as inducing high protection from morbidity and mortality in quails. Nowadays, *in-ovo* inoculation of antibiotics is considered a new trend to prevent the possibility of bacterial pathogen transmission through eggs (Tavakkoli and Gooshki, 2014). In a study by Jahan et al. (2018), the *in-vitro* antibiotic sensitivity test of *Salmonella* strains isolated from quails showed that 100% of strains were resistant to erythromycin and tetracycline, but were sensitive to ciprofloxacin and imipenem, 90% of strains were resistant to colistin sulfate and 80% were sensitive to neomycin. Also, all *Salmonella* isolates showed multidrug resistance.

Colibacillosis

Septicemic colibacillosis caused by *Escherichia coli* (*E. coli*) is an infectious avian disease that has been commonly reported in chicken, turkeys, ducks, and quails (Da Silva et al., 1989). Infection with *E. coli* was associated with several diseases including yolk sac infection, septicemia, airsacculitis, peritonitis, polyserositis, omphalitis, cellulitis, coligranuloma and enteritis (Barnes and Gross, 1997; Dho-Moulin and Fairbrother, 1999). Arenas et al. (1999) isolated *E. coli* serogroup O165 from the internal organs of 4-6 day old Japanese quails with 90% mortality rate. The *E. coli* infection caused hepatitis and pericarditis in Japanese quails at 21 days and 11 months of age (Ito et al., 1990), and coligranulomatosis in common quails at the ages of 8-12 months (Da Silva et al., 1989). In Bobwhite quails, *E. coli* was isolated from specimens of liver, spleen, and intestine (Radi, 2004). Roy et al. (2006) isolated *E. coli* serogroups such as O4, O9, O38, O42, and O88 from diseased Japanese quail, dead-in-shell embryos, fluff samples, footbath and drinking water samples in a hatchery. The *E. coli* isolates cultured from infected Japanese quails belonged mainly to serogroup O9 (54.5%) and the same serotype was also predominant in the hatchery environment (Roy et al., 2006). The capability of *E. coli* serogroup O2 to produce dose-dependent cellulitis, pericarditis, perihepatitis, and septicemia in quails was recorded (Burns et al., 2003; Nain and Smits, 2011). In Iraq, 37 out of 203 (18.2%) bacterial isolates obtained from liver, lung, gizzard, and intestine of 30 healthy quails identified as *E. coli* (Hamad et al., 2012). In India, 32 out of 154 *E. coli* isolates (20.77%) were detected in different organs of quail birds (Manickam et al., 2017). However, in Nigeria, 21 out of 200 eggs swabs identified as *E. coli*, of which 11/21 (52.4%) were from eggshell swabs and 13/21 (61.9%) were from internal egg contents (Mera et al., 2017). In Bangladesh, the prevalence rate of colibacillosis in quails was 15.34%, which was the highest rate among bacterial disease (Islam et al., 2016). The isolation rate of *E. coli* among Japanese quail of Sylhet and Narsingdi region in Bangladesh was 5.17% and 5.7%, respectively (Islam et al., 2003; Uddin et al., 2010). Antibiotic sensitivity tests should be used to select the suitable specific antimicrobials for the treatment of specific *E. coli* serotypes.

