SVU-IJAS
SVU-International Journal of Agricultural Sciences
Volume 4 Issue (4) pp.: 29-36, 2022
**Print ISSN 2636-3801 | Online ISSN 2636-381X**
Doi: 10.21608/svuijas.2022.178769.1248

**RESEARCH ARTICLE**

# Effects of probiotic feed additives on the growth performance and carcass criteria of broiler chickens exposed to an Aflatoxin B1 challenge

El-Sayed, H.G.M. [1], H.A.M. Elwan [2], A.F.A. Aboelhassan [3] and A.A.A. Abdel-Wareth [4] *

*[1] Regional Center for Food and Feed, Agricultural Research Center, 12619 Giza, Egypt.*
*[2] Animal and Poultry Production Department, Faculty of Agriculture, Minia University, 61519 El-Minya, Egypt.*
*[3] Central Laboratory of Residue Analysis of Pesticides and Heavy Metals in Food, Agricultural Research Center, 12619 Giza, Egypt.*
*[4] Department of Animal and Poultry Production, Faculty of Agriculture, South Valley University, 83523 Qena, Egypt.*

## Abstract

The purpose of this experiment was to examine the effects of probiotic feed additives on the growth performance, and carcass criteria of broiler chickens exposed to an aflatoxicosis challenge. A total of 256 Ross 308 broiler chicks were divided into four treatments which included eight replicates and eight birds in each over a 37-day period. Treatments included a negative control (without additions), a positive control with aflatoxin B1 for only the first 10 days (AFB1, 40 µg/kg), a negative control with probiotic (0.5 mg/kg), and a negative control with a combination of aflatoxin B1 and probiotic. Broiler chickens' body weight gain and feed conversion ratio were dramatically enhanced when their diets included probiotic supplements, either with or without Aflatoxin B1. In treated diets compared to the control group, protein, and ether extract digestibility increased. The broiler chickens fed probiotic additives in combination with AFB1 had a lower abdominal fat percentage compared to the control. Dietary treatments had no significant effect on the internal organs in broiler chickens. In conclusion, the present results indicated that probiotic supplements improved production sustainability and health status of broiler chickens exposed to the Aflatoxin B1 challenge.

**Keywords:** Aflatoxin; Broilers; Production; Probiotic; Sustainability.

## 1. Introduction

The natural environment contains a variety of biological toxins that could be harmful to both human and animal health. Currently, mycotoxins are regarded as some of the most harmful ones. They are toxic byproducts of several filamentous fungal species, primarily from the genera *Aspergillus, Penicillium and Fusarium* (Ostryl *et al.*, 2017). Aflatoxin B1 (AFB1), one of the 18 varieties of aflatoxins discovered, is the most toxic and prevalent of them, followed by the less toxic aflatoxins G1, B2, and G2 (Meji-Teniente *et al.*, 2011; Freire and Sant, 2018). Aflatoxin B1 (AFB1) exposure at high doses can result in sickness, vomiting, and even death, while prolonged exposure at low doses can develop liver cancer (Sherif *et al.*, 2009). Although there are less ideal conditions for the production of mycotoxins in Europe than in North America or Asia, the issue of mycotoxins in cereals is still a major concern for many European nations. The current European Union standards for AFB1 in poultry feed is 20 µg/kg (European Commission, 2002). The impact of broiler food contaminated with high or low levels of aflatoxins on the health

.***Corresponding author: Ahmed A.A. Abdel-Wareth**
Email: a.wareth@agr.svu.edu.eg
*Received: December 5, 2022; Accepted: December 16, 2022; Published online: December 17, 2022.*

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. Detoxification can happen as a result of mycotoxins being metabolically transformed by microbiota or as a result of their adhering to the cell walls of bacteria or yeast (Śliżewska *et al.*, 2019). Probiotic bacteria are known to bind various chemicals or complex structures, including mycotoxins, on the surface of cell walls (McCormick, 2013). Aflatoxin residues could be found in the tissues of animals fed contaminated feed, posing a risk to human health. Although adding probiotics to animal diets has been considered acceptable for contributing in the detoxification of aflatoxins (Chen *et al.*, 2019), the data on broiler chickens is still quite limited. Therefore, the purpose of this study was to examine the effects of probiotic feed additives on the growth performance and carcass criteria of broiler chickens exposed to an aflatoxicosis challenge.

