

Aflatoxins in poultry feed: Present status and future concerns

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Abstract

Aflatoxin B1, a mycotoxin that belongs to the group of aflatoxins, is mostly produced by *A. flavus* or *A. parasiticus* species of *Aspergillus*. Both human and animal health are adversely affected by these hazardous secondary metabolites. They can get into the food chain through tainted fruits and crops as well as through processed foods and animal feed. Products from agriculture and the food industry, such as cereals, spices, nuts, fruits, vegetables, and dry fruits, might contain aflatoxin B1. It has been shown in numerous investigations that feeding broilers pure aflatoxin B1 has a negative impact on their growth. Higher levels of Aflatoxin B1 (1–5 mg/kg) have been shown to be hepatotoxic to broilers, causing pathological liver lesions. The impact of broiler food contaminated with high or low levels of aflatoxins on the health and sustainability of production, however, has not been thoroughly explored in the literature. Although most of the experiments produced modestly beneficial benefits, substantial outcomes were infrequent. There needs to be more investigation because there are practically infinite options for aflatoxin B1 dosage and length of exposure. Results comparison becomes challenging when there is a lack of standardization. To assess the ideal aflatoxin B1 dosage, the precise mechanism of action, and its effects on the sustainability of broiler meat production and residues of aflatoxin B1 in broiler meat, additional research under more standardized conditions is still required.

Keywords: Aflatoxin B1; Broiler; Dosage; Mechanism; Productive; Sustainability.

1. Introduction

Contamination of dietary with different components of mycotoxins causes a major health problem that resulted in economic losses in humans and animals (Agag, 2004; Limaye *et al.*, 2018). This problem will extend to the people who consume these meats due to the mycotoxin's retention in broiler meat (Alam *et al.*, 2020; Wild and Gong, 2010). The economically adverse effect of aflatoxicosis in broiler chickens is a decrease growth rate (Denli *et al.*, 2009). The most common components of mycotoxins are aflatoxins, ochratoxin A, T-2

toxin, nivalenol, zearalenone, and Deoxynivalenol (Huwig *et al.*, 2001; Devegowda *et al.*, 1998). Aflatoxins are a generic name for a group of similar compounds in chemical composition and toxicity (aflatoxin B1, B2, G1, and G2) produced by fungi of the genus of *Aspergillus* genus (Huff *et al.*, 1986). *Aspergillus flavus* and *Aspergillus parasiticus* are the most important toxigenic fungi involved in the production of aflatoxin (Dutta and Das, 2001). These toxigenic fungi produce aflatoxin when encountering a favorable environment such as temperature, humidity, CO₂, O₂ in the feed (Abidin *et al.*, 2011).


Aflatoxin B1, aflatoxin B2, aflatoxin G1 and aflatoxin G2 are the principal aflatoxins in poultry feeds that are of concern (AFG2; Monbaliu *et al.*, 2010). AFB1 is typically the most prevalent among them in feedstuffs, and

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the order of toxicity is Aflatoxin B1 > aflatoxin B2 > aflatoxin G1 > aflatoxin G2 (Fandohan *et al.*, 2005). It has been shown in numerous investigations that feeding broilers pure Aflatoxin B1 has a negative impact on their growth (Kermanshahi *et al.*, 2007; Yarru *et al.*, 2009; Magnoli *et al.*, 2011).

In regions where there are no regulatory restrictions on the quantities of aflatoxin B1 in poultry feed, aflatoxin B1 residues in poultry tissues may accumulate to large levels and endanger the health of consumers (Hussain *et al.*, 2010). Although most of the experiments produced modestly beneficial benefits, substantial outcomes were infrequent. There needs to be more investigation because there are practically infinite options for aflatoxin B1 dosage and length of exposure. Results comparison becomes challenging when there is a lack of standardization. To assess the ideal aflatoxin B1 dosage, the precise mechanism of action, and its effects on the sustainability of broiler meat production and residues of aflatoxin B1 in broiler meat, additional research under more standardized conditions is still required. Therefore, this study aimed to give an overview of the effect of dietary contamination with aflatoxin B1 in broiler chickens, in order to explore the mode of action of aflatoxin, dosage and observe its effect on productive performance, nutrient digestibility, some blood biochemistry and residues of aflatoxin B1 in broiler meat of broilers.