Clostridial infection

Clostridial enteritis is a common problem in avian species (Ficken and Wage, 1997; Prescott, 2016). Ulcerative enteritis caused by *Clostridium colinum* (*C. colinum*) was recorded as an epidemic disease in Bobwhite quails (Berkhoff, 1975 and Cooper et al., 2013). Some outbreaks of highly contagious ulcerative enteritis have been described (Berkhoff and Kanitz, 1976; Berkhoff, 1985). Radi (2004) isolated *C. perfringens* from the intestine of Bobwhite quail with a history of anorexia, diarrhea, dehydration, weight loss, and acute death. In addition, ulceration and perforation of intestine, peritonitis, and multifocal necrotizing hepatitis were observed in histopathological examination. The detection limit of *C. colinum* in quails was $1.6X10^4$ colony forming units/g feces (Bano et al., 2008). Ulcerative enteritis-like disease due to *C. perfringens* type A was attributed as the cause of mortality in 10 to 16-week-old Bobwhite quails (Shivaprasad et al., 2008). Also, *C. sordellii* was associated with ulcerative enteritis in quails (Crespo et al., 2013). Penicillin-streptomycin was the most effective prophylactic and streptomycin was the most effective therapeutic agent for ulcerative enteritis in Bobwhite quail (Brown et al., 1970). Five days water treatment with tylosin was effective in controlling ulcerative enteritis in Bobwhite quails (Jones et al., 1976). Beltran-Alcrudo et al. (2008) described an outbreak of ulcerative enteritis caused by *C. colinum*, *C. perfringens* and *Eimeria* spp. in Bobwhite quail farm and found that combined treatment with an anticoccidial drug and tylosin was effective in controlling clinical disease. The addition of bacitracin (50 g/ton feed) is recommended as a preventative measure against the disease in quails. Adoption of hygienic measures such as wearing disposable shoes and gloves is very crucial to prevent spread of infection (Cooper et al., 2013).

Pasteurellosis

Pasteurellosis or Fowl Cholera (FC) in quails was first reported by Hinshaw and Emlen (1943) in captive California Valley quail (*Lophortyx caflfornicus*). Later on, the disease was described in different species of quails with a high mortality rate (13%) (Myint and Carter, 1988). *Pasteurella multocida* (*P. multocida*) serotype A:3 causing acute FC with high mortality was first reported in commercially raised Bobwhite quail in America (Panigrahy and Glass, 1982). Natural outbreaks of FC were reported in quails in Burma (Naveen and Arun, 1992), USA (Glisson et al., 1989), India (Chadran et al., 1995), Japan (Gowthaman et al., 2013), and Iraq (Hamad et al., 2012). In addition, signs and lesions of FC in quails were reported previously (Glisson et al., 1989; Bermudez et al., 1997; Goto et al., 2001; Odugbo et al., 2004; Akpavi et al., 2011). The mortality rate in natural outbreaks of FC in quails can vary from 60% (Naveen and Arun, 1992; Miguel et al., 1998) to 99% (Bermudez et al., 1997). Japanese quails were susceptible to experimental infection with *P. multocida* serotypes A: 1, 3 and 4 and showed signs of weakness, inappetence, and sudden death. On pathological examination, petechial and ecchymotic hemorrhages on the heart and breast muscles as well as congestion of heart, liver, and lung were observed (Yakubu et al., 2015). Similar signs with 90% mortality were recorded in Japanese quails within 24 h post-inoculation with *P. multocida* serotype A: 4 (Akpavi et al., 2011). In India, the majority of *P. multocida* belonging to serotypes A: 1, 3 and 4 were associated with FC in quails (Kumar et al., 2004), however, *P. multocida* was isolated and molecularly identified from 330 apparently healthy quail chicks (8-day-old) with severe liver congestion and necrosis as well as bronchopneumonia (Babu Prasath et al., 2018). In Africa, a recurrent outbreak of FC in a Japanese quail farm was attributed to rats cohabiting quail houses (Mwankon et al., 2009). Treatment of Japanese quails infected with *P. multocida* using some antimicrobials (sulfonamides, oxytetracycline, doxycycline, neomycin, and norfloxacin) administered in the drinking water for five consecutive days was highly effective (Rigobelo et al., 2013).