## 2. Material and methods

### *2.1. Animals, diets, and experimental design*

An experiment was conducted to study the effect of probiotic, with or without aflatoxin B1 supplementations on the growth performance, and carcass criteria of broiler chickens. A total of 256 Ross 308 broiler chicks were divided into four treatments which included eight replicates and eight birds in each over a 37-day period. Treatments included a negative control, a positive control with aflatoxin B1 (40 µg/kg), a negative control with probiotic (0.5 mg/kg), and a negative control with a combination of aflatoxin B1 and probiotic. In an open house, all chicks were raised on the floor with a litter of wooden dust. Isonitrogen – isocalory diets were created to fulfill the NRC's recommendations (Table 1). Throughout the trial period, the experimental feed and clean drinking water were freely available. Throughout the experiment, there was a constant light source. Aflatoxin B1 used in the experiment was produced in the Mycotoxin Laboratory of the Animal and Poultry Production Department, Faculty of Agriculture, Minia University, as described by Lin and Dianese (1976). Probiotic was used based on company recommendations (AmPhiBact, American Pharmaceutical Innovations Company®) contains *Lactobacillus acidophilus* and *Bacillus subtilis*.

### *2.2. Performance indices*

To evaluate body weight gain (BWG), the birds were weighted at the start of the experiment, 21 and 37 days later, and feed intake was estimated as the difference between the offer and residual feed for each replicate of age. At the same ages, the feed conversion ratio (FCR) and the rate of death were calculated.

### *2.3. Carcass criteria*

At the marketing age of 37 days, the carcass weight of slaughtered broilers from each group was recorded, and the dressing % was computed by subtracting dressed weight from total live body weight. In proportion to carcass weight, fat percentages in the liver, gizzard, heart, and abdomen were calculated.

### *2.4. Statistical Analysis*

All generated data were subjected to a one-way analysis of Variance (ANOVA) using SAS (2009). Pen was the experimental unit for growth performance, whereas other parameters were analyzed in individual birds. Treatment means were compared using Duncan’s Multiple Range Test, and differences were considered significant at $P < 0.05$.

**Table 1.** Ingredients and chemical composition of diets

| Ingredients, g/kg | Starter diet | Grower diet |
|---|---|---|
| Maize, ground | 276 | 300 |
| Sorghum, ground | 276 | 300 |
| Soybean meal (44% CP) | 285 | 250 |
| Corn gluten meal (60% CP) | 95.0 | 60.0 |
| Vit & Min. Premix[a] | 3.00 | 3.00 |
| Sunflower oil | 30.0 | 55.2 |
| Dicalcium phosphate | 20.0 | 18.0 |
| Limestone | 10.0 | 10.00 |
| Salt | 3.80 | 3.80 |
| DL-methionine | 0.40 | --- |
| L-lysine HCl | 1.00 | --- |
| Total | 1000 | 1000 |
| Analysis chemical composition, g/kg | | |
| Dry matter | 925 | 924 |
| Crude protein | 233 | 216 |
| Ether extract | 53.7 | 57.5 |
| Crude fibre | 25.8 | 37.8 |
| Ash | 67.4 | 61.8 |
| Ca | 13.22 | 12.84 |
| P | 7.05 | 7.21 |
| GE, MJ/kg | 18.55 | 19.18 |