2. Mode of action of aflatoxins

Aflatoxicosis can cause a variety of symptoms in broilers, such as enlarged livers, pancreas, and spleen (Daghir, 2008). Osborne and Hamilton. (1981) observed that pancreatic enzyme secretion (Trypsin and Lipase) was lower in broilers fed a diet supplemented with aflatoxin at 1.25 up to 10 µg/g than non-treated broilers. pancreatic enzymes and bile acid reduction resulted in inhibit fat digestion of broilers (Osborne *et al.*, 1975), and protein utilization

and metabolizable energy (Liu *et al.*, 2018a; Verma *et al.*, 2007). Liver damage caused higher liver enzyme concentration in the serum of blood (Saei *et al.*, 2013). The relative weight of the bursa of Fabricius and thymus was reduced when broilers received a contaminated diet with aflatoxin 10 µg/g, this contributes to immune suppression of male broiler chicks (Thaxton *et al.*, 1974; Nazarizadeh *et al.*, 2019). So that, several investigations indicated that dietary contamination with different concentrations of aflatoxin has adversely reduced the productive performance of broiler chickens. It is worth indicating that low dietary concentrations of aflatoxin may result in liver damage, decrease reproductive performance, and inhibitor immune responsibility in animals (Agag, 2004; Denli *et al.*, 2009). Aflatoxicosis can cause a variety of symptoms in broilers, such as enlarged livers, pancreas, and spleen (Daghir, 2008). Osborne and Hamilton. (1981) observed that pancreatic enzymes secretion (Trypsin and Lipase) was lower in broilers fed a diet supplemented with aflatoxin at 1.25 up to 10 µg/g than non-treated broilers. pancreatic enzymes and bile acid reduction resulted in inhibit fat digestion of broilers (Osborne *et al.*, 1975). Additionally, aflatoxins are contributed to the suppression of hepatic storage of vitamin A and increased broilers requirement of vitamin D3 by 6.6 IU/kg of feed for each 1 p.p.m (Bird, 1978). Also, vitamins requirements for broilers in feedstuff have been increased during aflatoxicosis (Daghir, 2008). Broilers' performance and immune system function were negatively impacted by dietary contamination with aflatoxin B1 at 0.5g/kg diet either alone or in conjunction with ochratoxin A when compared to the control group (Nazarizadeh *et al.*, 2019). This broiler performance decline may be caused by liver and renal injury as well as a suppressive effect on protein synthesis (Johri and Majmudar., 1990). When broilers were given aflatoxin B1 at 50 g/kg alone or in conjunction with fumonisin B, neither histological nor

serological parameters changed (Del Bianchi *et al.*, 2005). This might be because of the reduced aflatoxin doses employed.

3. Effect of aflatoxin B1 on growth Performance of broilers

In tropical and subtropical regions, aflatoxin B1 is a typical feed contamination for poultry. The detrimental effects of mycotoxin on the health of chickens have been clearly established by research conducted over the past 50 years. However, the last ten years' worth of pertinent data have highlighted how broiler performance can be negatively impacted by low levels of aflatoxin B1. Dietary contamination with aflatoxin B1 levels 100, 200 and 400 ng/g had been significantly ($p < 0.05$) reduced feed consumption of broilers compared to the control group (Alam *et al.*, 2020). Likewise, Nazarizadeh *et al.* (2019) observed a significant ($p < 0.05$) decrease in feed intake of broilers treated with dietary 0.5 g/kg aflatoxin B1 during the period from 1 to 20 days of age, compared to the control group. Also, feed intake was significantly lower in broilers fed contaminated diet with aflatoxin B1 at 0.25 mg/kg than control group (Alharthi *et al.*, 2022). Additionally, Khaleghipour *et al.* (2019) reported that supplementation of 2.2 mg/kg aflatoxin B1 to broiler Japanese quail diet during the period from 7 to 35 days of age had been significantly ($p < 0.05$) reduced feed intake compared to the control group. Furthermore, Santurio. (1999) found that broiler fed diet supplemented with aflatoxin at 3 mg/kg was significantly ($p < 0.05$) reduced feed intake compared to non-treated broilers. Moreover, feed intake was reduced ($p < 0.05$) in broilers consumed contaminated feed with 0.8 mg/kg compared to the control diet (Tedesco *et al.*, 2004). Thus, Nazarizadeh and Pourreza (2019) indicated that average daily feed intake was significantly lower in broilers fed a diet supplemented with aflatoxin B1 at 2 and 4 $\mu\text{g/g}$ than the control group. Additionally, Liu *et al.* (2018a) observed that feed intake was