Mycoplasmosis

Madden et al. (1967) reported the first isolate of *Mycoplasma gallisepticum* (*M. gallisepticum*) from a commercial Bobwhite quail flock with chronic respiratory disease. After, several quail cases of mycoplasmosis infection were reported (Tiong, 1978; Nascimento and Nascimento, 1986; Reece et al., 1986). Quails with mycoplasmosis indicate fibrinous perihepatitis, pericarditis and pleuritis, caseous materials in the air sacs and congested trachea (Barnes and Gross, 1997; Chauhan and Roy, 2008; Islam et al., 2016). Both *M. gallisepticum* and *M. synoviae* have been frequently isolated from quails as reported previously (Nascimento and Nascimento, 1986; Nascimento et al., 1997 and 1998). Infection with *M. gallisepticum* was serologically determined for the first time in 10-week-old quails with nasal discharge, mortality and swollen infraorbital sinuses in the Aydın region of Turkey (Türkyilmaz et al., 2007). In Bangladesh, the isolation rate of *Mycoplasma* from diseased and dead quails with chronic respiratory diseases was 5% (Islam et al., 2003, 2016). In a layer flock suffering from respiratory manifestation, mortality and egg production loss, *M. gallisepticum* were detected in 15 out of 17 (88.8%) quails and 12 out of 15 (80%) of birds showed mixed infections with *M. gallisepticum, P. multocida* and *E. coli* (Murakami et al., 2002). Concurrent infection of *M. gallisepticum* and *Subulura brumpti* was recorded in an 8-week-old Japanese quail breeder with mortality, caseous airsacculitis, and drop in egg production (Arulmozhi et al., 2018).

Infectious coryza

Infectious Coryza (IC), caused by *Avibacterium paragallinarum* (*A. paragallinarum*), is an upper respiratory disease in chickens and quails (Blackall and Hinz, 2008). Quail of all ages are susceptible to IC infection and the pathogen was isolated from naturally and experimentally infected Japanese quails (Cundy, 1965; Reece et al., 1981). Although quails are susceptible to IC, reports on isolation and identification of *A. paragallinarum* were rare (Blackall and Yamamoto, 1989). In a study, 53 Japanese quails representing from five commercial farms suffering typical IC, 8 isolates of *A. paragallinarum* were identified and molecularly characterized (Thenmozi and Malmarungan, 2013). In Indonesia, 5 out of 9 isolates (55.5%) of *A. paragallinarum* were identified from quails with typical sinusitis and facial edema. However, 3 out of 5 isolates were serologically identified as serovar B (Wahyuni et al., 2018). Recently, the migration pattern of *A. paragallinarum* was studied after experimental infection of Japanese quails and chicken. The results revealed prominent localization of the bacteria at 12 hours post-infection in nasal turbinates of quails and then decline in immunostaining intensity in the nasal tissue by 72 hours post-infection, indicating that the infection was resolved by the resident immune cells or by certain inherent innate immune factors in the nasal passage (Balouria et al., 2019).

Different antimicrobials have been used to treat IC infection, but many of them only lower the severity of the disease without complete curing the disease. Repeated treatments lead to the development of resistance to the used antibiotics (Tabbu, 2000). The antibiogram of *A. paragallinarum* in Japanese quails revealed complete (100%) resistance to ampicillin, neomycin, pefloxacin, co-cotrimoxazole, furazolidone, streptomycin, cephalexin and amikacin, 90% to gentamycin and 70% to oxytetracycline (Thenmozi and Malmarungan, 2013). Appropriate treatment requires antibiotic sensitivity tests to select effective and efficient drugs against the infection (Wahyuni et al., 2018). Diseased quails should be isolated from healthy ones and preventive sanitary measures, such as cleaning and disinfection of utensils, washing hands, and change shoes during visiting the farm, should be applied (Blackall and Yamamoto, 1989; Blackall and Hinz, 2008)

Chlamydiosis

The correlation between the latent and lethal forms of avian chlamydiosis by using a Japanese quail as a model was examined. The results demonstrated that the latent chlamydial infection was converted to the lethal form in quails receiving cyclophosphamide treatment (Takashima et al., 1996). *Chlamydia psittaci* was histopathologically identified in a flock of Bobwhite quail aged 2-4 weeks old with 100% morbidity and 40-50% mortality, stunting and yellow/green diarrhea (Erbeck and Nunn, 1999). Tetracycline, erythromycin, azithromycin, and fluoroquinolones were proven to be effective against chlamydia infection (Takashima et al., 1996).