*[a]Supplied vitamin-mineral premix contains per kg: 2400.000 IU vitamin A; 1000.000 IU vitamin D; 800 mg vitamin K;16.000 IU vitamin E; 650 mg vitamin B1; 1.600 mg vitamin B2; 1.000 mg vitamin B6; 6 mg vitamin B12; 8.000 mg niacin; 400 mg folic acid; 3.000 mg pantothenic acid; 40 mg biotin; 3.000 mg antioxidant; 80 mg cobalt; 2.000 mg copper; 400 mg iodine; 1.200 mg iron; 18.000 mg manganese; 60 mg selenium; 14.000 mg zinc.*

## 3. Results

### *3.1. Productive performances*

Neither control birds nor birds fed diets containing 40 µg AFB1/kg during their first 10 days of life exhibited any mortality. In comparison to early contaminated AFB1 or control diets, broiler chickens' body weight gain and body weight gain were significantly improved when their diets contained probiotic supplements, whether they were contaminated with or without AFB1(Table 2). Feeding chickens a feed contaminated with 40 µg AFB1/kg for the first 10 days (1-10 days of age) had increased feed intake during 21-30 and 1-37 days of age and enhanced feed conversion ratio during 1-10, 11-20, 21-30, and 1-37 days of ages compared to birds fed the control diet (Table 3).

**Table 2.** Effect of Aflatoxin B1, probiotic and their combination on body weight and body weight gain of broiler chickens.

| Items | Treatments | | | | SEM* | P-Value |
|---|---|---|---|---|---|---|
| | Control | AFB1 | Pro | AFB1+Pro | | |
| Body weight, g | | | | | | |
| 1 day of age | 41.33 | 41.67 | 41.0 | 42.67 | 0.298 | 0.231 |
| 10 days of age | 282 | 259 | 294 | 289 | 3.015 | <0.001 |
| 20 days of age | 844 | 785 | 910 | 871 | 9.965 | <0.001 |
| 30 days of age | 1605 | 1603 | 1727 | 1700 | 14.09 | <0.001 |
| 37 days of age | 2129 | 2170 | 2293 | 2235 | 16.03 | <0.001 |
| Body weight gain, g | | | | | | |
| 1-10 days of age | 241 | 217 | 253 | 246 | 3.033 | <0.001 |
| 11-20 days of age | 562 | 526 | 616 | 582 | 7.283 | <0.001 |
| 21-30 days of age | 761 | 818 | 817 | 829 | 11.17 | 0.123 |
| 31-37 days of age | 524 | 568 | 567 | 543 | 6.238 | 0.024 |
| 1-37 days of age | 2088 | 2129 | 2252 | 2192 | 16.03 | <0.001 |

*[a-d] Means not sharing a common superscript in a row are significantly different (P<0.05)*
*SEM: Standard error of the means*
*AFB1: 40 µg/kgAflatoxin B1 supplemented to control diet.*
*Pro: 0.5 mg/kg probiotic supplemented to control diet*
*AFB1+Pro: 40 µg/kgAflatoxin B1 and 0.5 mg/kg probiotic supplemented to control diet*

**Table 3.** Effect of Aflatoxin B1, probiotic and their combination on feed intake and feed conversion ratio of broiler chickens.

| Items | Treatments | | | | SEM* | P-Value |
|---|---|---|---|---|---|---|
| | Control | AFB1 | Pro | AFB1+Pro | | |
| Feed intake, g | | | | | | |
| 1-10 days of age | 340.3 | 318.7 | 329.3 | 323.3 | 4.130 | 0.288 |
| 11-20 days of age | 781.3 | 773.7 | 759.3 | 759.7 | 6.18 | 0.536 |
| 21-30 days of age | 1116.0 | 1239.2 | 1127.9 | 1089.2 | 15.89 | 0.001 |
| 31-37 days of age | 879.3 | 908.7 | 927.9 | 888.6 | 11.14 | 0.440 |
| 1-37 days of age | 3116.9 | 3240.3 | 3144.5 | 3060.8 | 21.88 | 0.019 |
| Feed conversion ratio | | | | | | |
| 1-10 days of age | 1.413 | 1.469 | 1.305 | 1.313 | 0.021 | 0.005 |
| 11-20 days of age | 1.390 | 1.471 | 1.232 | 1.307 | 0.022 | <0.001 |
| 21-30 days of age | 1.468 | 1.522 | 1.385 | 1.319 | 0.025 | 0.013 |
| 31-37 days of age | 1.683 | 1.601 | 1.636 | 1.636 | 0.016 | 0.385 |
| 1-37 days of age | 1.494 | 1.523 | 1.396 | 1.396 | 0.014 | <0.001 |