reduced ($P < 0.05$) in broiler fed diet added with 40 $\mu\text{g/kg}$ of aflatoxin B1 from 1 to 42 days of age compared with the control group. Also, Supplementation of aflatoxin B1 at 0.5 mg/kg to broilers diet from 1 to 42 days of age was significantly ($P < 0.05$) reduced feed intake compared to the negative control (Saei *et al.*, 2013). Thus, Liu *et al.* (2018b) found a significant decreased in feed intake of broilers fed contaminated diet with aflatoxin at 2 $\mu\text{g/g}$ compared to control group. Feed intake was significantly ($P < 0.05$) decreased in broilers fed contaminated diet with aflatoxin B1 at 2 mg/kg when compared to control group (Yarru *et al.*, 2009). In addition, Raju and Devegowda. (2000) noted that feed intake was significantly decreased ($P < 0.01$) in broilers consumed diet added with aflatoxin B1 at 0.3 mg/kg alone or in combination with ochratoxin A when compared to the control group. However, feed intake did not affect in broilers fed diet supplemented with aflatoxin B1 at 0.5 mg/kg (Rashidi *et al.*, 2020). Also, Denli *et al.* (2009) noted that the dietary supplementation of aflatoxin B1 at 1mg/kg had a non-significant effect on feed intake of broiler chickens. In addition, Chen *et al.* (2016) who found that feed intake did not affect in broiler chickens fed 1.5 mg/kg aflatoxin B1 from 1 to 20 days of age. Likewise, Cao and Wang (2014) stated that supplementation of aflatoxin B1 at 0.4 mg/kg of broilers diet did not affect feed intake. Thus, feed intake was not affected in broilers fed diet supplemented with 2 ppm aflatoxin B1 (Solis-Cruz *et al.*, 2019).

Average daily body weight gain was significantly decreased ($p < 0.05$) in broilers consumed 0.5g/kg aflatoxin B1 compared to control diet (Nazarizadeh *et al.*, 2019). Also, Bhatti *et al.* (2016) summarized that a significant decrease ($p < 0.05$) had been observed in body weight gain of broiler fed dietary added with 0.1, 0.2 and 0.6 mg/kg aflatoxin B1 compared to control group. In addition, Khaleghipour *et al.* (2019) observed a significant ($p < 0.05$) reduce in body weight gain of broiler Japanese quail when

fed diet supplemented with 2.2 mg/kg aflatoxin B1 during the period from 7 to 35 days of age compared to non-treated broilers. Thus, Huff, *et al.* (1986) found that supplementation of aflatoxin at 2.5 µg/g diet had been significantly ($p < 0.05$) reduced body weight gain of broilers compared to control group. Likewise, Alam *et al.* (2020) who indicated that body weight gain was significantly ($p < 0.05$) decreased in broilers consumed dietary added with aflatoxin B1 at 200 and 400 ng/g compared to non-treated broilers. Additionally, daily body weight gain was significantly lower ($p < 0.05$) in broilers fed contaminated diet with aflatoxin B1 at 0.25 mg/kg than control group (Alharthi *et al.*, 2022). Also, Santurio. (1999) reported that supplementation of aflatoxin at 3 mg/kg to broilers diet had been significantly ($p < 0.05$) decreased body weight gain compared to control group. Thus, daily body weight gain was significantly ($p < 0.05$) reduced when broilers fed diet added with aflatoxin B1 at 0.5 mg/kg compared with control group (Rashidi *et al.*, 2020). Also, Tessari *et al.* (2006) Indicated that body weight gain was significantly ($p < 0.05$) lower in broiler chickens receiving a diet added with aflatoxin B1 at 50 and 200 µg/kg of feed. Thus, Denli *et al.* (2009) reported that body weight gain was significantly ($p < 0.05$) decreased by supplementation of aflatoxin B1 at 1mg/kg to broilers diet. In addition, Nazarizadeh and Pourreza (2019) who found that body weight gain was lower in broilers fed diet added with aflatoxin B1 at 2 and 4 µg/g than control group. Thus, there were a significant ($P < 0.01$) decreased in body weight gain of broilers fed diet added with aflatoxin B1 at 0.3 mg/kg alone or in combination with ochratoxin A when compared to control group (Raju and Devegowda, 2000). Thus, body weight gain was significantly ($P < 0.05$) reduced in broilers fed diet supplemented with 1 and 2 mg/kg (Yarru *et al.*, 2009)