Mycotic diseases

Aspergillosis

Aspergillosis is a respiratory disease detected in a Japanese quail breeder with multiple grey lung nodules and airsacculitis (Basheer et al., 2017). *Aspergiluus flavus* (*A. flavus*) was associated with mycotic salpingitis in Japanese quails and white to grayish nodules (2-5 mm in diameter) were found on the serosal surface of oviduct (Singh et al., 1994). Also, natural and experimental aspergillosis caused by *A. fumigatus* and *A. flavus* was recorded in broiler quails (Gumussoy et al., 2004; Borah et al., 2010). In Bangladesh, the prevalence rate of aspergillosis was 3.99% among 476 diseased and dead quails. (Islam et al., 2016). Early treatment could be effective in case of mild or moderate lesions. Some medicaments including ketoconazole and amphotericin-B could be used to control aspergillosis (Dhama et al., 2012). Using copper sulfate for treatment of birds or litter can help in reducing fungal growth (Dyar et al., 1984). Birds severely affected should be culled from the flock. Strict sanitary and hygienic measures in the hatchery are very important (Beernaert et al., 2010). Good ventilation, good litter quality, proper stocking density and keeping feeders dry in the flocks are crucial to prevent *Aspergillus* growth (Kunkl, 2003).

Candidiasis

Experimental oral infection with *Candida albicans* (*C. albicans*) was successful in Japanese quails with severe macroscopic and microscopic hyperkeratosis along the digestive tract (Asrani et al., 1993). Cutaneous candidiasis with isolation of *C. albicans* was detected in the footpad lesions of Japanese quails (Sah et al., 1982). Adequate cleaning and disinfection, proper management, vitamin A supplementation and stopping of antibiotic administration are important for reducing the incidence of candidiasis (Dhama et al., 2013). Treatment with antifungal drugs such as nystatin, fluconazole or itraconazole is useful (Tiwari et al., 2011).