*[a-d] Means not sharing a common superscript in a row are significantly different (P<0.05)*
*SEM: Standard error of the means*
*AFB1: 40 µg/kgAflatoxin B1 supplemented to control diet.*
*Pro: 0.5 mg/kg probiotic supplemented to control diet*
*AFB1+Pro: 40 µg/kgAflatoxin B1 and 0.5 mg/kg probiotic supplemented to control diet*

### *3.2. Carcass criteria*

In comparison to the control group, feeding chicken's diets containing probiotic supplements, whether they were contaminated with or without AFB1, significantly increased the weight of dressing percentage and decreased fat (Table 4). The weights of the liver, gizzard, heart, kidneys, spleen, intestine, and cecum of broiler chickens did not change when the probiotic, AFB1, and their combination were added to the control diet.

**Table 4.** Effect of Aflatoxin B1, probiotic and their combination on carcass criteria and internal organs of broilers.

| Items % | Treatments | | | | SEM* | P-Value |
|---|---|---|---|---|---|---|
| | Control | AFB1 | Pro | AFB+Pro | | |
| Dressing | 76.35 | 76.18 | 78.19 | 78.51 | 0.285 | 0.032 |
| Liver | 2.046 | 2.070 | 2.005 | 1.898 | 0.036 | 0.379 |
| Heart | 0.411 | 0.430 | 0.478 | 0.539 | 0.042 | 0.057 |
| Gizzard | 1.372 | 1.512 | 1.577 | 1.548 | 0.034 | 0.131 |
| Spleen | 0.088 | 2.657 | 0.095 | 0.118 | 0.648 | 0.455 |
| Pancreas | 0.388 | 0.351 | 0.370 | 0.386 | 0.028 | 0.074 |
| Fat | 1.422 | 0.795 | 0.786 | 0.627 | 0.104 | 0.005 |
| Small intestine | 3.313 | 3.368 | 3.182 | 3.662 | 0.122 | 0.621 |
| Small intestine, cm | 153.3 | 172.3 | 180.0 | 163.3 | 4.350 | 0.139 |
| Cecum | 0.668 | 0.736 | 0.692 | 0.795 | 0.028 | 0.446 |
| Cecum, cm | 16.00 | 17.00 | 18.33 | 19.33 | 0.432 | 0.042 |

*[a-d] Means not sharing a common superscript in a row are significantly different (P<0.05)*
*SEM: Standard error of the means*
*AFB1: 40 µg/kgAflatoxin B1 supplemented to control diet.*
*Pro: 0.5 mg/kg probiotic supplemented to control diet*
*AFB1+Pro: 40 µg/kgAflatoxin B1 and 0.5 mg/kg probiotic supplemented to control diet.*