Also, Chen *et al.* (2016) discovered a significant ($p < 0.05$) decrease of body weight gain when

broilers received diet supplemented with aflatoxin at 1.5 mg/kg from 1 to 20 days of age compared to without broilers treated. Thus, dietary inclusion of aflatoxin B1 at 0.5 mg/kg had been significantly ($P < 0.05$) decreased body weight gain of broiler chickens compared to negative control (Saei *et al.*, 2013). Solis-Cruz *et al.* (2019) discovered a reduction ($P < 0.05$) of body weight gain when broilers fed diet added with 2 ppm of aflatoxin B1 during the period from 1 to 21 days of age compared to control group. Additionally, Liu *et al.* (2018a) observed that body weight gain was decreased ($P < 0.05$) in broiler fed diet contaminated with 40 µg/kg of aflatoxin B1 from 1 to 42 days of age compared with control group. On the other hand, there was non-significant ($p > 0.05$) differences in body weight gain of broilers fed diet supplemented with 0.8 mg/kg aflatoxin B1 compared to non-treated broilers (Tedesco *et al.*, 2004). Likewise, Cao and Wang (2014) who proposed that dietary inclusion of 0.4 mg/kg aflatoxin B1 had been non-significant affect on average daily body weight gain of broilers.

In poultry husbandry, feed conversion ratio (FCR) or feed conversion rate is a ratio or rate measuring of the efficiency with which the bodies of birds convert animal feed into the desired output. Feed conversion ratio was significant ($p < 0.5$) increase in broilers consumed contaminated dietary 200 and 400 ng/g aflatoxin B1 compared to control group (Alam *et al.*, 2020). Likewise, Bhatti *et al.*, (2016) indicated that dietary incorporation with 0.1, 0.2 and 0.6 mg/kg aflatoxin B1 had a significant ($p < 0.5$) increased in feed conversion ratio of broilers compared to control group. In addition, Huff, *et al.* (1986) who indicated that feed conversion ratio was significantly higher in broilers fed diet added with 2.5 µg/g aflatoxin than control group. Thus, there was a significant increase in feed conversion ratio of broilers fed diet supplemented with aflatoxin B1 at 4 µg/g compared to control group (Nazarizadeh and Pourreza, 2019). Likewise, Saei *et al.* (2013)

who indicated that feed conversion ratio was significantly higher in broilers fed contaminated diet with 0.5 aflatoxin B1 during the period of 1 to 42 day of age than negative control. Alharthi *et al.* (2022) observed significant increase in feed conversion ratio of broilers fed diet supplemented with aflatoxin B1 at 0.25 mg/kg compared to control group. Thus, Solis-Cruz *et al.* (2019) who discovered that feed conversion ratio was significantly ($p < 0.05$) increased in broilers consumed contaminated diet with 2ppm aflatoxin B1 during the period from 1 to 21 days of age than control group. Also, Liu *et al.* (2018a) observed that feed conversion ratio had been significantly ($P < 0.05$) increased in broiler fed diet supplemented with 40 $\mu\text{g}/\text{kg}$ of aflatoxin B1 from 1 to 42 days of age compared with control group.

Dietary inclusion aflatoxin B1 at 0.5 mg/kg was not affected on feed conversion ratio of broilers (Tedesco *et al.*, 2004). Also, Nazarizadeh *et al.*, (2019) indicated that feed conversion ratio was non-significant affected in broilers fed 0.5g/kg aflatoxin B1 from 1 to 20 days of age. In addition, Santurio. (1999) found that contaminated of dietary with aflatoxin at 3 mg/kg had non-significant affect FCR of broilers. Thus, there was non-significant changed in FCR value in broilers feeding contaminated with 0.8 mg/kg (Tedesco *et al.*, 2004). Likewise, Denli *et al.* (2009) who reported that feed conversion ratio was non-significant different when broilers consumed contaminated diet with 1 mg/kg aflatoxin B1. Thus, there was not changed in feed conversion ratio when broilers fed diet supplemented with aflatoxin B1 at 0.3 mg/kg compared to control group (Raju and Devegowda., 2000). In addition, Khaleghipour *et al.* (2019) noted that supplementation of aflatoxin B1 2.2 mg/kg to broiler Japanese quail during the period from 7 to 35 days of age did not affect feed conversion ratio. Likewise, feed conversion ratio did not affect in broilers fed diet contaminated with 0.4 mg/kg (Cao and Wang, 2014).