Mycotoxicosis

Mycotoxins are secondary toxic metabolites produced by fungal species under high temperature and high humidity during storage of poultry diets. Fumonisins B1 produced by *Fusarium* spp. is considered one of the most important mycotoxins that adversely affect the kidney tubules in the Japanese quail chicks fed with 200 ppm in diet for 21 days (Khan et al., 2013). Ochratoxin A is a fungal metabolite produced by *Penicillium* and several species of *Aspergillus* has embryotoxic, teratogenic and nephrotoxic effects on Japanese quail chicks at a dose of 16.5 mg/kg of body weight (Prior et al., 1976; Khan et al., 2013; Patial et al., 2013 a and b). Moniliformin, a water-soluble fungal metabolite produced by *Fusarium* spp., is associated with severe hypertrophic cardiomyopathy in Japanese quails (Sharma et al., 2012). Aflatoxin is an important toxin produced by *Aspergillus* especially *A. fumigatus*, *A. flavus, and A. parasiticus*. Quails are more sensitive to aflatoxins than other poultry species (Lozano and Diaz, 2006). Chang and Hamilton (1982) found decrease in body weight of laying Japanese quails fed diet containing aflatoxin concentrations (500 to 10,000 µg/kg) for 28 to 100 days. Japanese quails fed diets containing 25-100 µg/kg aflatoxin B1 showed poor feed intake, low egg weight and poor eggshell (Sawhney et al., 1973, Oliveira et al., 2002, Ogido et al., 2004, Oguz and Parlat, 2004, Sehu et al., 2005). The synergistic effect of aflatoxicosis and coccidiosis was studied in Japanese quails and the results revealed significant reduction in body weight and increase in oocyst production (Rao et al., 1990). Manafi (2018) mentioned that aflatoxin B1 (1.5mg/kg) had adverse effects on performance and biochemical parameters, gut physiology and immunity of laying Japanese quails and those alterations could be bypassed through using of herbal mycotoxin binder containing antioxidants, enzymes, and diatomaceous earth minerals. In addition, Sakamoto et al. (2018) reported that aflatoxin B1 (1500 µg/kg of diet) impaired hepatic function, productive performance and reduced egg weight in laying quails; however, addition of silymarin (500 g/ton) or adsorbent (1 kg/ton) was not able to ameliorate the adverse effects of aflatoxins on performance and metabolism. It was observed that adverse effects of contamination of the diet with aflatoxin B1 in 21-day-old Japanese quails could be overcome by addition of probiotics containing *Bacillus*, which improved meat quality and microbial ecosystem of growing quail chicks (Kasmani et al., 2012 and 2018). *Nigella sativa* (black cumin seed) was found to be potent detoxifier for dietary aflatoxins in growing quails as inclusion of these seeds in the diet of quails induced significant improvement in immune responses, meat quality and intestinal *E. coli* populations (Rasouli-Hiq et al., 2016). Addition of glucomannan (2g/kg of the diet) overcome the adverse effects of aflatoxicosis in 60-day-old Japanese quails and reduced the pathological lesions in liver, kidneys, spleen, thymus glands and bursa of Fabricius (Yavuz et al., 2017). The role of dietary *Saccharomyces cerevisiae* inclusion to aflatoxin-contaminated diet was studied and the results indicated significant improvements in feed consumption, body weight and feed conversion ratio of Japanese quails (Parlat et al., 2001; Atalay, 2010). Citil et al. (2007) evaluated the protective capacity of L-carnitine to prevent the adverse effects of chronic aflatoxicosis in 8-week-old Japanese quails. Feeding of 2-week-old Japanese quail chicks on different doses of hydrated sodium calcium aluminosilicate partially protected the birds from the toxic effect of aflatoxicosis regarding measuring of some biochemical parameters, body performance and pathological lesions in different organs (Eraslan et al., 2004). Moreover, Migliorin et al. (2017) found that the use of adsorbent containing aluminosilicates, yeast cell wall, silymarin and bentonite after feeding of quails with aflatoxin-contaminated diet, prevented lipid peroxidation and free radical production and resulted in reduced histopathological lesions in liver.

Parasitic diseases

Coccidiosis

Coccidiosis is often a hidden disease in quails and causes severe economic losses due to increased mortality, decreased productivity and a predisposing factor for necrotic enteritis as a secondary bacterial infection (Simiyoon et al., 2018). Earlier in Oklahoma, *Eimeria* spp. was detected in 28% of Bobwhite quails (Alan Kocan et al., 1979). Three *Eimeria* spp. (*E. uzura*, *E. bateri* and *E. tsunodai*) have been identified in Japanese quails (Gesek et al., 2014). Natural infections with coccidiosis in Japanese quails exhibit signs of depression, anemia and blood mixed droppings (Teixeira et al., 2004; Simiyoon et al., 2018). On pathological examination, the caecum shows ballooning appearance with severe serosal and mucosal congestion and its lumen contained foul smelled necrotic materials admixed with blood (Umar et al., 2014; Anbarasi et al., 2016; Simiyoon et al., 2018). The histopathological changes revealed damage of intestinal villi and crypt epithelial cells with multiplying endogenous stages of *Eimeria* and a high number of oocysts (Teixeira and Lopes, 2002; Simiyoon et al., 2018). Arafat and Abbas (2018) detected that 34 out of 107 (31.78%) examined Japanese quail farms were positive for *Eimeria bateri*. Proper control measures should be considered in quail farms by avoiding water spillage, good stocking density, regular and hygienic disposal of litter and improving hygienic practices (Umar et al., 2014). Moreover, application of coccidiostats in the feed or coccidiocidal drugs in water is another way to control coccidiosis. Sokół et al. (2014) demonstrated that administration of toltrazuril in the drinking water completely eliminated *E. bateri* and induced significant reduction in *E. tsunodai* oocysts number in Japanese quails. A study conducted in Egypt compared the efficacy of coccidiocidal amprolium ethopabate and toltrazuril in the drinking water and prophylactic salinomycin and diclazuril as feed additives against *E. tsunodai* in Japanese quails, the results indicated that effects of curative drinking water treatments had the preference in comparison to prophylactic treatment (El-Morsy et al., 2016). The effect of feeding some herbal plants like *Matricaria chamomilla* on *E. bateri* infestation in 15-day-old quails was studied and the results revealed effective reduction of fecal oocyst shedding after treatment (Ahmadov et al., 2014). In addition, Arafat and Abbas (2018) concluded that oral immunization of 2-day-old Japanese quails with either 100 or 1000 sporulated oocysts of *E. bateri* improved weight gain and feed conversion rate as well as reduced diarrhea, intestinal lesions, and oocyst production. The FDA approved using of monensin sodium and amprolium as coccidiostats in the quail ration (El-Morsy et al., 2016). In conclusion, vaccination is a viable method to control coccidiosis in quails (Arafat and Abbas, 2018).