## 4. Discussion

The loss of productive performance is one of the most significant economic effects of AFB1 in broiler chickens. Feeding chickens a feed contaminated with 40 µg AFB1/kg for the first 10 days (1-10 days of age) had improved body weight gain and feed conversion ration compared to birds fed the control diet. This study's findings are in line with those that have already been published (Suganthi *et al.,* 2011; Yunus *et al.,* 2011). At the end of the 21-day feeding period, the administration of 2 ppm AFB1 in poultry diets significantly reduced BW and BWG and increased FCR; however, the addition of curcumin (0.2%) or Cellulosic polymers (0.3%) to the diet containing AFB1 significantly reduced its adverse effects on these performance parameters (Solis-Cruz *et al.,* 2019). Furthermore, in the present study, Feeding chicken diets with probiotic supplements, whether they were contaminated with or without AFB1, significantly increased the weight of dressing percentage and decreased fat compared to the control group. The findings demonstrate that contamination of feed with 2 ppm of AFB1 led to a significant increase in the relative weight of the liver and spleen, a considerable decrease in the relative weight of the bursa of Fabricius, and no significant difference in the relative weight of the intestine. These findings are in line with those of other investigations (Aravind *et al.,* 2003; Indresh *et al.,* 2013), which found that lipid accumulation causes an increase in the relative weight of the liver and resulting in the characteristically enlarged, friable, and fatty liver (Tung *et al.,* 1983). Additionally, the histological findings, which concur with earlier research, support the conclusions regarding the relative weight of the liver (Fan *et al.,* 2015; Tessari *et al.,* 2006).

When compared to controls, broilers fed 0.5g/kg of aflatoxin B1 showed lower weight in the gizzard, liver, and pancreas of the carcass (Nazarizadeh *et al.,* 2019). Similar findings were made by Alam *et al.* (2020), who discovered that broilers given diets contaminated with 200 and 400 ng/g aflatoxin B1 had a significantly lower dressing percentage of carcass than the control group. Furthermore, Tessari *et al.* (2006) discovered that broiler hens fed diets enriched with aflatoxin B1 at 50 and 200 g/kg of feed had significantly larger relative weights of the heart while the weights of the liver and spleen were unaffected. Broilers fed contaminated feed with 1g/kg aflatoxin B1 had considerably increased relative weights of the liver, but not the spleen (Denli *et al.,* 2009). In broiler fed feed treated with aflatoxin at 2.5 g/g compared to control group, the relative weights of the spleen, liver, and kidney were significantly increased (Huff *et al.,* 1986). Additionally, liver weight was considerably larger in broilers fed a diet containing 3 mg/kg of aflatoxin than in the control group, although heart and pancreas weight were unaffected (Santurio, 1999). Raju and Devegowda, (2000) also reported that broilers fed diets enriched with aflatoxin B1 at 0.3 mg/kg had considerably higher weights for the liver and kidneys than the control group. In addition, Khaleghipour *et al.* (2019) discovered that broiler Japanese quail fed 2.2 mg/kg aflatoxin B1 throughout the period from 7 to 35 days of age had considerably lower liver and spleen percentages than the control group. Broiler chicks fed a contaminated diet containing 0.5 mg/kg of aflatoxin B1 from 1 to 42 days of age had considerably larger livers than the control group, but their weights of the spleen, abdominal fat, and pancreas were unaffected (Saei *et al.,* 2013). Similar findings were made by Solis-Cruz *et al.* (2019), who found that broilers given a feed contaminated with 2ppm aflatoxin B1 over the period from 1 to 21 days of age had significantly larger relative weights of the liver and spleen than the control group.

## 5. Conclusion

In conclusion, the present results indicated that probiotic supplement improved production sustainability of broiler chickens exposed to Aflatoxin B1 challenge.

**Authors' Contributions**

*All authors are contributed in this research.*

**Funding**

*There is no funding for this research.*

**Institutional Review Board Statement**

*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**

*Not applicable*

**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.*

## 6. References

Alam, S., Khan, N.A., Muhammad, A., Jan, I., Hashmi, M.S., Khan, A., Khan, M.O. (2020). **'**carryover of aflatoxin b1 from feed to broilers'tissues and its effect on chicken performance**'**, *fresenius environmental bulletin*, 29, pp. 214-221.

Aravind, K., Patil, V., Devegowda, G., Umakantha, B., Ganpule, S. (2003). **'**Efficacy of esterified glucomannan to counteract mycotoxicosis in naturally contaminated feed on performance and serum biochemical and hematological parameters in broilers**'**, *Poult. Sci.*, 82, pp. 571–576.