4. Effect of aflatoxin B1 on carcass criteria of broilers

To date, various aspects of the aflatoxicosis in poultry farm including effects on broiler performance and carcass criteria have been the subjects of several comprehensive reviews. Internal parts of carcass (gizzard, liver, and pancreas weight) have been indicated to decreased in broilers fed 0.5g/kg of aflatoxin B1 compared with control diet (Nazarizadeh *et al.*, 2019). Likewise, Alam *et al.* (2020) who found that dressing percentage of carcass was significantly ($p < 0.05$) reduced in broilers fed diet contaminated with 200 and 400 ng/g aflatoxin B1 compared to control group. Furthermore, Tessari *et al.* (2006) found that relative weights of the heart was significantly ($p < 0.05$) higher in broiler chickens feeding a diet supplemented with aflatoxin B1 at 50 and 200 $\mu\text{g}/\text{kg}$ of feed however, liver and spleen weight were not affected. relative weight of liver was significantly higher in broilers fed contaminated feed with 1g/kg aflatoxin B1 however, spleen weight was not affected (Denli *et al.*, 2009). The relative weights of the spleen, liver and kidney were significantly ($p < 0.05$) increased in broiler fed diet added with aflatoxin at 2.5 $\mu\text{g}/\text{g}$ compared to control group (Huff *et al.* 1986). Furthermore, weight of liver was significantly ($p < 0.05$) higher in broilers fed diet contaminated with aflatoxin at 3 mg/kg than control group however, heart and pancreas weight were not affected (Santurio, 1999). Likewise, Raju and Devegowda (2000) indicated that liver and kidney weight were significantly increased in broilers fed diet supplemented with aflatoxin B1 at 0.3 mg/kg compared to control group. Thus, Denli *et al.* (2004) noted that liver weight was ($p < 0.05$) higher in broilers consumed 200,300 ng/kg aflatoxin B1 compared to control group. Also, Khaleghipour *et al.* (2019) found that liver and spleen percentage were significantly ($p < 0.05$) reduced in broiler Japanese quail fed 2.2 mg/kg aflatoxin B1

during the period from 7 to 35 days of age compared to control group. Liver weight was significantly ($p < 0.05$) increased in broiler chickens received contaminated diet with 0.5 mg/kg aflatoxin B1 from 1 to 42 days of age however spleen, Abdominal fat and pancreas weights were non-affected compared to control group (Saei *et al.*, 2013). Likewise, Solis-Cruz *et al.* (2019) who discovered that the relative weight of liver and spleen were significantly ($p < 0.05$) higher in broilers fed contaminated diet with 2ppm aflatoxin B1 during the period from 1 to 21 days of age than control group.

5. Effect of aflatoxin B1 on nutrient digestibility and digestive enzymes of broiler chickens

Numerous in-depth reviews have been written so far on a variety of elements of aflatoxicosis in chicken farms, such as its effects on broiler metabolism and toxin metabolism. The α -amylase, trypsin, chymotrypsin, and lipase are a digestive enzymes secreted from pancreas which affected on carbohydrate, protein and fat digestion, and are reflected in the performance of chickens. Many of researchers observed that aflatoxin B1 had been negative effect on performance of broilers (Nazarizadeh *et al.*, 2019; Bhatti *et al.*, 2016; Saei *et al.*, 2013). Releasing pancreatic enzymes broilers fed diets enriched with aflatoxin at 1.25 to 10 g/g had lower trypsin and lipase levels than broilers not given any treatment (Osborne and Hamilton, 1981). Furthermore, Matur *et al.* (2010) who added 100 g/kg of supplements to the diet of Ross 308 female chickens saw a substantial rise in the pancreatic enzymes chymotrypsin and α -amylase activity while observing a decline in the activity of lipase when compared to the control group. On the other hand, dietary including on 40 μ g/kg of aflatoxin B1 (from 19 to 21 days of age) have been significantly ($p < 0.05$) decreased dry matter, crud protein and gross energy digestibility of broilers compared with control group (Liu *et al.*, 2018a). Supplementation of