Other parasites

The examined intestine of Bobwhite quails revealed presence of a wide variety of nematodes, cestodes and protozoa including 27% *Subulara brumpti*, 4% *Heterakis gallinarum*, 6% unidentified cestodes, 45% *Trichomonas* spp., 30% *Chilomastix* spp., 27% *Eimeria* spp., 25% *Trichomonas gallinarum* and 7% *Histomonas melegridis* (Alan Kocan et al., 1979). The findings of a survey on 40 Bobwhite and Japanese quails conducted in Iran

(Shemshadi et al., 2014) indicated that 5% of the quails harbored *Raillietina echinobothrida* and *Raillietina cysticillus*, 20% quails harbored intestinal cryptosporidiosis and 32.5% quails had tracheal cryptosporidiosis. Microscopic examination on four young Bobwhite quails with anorexia, diarrhea, emaciation, and mortality as well as severe ulcerative enteritis, hepatic necrosis and peritonitis showed the presence of *Capillaria* spp., *Eimeria* spp. and *Histomonas* spp. (Roy et al., 2006). Cryptosporidiosis has been associated with high mortality in young quail with diarrhea (Hoerr et al., 1984 and 1986; Lindsay et al., 1991). Cryptosporidium infection also induced respiratory affections in quails (Tham et al., 1982). Mixed infections of *Cryptosporidium* spp., adenovirus (Tsai et al., 1998), *M. gallisepticum* (Murakami et al., 2002) and reovirus (Ritter et al., 1986) were previously recorded in quails. Experimental challenge of young Bobwhite quail with *Cryptosporidium* and reovirus showed an increase in the oocyst shedding; indicating the synergistic action of parasites and viral infections (Guy et al., 1987). Monte et al. (2018) demonstrated presence of different mixed protozoon parasites *Eutrichomastix globosus*, *Sphaerita* spp. and *Blastocystis hominis* in 12-week-old Japanese quails in Amazon region. An outbreak of histomoniasis caused by protozoan parasite *Histomonas meleagridis* was discovered in Bobwhite quails with high mortalities as well as typical cecal and liver lesions (McDougald et al., 2012). Application of sanitary measures including cleaning and disinfection of drinkers and feeders, all-in/all-out policy, control of rodents and insects, avoid mixing between different ages and species, and hygienic disposal of old litter are the essential (Alan Kocan et al., 1979). Specific treatment using anthelmintic or anti protozoon drugs is very important for disease eradication.

CONCLUSION

It is very important to give attention to quail production, as it could be considered an alternative to chicken meat or egg. Good management, prevention, and control of serious diseases affecting quails are very critical to improve production and immunity.

DECLARATIONS

Author's contribution

Wafaa Abd El-Ghany collected all the data, wrote and revised the manuscript.

Competing interests

The author has no conflict of interest.

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