Chen, Y., Li, R., Chang, Q., Dong, Z., Yang, H., Xu, C. (2019). **'**Lactobacillus bulgaricus or Lactobacillus rhamnosus suppresses NF-_B signaling pathway and protects against AFB1-induced hepatitis: A novel potential preventive strategy for aflatoxicosis', *Ttoxis*, 11, pp. 17.

Denli, M., Blandon, J., Guynot, M., Salado, S., Perez, J. (2009). **'**Effects of dietary AflaDetox on performance, serum biochemistry, histopathological changes, and aflatoxin residues in broilers exposed to aflatoxin B1**'**, *Poultry Science*, 88, pp. 1444-1451.

European Commission (EC). *'Directive 2002/32/EC of European Parliament and of the Council of 7 May 2002 on Undesirable Substances in Animal Feed',* Off. J. Eur. Union **2002**, L40, pp. 10–22.

Fan, Y., Zhao, L., Ji, C., Li, X., Jia, R., Xi, L., Zhang, J., Ma, Q. (2015). **'**Protective effects of Bacillus subtilis ANSB060 on serum biochemistry, histopathological changes and antioxidant enzyme activities of broilers fed moldy peanut meal naturally contaminated with aflatoxins**'**, *Toxins*, 7, pp. 3330–3343.

Freire, L., Sant., Ana, A.S. (2018). **'**Modified mycotoxins: An updated review on their formation, detection, occurrence, and toxic effects. Food Chem**',** *Toxicol.*, 111, pp. 189–205.

Hojnik, N., Cvelbar, U., Tavˇcar-Kalcher, G., Walsh, J.L., Križaj, I. (2017). **'**Mycotoxin decontamination of food: Cold atmospheric pressure plasma versus "Classic" decontamination**',** *Toxins,* **pp.** 9.

Huff, W.E., Kubena, L.F., Harvey, R.B., Hagler Jr, W.M., Swanson, S.P., Phillips, T.D., Creger, C.R. (1986). **'**Individual and combined effects of aflatoxin and deoxynivalenol (DON, vomitoxin) in broiler chickens**',** *Poultry Science*, 65(7), pp. 1291-1298.

Indresh, H., Devegowda, G., Ruban, S.W., Shivakumar, M. (2013). **'**Effects of high grade bentonite on performance, organ weights and serum biochemistry during aflatoxicosis in broilers', *Vet. World***,** 6, pp. 313–317.

Lin, M.T., Dianese, J.C. (1976). **'**A coconut production by *Aspergillus* spp**',** *Phytopathology*, 66, pp. 1466–1469.

Khaleghipour, B., Khosravinia, H., Toghiyani, M., Azarfar, A. (2019). **'**Effects of silymarin on productive performance, liver function and serum biochemical profile in broiler Japanese quail challenged with dietary aflatoxins**',** *Italian Journal of Animal Science,* 18 (1), pp. 564-573

McCormick, S.P. (2014). 'Microbial detoxification of mycotoxins**',** *J. Chem. Ecol.,* 39, pp. 907–918.

Meji-Teniente, L., Chapa-Oliver, A.M., Vazquez-Cruz, M.A., Torres-Pacheco, I., Guevara-González, R.G. (2011). **'***Aflatoxins biochemistry and molecular biology—Biotechnological approaches for control in crops',* In Aflatoxins—Detection, Measurement and Control, Torres-Pacheco, Ed., InTech Europe: Rijeka, Croatia, 2011, pp. 317–354.

Nazarizadeh, H., Mohammad Hosseini, S., Pourreza, J. (2019). **'**Effect of plant extracts derived from thyme and chamomile on the growth performance, gut morphology and immune system of broilers fed aflatoxin B1 and ochratoxin A contaminated diets**',** *Italian Journal of Animal Science*, 18, pp. 1073-1081.

Negash, D. (2018). **'**A Review of Aflatoxin: Occurrence, Prevention, and Gaps in Both Food and Feed Safety**',** *J. Appl. Microbiol. Res.*, 1, pp. 35–43.