aflatoxin B1 at 2.5, 3.13 and 3.91 mg/kg to White Leghorn female chicks diet have been significantly ($p < 0.05$) reduced retention of dry matter, ether extract, crud protein and calcium compared to control treatment (Pandey and Chauhan, 2007). Protein utilization and metabolizable energy were significantly depressed when laying hens consumed contaminated diet with aflatoxin B1 at 1 or 2 mg/kg compared to control group (Verma *et al.*, 2007). However, Denli *et al.* (2009) noted that crude protein and gross energy digestibility were not affected in broilers fed diet contaminated with 1mg/kg aflatoxin B1.

6. Effect of aflatoxin B1 on blood biochemistry of broilers

6.1. Total cholesterol

The effects of aflatoxin B1 in poultry farms, including those on animal performance and physiological responses, the toxin's metabolism, and the transfer of hazardous residues to animal products, have all been the focus of numerous in-depth reviews to date. Denli *et al.* (2009) demonstrated that serum contain of total cholesterol did not affected in broilers consumed contaminated feed with 1 mg/kg. Also, Nazarizadeh and Pourreza (2019) indicated that supplementation of aflatoxin B1 at 2 and 4 μ g/g to broilers feed did not affect HDL, LDL and total cholesterol. Likewise, there were non-significant changed in serum total cholesterol when broiler chickens fed contaminated diet with 0.5 mg/kg aflatoxin B1 from 1 to 42 days of age when compared with negative control (Saei *et al.*, 2013). However, Khaleghipour *et al.* (2019) summarized that low density lipoprotein (HDL), high density lipoprotein (LDL) and total cholesterol were significantly lower in broiler Japanese quails fed 2.2 mg/kg aflatoxin B1 during the period from 7 to 35 days of age than control group. Also, Solis-Cruz *et al.*, (2019) reported that serum total cholesterol level was significantly ($p < 0.05$) reduced in broilers fed

contaminated diet with 2 ppm aflatoxin B1 when compared to control group. On the other side, Liu *et al.* (2018a) found that supplementation of 40 µg/kg of aflatoxin B1 had been significantly ($p<0.05$) increased serum total cholesterol of broilers compared to control group.

6.2. Liver function

It has been documented that dietary contamination with 0.1, 0.2 and 0.6 mg/kg aflatoxin B1 had significant ($p<0.05$) increased serum concentration of ALT compared to broilers fed non-contamination diet (Bhatti *et al.*, 2016). Likewise, Santurio (1999) who indicated that serum concentration of ALT was significant ($p<0.05$) higher in broilers fed dietary contaminated with aflatoxin at 3g/kg than control group. Feeding aflatoxin B1 contaminated diet at 0.5 mg/kg resulted in a significant ($p<0.05$) increased serum concentration of ALT compared to control group (Rashidi *et al.*, 2020). Also, Denli *et al.* (2009) indicated that serum contain of Alanine amino transferase (ALT) was significant ($p<0.05$) increased when broilers consumed contaminated feed with 1 mg/kg. Thus, serum concentration of ALT was significantly ($p<0.05$) increased in broilers fed contaminated diet with 200,300 ng/kg aflatoxin B1 compared to control diet (Denli *et al.*, 2004). In addition, Khaleghipour *et al.* (2019) who added 2.2 mg/kg aflatoxin B1 to broiler Japanese quail diet during the period from 7 to 35 days of age and observed a significantly ($p<0.05$) increase in serum concentration of ALT compared to control group. Serum concentration of alanine amino transferase was significantly higher in broiler chickens received contaminated diet with 0.5 mg/kg aflatoxin B1 from 1 to 42 days of age than control group (Saei *et al.*, 2013). Also, Solis-Cruz *et al.* (2019) indicated that serum ALT level was significantly ($p<0.05$) increased in broilers consumed diet supplemented with 2 ppm aflatoxin B1 when compared to control group. However, Raju and Devegowda (2000)

found that serum concentration of ALT did not affected in broilers fed diet supplemented with aflatoxin B1 at 0.3 mg/kg compared to control group. Thus, Nazarizadeh and Pourreza (2019) found that supplementation of aflatoxin B1 at 2 and 4 µg/g to broilers diet had been non-significantly affected serum concentration of ALT. Likewise, Cao and Wang (2014) noted that dietary inclusion of 0.4 mg/kg aflatoxin B1 had been non-significant affected serum concentration of alanine amino transferase of broilers. On the other hand, a significant ($p<0.05$) reduction was observed in serum concentration of ALT in broilers fed dietary contaminated with aflatoxin B1 at 0.8 mg/kg compared to control diet (Tedesco *et al.*, 2004). Likewise, Valdivia *et al.* (2001) indicated that serum concentration of ALT was significantly reduced ($p<0.05$) in broilers fed contaminated diet with aflatoxin B1 at 3 µg/g compared with non-treated group.

Serum concentration of AST was significantly ($p<0.01$) increased when broilers fed contaminated diet with 250 and 500 ppb compared to control group (Fani Makki *et al.*, 2014). Additionally, Denli *et al.* (2009) who noted that AST serum concentration was significantly increased when broilers fed contaminated diet with 1 mg/kg aflatoxin B1 compared to control group. Likewise, Nazarizadeh and Pourreza. (2019) found that addition of aflatoxin B1 at 2 and 4 µg/g to broilers diet had been significantly ($p<0.05$) increased serum concentration of ALT compared to control group. In addition, serum concentration of AST was significantly ($p<0.05$) higher in broilers fed contaminated diet with 200,300 ng/kg aflatoxin B1 than to control diet (Denli *et al.*, 2004). In addition, Valdivia *et al.*, (2001) found that serum concentration of AST was significantly ($p<0.05$) increased in broilers fed diet supplemented with aflatoxin B1 at 3 µg/g compared with non-treated group. Likewise, Cao and Wang, (2014) reported that dietary inclusion of 0.4 mg/kg aflatoxin B1 had

been significant ($p < 0.05$) increased serum concentration of alanine amino transferase of broilers compared to control group. Also, Serum concentration of aspartate amino transferase was significantly ($p < 0.05$) higher in broiler chickens received contaminated diet with 0.5 mg/kg aflatoxin B1 from 1 to 42 days of age than control group (Saei *et al.*, 2013). However, Serum concentration of AST was non-significant affected in broilers consumed dietary contaminated with aflatoxin at 3 mg/kg (Santurio, 1999). Likewise, Tedesco *et al.* (2004) found that serum contain of Aspartate amino transferase (AST) did not affected in broilers fed diet supplemented with 0.8 mg/kg aflatoxin B1. Thus, Chen *et al.* (2016) reported that serum contain of AST did not change in broilers fed diet contaminated with 1.5 gm/kg aflatoxin B1 from 1 to 20 days of age. Also, Khaleghipour *et al.* (2019) found that supplementation of 2.2 mg/kg aflatoxin B1 had been non-significantly ($p > 0.05$) affected serum concentration of AST in broiler Japanese quails during the period from 7 to 35 days of age. likewise, Solis-Cruz *et al.*, (2019) summarized that serum AST level did not impacted in broilers fed diet added with 2 ppm aflatoxin B1 during the period from 1 to 21 days of age.

6.3. *Kedinys function*

Serum concentration of creatinine was significantly ($p < 0.05$) higher in broilers fed diet supplemented with 3 mg/kg aflatoxin when compared to control group (Santurio, 1999). Likewise, Bhatti *et al.* (2016) observed a significant ($p < 0.05$) increase in serum concentration of creatinine when broiler fed contamination diet with 0.1, 0.2 and 0.6 mg/kg aflatoxin B1 compared to control diet. Additionally, Liu *et al.* (2018a) indicated that addition of 40 $\mu\text{g}/\text{kg}$ of aflatoxin B1 had been significantly ($p < 0.05$) increased concentration of serum creatinine of broilers compared to control group. However, Khaleghipour *et al.* (2019) stated that supplementation of aflatoxin B1 at