Ostryl, V., Malir, F., Toman, J., Grosse, Y. (2017). **'**Mycotoxins as human carcinogens—the IARC Monographs classification**',** *Mycotoxin Res.*, 33, pp. 65–73.

Saei, M.M., Sadeghi, A.A., Ahmad V.H. (2013). **'**The effect of Myrtus communis oil extract on growth performance, serum biochemistry and humoral immune responses in broiler chicks fed diet containing aflatoxin B1**',** *Archives Animal Breeding,* 56, pp. 842-850.

Santurio, J. (1999). **'**Effect of sodium bentonite on the performance and blood variables of broiler chickens intoxicated with aflatoxins**',** *British Poultry Science,* 40, pp. 115-119.

SAS, Institute. (2009). *'User's Guide: Statistics',* Version 9.2. SAS Institute, Inc., Cary, NC, USA

Sherif, S.O., Salama, E.E., Abdel-Wahhab, M.A. (2009). **'**Mycotoxins and child health: The need for health risk assessment**',** *Int. J. Hyg. Envir. Heal.*, 212, pp. 347–368.

Śliżewska, K., Cukrowska, B., Smulikowska, S., Cielecka-Kuszyk, J. (2009). **'**The Effect of Probiotic Supplementation on Performance and the Histopathological Changes in Liver and Kidneys in Broiler Chickens Fed Diets with Aflatoxin $B_1$**',** *Toxins, 11,* pp. 112. https://doi.org/10.3390/toxins11020112

Solis-Cruz, B., Hernandez-Patlan, D., Petrone, V.M., Pontin, K.P., Latorre, J.D., Beyssac,E., Hernandez-Velasco, X., Merino-Guzman, R., Arreguin, M.A., Hargis, B.M. (2019).

'Evaluation of a Bacillus-based direct-fed microbial on aflatoxin B1 toxic effects, performance, immunologic status, and serum biochemical parameters in broiler chickens', *Avian diseases*, 63, pp. 659-669.

Solis-Cruz, B., Hernandez-Patlan, D., Petrone, V.M., Pontin, K.P., Latorre, J.D., Beyssac, E., Hernandez-Velasco, X., Merino-Guzman, R., Owens, C., Hargis, B.M., Lopez-Arellano, R., Tellez-Isaias, G. (2009). 'Evaluation of Cellulosic Polymers and Curcumin to Reduce Aflatoxin B1 Toxic Effects on Performance, Biochemical, and Immunological Parameters of Broiler Chickens', *Toxins*, 11, pp. 121. https://doi.org/10.3390/toxins11020121

Suganthi, R.U., Suresh, K., Parvatham, R. (2011). 'Effect of aflatoxin on feed conversion ratio in broilers: Ameta-analysis', *Asian-Aust. J. Anim. Sci.*, 24, pp. 1757–1762.

Tessari, E., Oliveira, C., Cardoso, A., Ledoux, D., Rottinghaus, G. (2006). 'Effects of aflatoxin B1 and fumonisin B1 on body weight, antibody titres and histology of broiler chicks', *British poultry science,* 47, pp. 357-364.

Tessari, E., Oliveira, C., Cardoso, A., Ledoux, D., Rottinghaus, G. (2006). 'Effects of aflatoxin B1 and fumonisin B1 on body weight, antibody titres and histology of broiler chicks', *Br. Poult. Sci.,* 47, pp. 357–364.

Tung, H.T., Donaldson, W., Hamilton, P. (1983). 'Altered lipid transport during aflatoxicosis', *Toxicol. Appl. Pharmacol.*, 22, pp. 97–104.

Yunus, A.W., Razzazi-Fazeli, E., Bohm, J. (2011). 'Aflatoxin B1 in affecting broiler's performance, immunity, and gastrointestinal tract: A review of history and contemporary issues', *Toxins,* 3, pp. 566–590.