2.2 mg/kg had been significantly ($p < 0.05$) reduced serum concentration of creatinine in broiler Japanese quails during the period from 7 to 35 days of age compared to control group. Also, serum concentration of creatinine was significantly lower in broilers fed contaminated diet with 2 ppm of aflatoxin B1 during the period from 1 to 21 days of age than control group (Solis-Cruz *et al.*, 2019). On the other side, there were non-significant differences in serum concentration of creatinine when broiler chickens consumed contaminated diet with 0.5 mg/kg aflatoxin B1 from 1 to 42 days of age compared with control group (Saei *et al.*, 2013). Serum concentration of urea was significantly ($p < 0.05$) higher in broilers consumed dietary supplemented with aflatoxin B1 at 0.1, 0.2 and 0.6 mg/kg than control group (Bhatti *et al.*, 2016). Likewise, Santurio (1999) reported a-significant ($P < 0.05$) increase in serum concentration of uric acid of broilers fed diet contaminated with 3 mg/kg aflatoxin compared to control group. Also, Rashidi *et al.* (2020) indicated that supplementation of 0.5 mg/kg aflatoxin B1 to broiler diet had been increased ($p < 0.05$) serum concentration of uric acid compared to control group. Serum concentration of uric acid was significantly ($p < 0.01$) higher in broilers fed diet supplemented with 1 mg/kg aflatoxin B1 than control group (Denli *et al.*, 2009). Also, Khaleghipour *et al.* (2019) noted that supplementation of 2.2 mg/kg aflatoxin B1 significantly ($p < 0.05$) increased serum concentration of uric acid in broiler Japanese quails during the period from 7 to 35 days of age compared to control group. In addition, Fani Makki *et al.* (2014) indicated that serum contain of uric acid was significantly ($p < 0.05$) increased when broilers fed contaminated diet with 250 and 500 ppb compared to control group. However, Huff *et al.* (1986) observed that dietary contaminated with 2.5 $\mu\text{g}/\text{g}$ of aflatoxin alone or in combination with deoxynivalenol had a significant ($p < 0.05$) reduced serum concentration of uric acid compared to control

group. Thus, Raju and Devegowda (2000) indicated that supplementation of 0.3 mg/kg aflatoxin B1 to broilers diet result in a significant decreased in serum concentration of urea nitrogen compared to control group. Likewise, Denli *et al.* (2004) observed that serum contain of uric acid significantly ($p < 0.05$) decreased in broilers consumed contaminated diet with 200,300 ng/kg aflatoxin B1 than to control diet. Additionally, Mesgar *et al.*, (2022) supplementation of aflatoxin at 500 $\mu\text{g}/\text{kg}$ did not affected serum concentrate of uric acid and urea. Thus, There were non-significant differences in serum concentration of uric acid in broilers consumed diet added with 1.5 mg/kg from 1 to 20 days of age (Chen *et al.*, 2016). Also, serum concentration of uric acid was not affected in broilers fed diet supplemented with 2 ppm of aflatoxin B1 during the period from 1 to 21 days of age (Solis-Cruz *et al.*, 2019).

There were non-significant differences in serum concentration of albumin in broilers fed diet added with aflatoxin at 500 $\mu\text{g}/\text{kg}$ (Mesgar *et al.*, 2022). Likewise, Tavangar *et al.*, (2021) supplementation of aflatoxin B1 at 1 ppm to broilers diet did not influenced concentration of albumin. Serum concentration of total protein was significantly ($P < 0.05$) lower in broilers fed diet supplemented with 1 and 2 mg/kg than control group (Yarru *et al.*, 2009). Additionally, Tavangar *et al.* (2021) supplementation of aflatoxin B1 at 1 ppm to broilers diet had been significantly ($P < 0.01$) reduced serum total protein compared to control group. However, there was non-significant change in serum total protein of broilers fed diet contaminated with aflatoxin B1 at 500 $\mu\text{g}/\text{kg}$ (Mesgar *et al.*, 2022).

7. Conclusion

It can be concluded that aflatoxin B1 has an adverse effects on the productive performance of broilers. Additionally, it can contribute to immune suppression, liver damage and reduction of nutrient digestibility by decreasing pancreatic enzyme secretion. Nevertheless, there are still

further studies to evaluate the exact mode of action and determine the appropriate methods and materials to combat the spread of mycotoxins in the poultry diet.

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All Institutional Review Board Statements are confirmed and approved.

Data Availability Statement

Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate

This work was carried out in Department of Animal and Poultry Production, Faculty of Agriculture, South Valley University and followed all the department instructions.

Consent for Publication

Not applicable.

Conflicts of Interest

The authors disclosed no conflict of interest starting from the conduct of the study, data analysis, and writing until the publication of this research work.

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