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Effect of Dietary Esterified Glucomannan on the Performance of Broiler Chickens During Experimental Aflatoxicosis

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ABSTRACT

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The amelioration effect of dietary esterified glucomannan (EGM) was studied in experimental aflatoxicosis using broiler chickens. Day-old chicks (n=270) were divided into 6 treatment groups, containing 45 numbers in each and the study was made in triplicates for 6 weeks. A control ration was prepared with conventional feedstuffs and an experimental diet was made from this ration after incorporating aflatoxin (AF) B_1 at 300 ppb. From experimental diet, three rations were prepared by mixing EGM at graded levels i.e., 0.025, 0.05 or 0.10%; whereas, the positive control diet had 0.05% EGM. Significantly ($P<0.05$) higher BW gain was recorded in the control as well as positive control birds as compared to all treated groups. Toxin-alone fed group showed significantly lowest BW. Feeding of EGM could partially improve the BW of toxin fed broilers. The feed consumption in toxin-fed groups were significantly depressed; however, there was partial improvement due to the supplementation of EGM in their diets. The feed efficiency was also inferior in the toxin-alone fed group; however, when EGM was supplemented there was significant ($P<0.05$), though partial improvement. The cost of feeding per kg live weight was found to be lowest in control group whereas highest in toxin-alone fed group; nevertheless, dietary EGM reduced cost of feeding. The highest performance index was noted in control group whereas the lowest in toxin-alone fed group. Among the various treatments, 0.10 per cent of EGM gave the best results.

Keywords: Aflatoxicosis, Broiler chicken, Esterified glucomannan, Performance.

INTRODUCTION

Aflatoxin producing moulds like *Aspergillus flavus* and *Aspergillus parasiticus* grow well in common poultry feed ingredients under congenial atmosphere of moisture (12% or above), relative humidity (80-90% or above) and temperature (between 10-

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42°C). Aflatoxicosis occurs by direct consumption of toxin contaminated feeds and among the animals, poultry has been recognized as one of the most susceptible (Diazand Murcia, 2011). The disease causes great economic loss in poultry production resulting from poor growth rate and increased feed-to-gain ratio due to impaired protein metabolism. (Sapcota *et al*., 2009; Liu *et al*., 2011). Extensive research has been conducted as regards to prevention and control of aflatoxicosis by the use of various chemicals or dietary supplementation of certain agents. Zeolite (Miazzo *et al*., 2000), activated charcoal (Edrington *et al*., 1997), inorganic sorbents (Baily *et al*., 1998) and a blend of organic acids and aluminosilicates (Mahesh and Devegowda, 1996) have shown considerable promise in detoxifying aflatoxins in contaminated feeds. Several yeasts and moulds have been reported to possess the ability to either destroy or biotransform the aflatoxin (Mahesh and Devegowda, 1996). The use of yeast culture derivative (Mycosorb) to solve the health problem is a recent concept. Esterified glucomannan is a cell wall of yeast that has received much attention in the recent past in minimizing the adverse effects of aflatoxin contaminated diets in poultry. Further, it is also found beneficial as a low-inclusion binder in minimizing the adverse effects of aflatoxins present in contaminated livestock and poultry feeds (Karaman *et al.,* 2005; Girish and Devegowda, 2006). For understanding the effect of Mycosorb on aflatoxin detoxification, a study was conducted to investigate its effect on performance of broiler chickens during aflatoxicosis.

MATERIALS AND METHODS

Aflatoxin B_1 was produced in the laboratory through solid substrate fermentation in broken rice using pure culture of *Aspergillus parasiticus*, NRRL 2999 strain (Shotwell *et al*., 1966). The fermented rice was autoclaved (15 lbs pressure for 15 min) to kill the fungi, dried at 55-60°C for overnight, ground to powder form and its AFB1 content was measured by the method of Romer (1975) using TLC. A standard basal diet was prepared with toxin-free conventional feedstuffs as per BIS (1992) and the rice powder along with known amount of AFB_1 was incorporated into it to provide the desired level of 300 ppb of toxin per kg of diet. Mycosorb (Esterified glucomannan) required for the experiment was procured from M/s Alltech Biotechnology Pvt. Ltd, Bangalore. Dietary treatments is given in Table 1.

Table 1. Experimental groups and dietary treatments

Group	Treatments	
	AFB_1 (ppb)	EGM (%)†
T_0	-	-
Tx	300	-
TxM_1	300	0.025
TxM_2	300	0.05
TxM_3	300	0.10
T_0M_2	-	0.05

†Esterified glucomannan.

All the experimental diets were iso-caloric and iso-nitrogenous (Table 2). Altogether 270 numbers of day-old commercial chicks with uniform body weight were distributed randomly into 6 treatment groups. Each group had a total of 45 numbers of chicks in triplicates of 15 numbers, housed in iron battery cage under optimal managemental conditions from day-old to 42 days. The birds were offered water and feed *ad libitum*

Table 2. Ingredient and nutrient composition of the experimental diets

	Starter (0-3 weeks)	Finisher (4- 6 weeks)
Ingredients (%)		
Maize	50.0	52.0
Rice polish	6.0	12.5
Groundnut cake	11.0	11.0
Soybean meal	20.75	12.0
Fish meal	6.0	6.0
Sunflower meal	4.0	4.0
Mineral mixture† and vitamin‡	2.0	2.0
Salt	0.5	0.5
Nutrients		
ME§ (kcal/kg)	2797.63	2842.48
Crude protein§ (%)	22.83	19.68
Lysine§ (%)	1.0903	0.9328
Methionine§ (%)	0.42005	0.4205
Calcium (%)	1.30	1.40
Available phosphorus (%)	0.70	0.85

†Poultry mineral mixture (M/s. Aries Agro-vet Industries Pvt. Ltd., India) containing: Ca (32%), P (6%), Cu (100 ppm), Mn (2700 ppm), I (100 ppm), Zn (2600 ppm) Mg (1000 ppm) and Fe (0.1%).

‡AB_2D_3K Feed premix (Spectro Mix; 20 g/100 kg diet) containing per gram: vitamin A (82,500 IU), vitamin B2 (50mg), vitamin D3 (12000 IU), vitamin K (10 mg).

§Calculated value.

throughout the experimental period of 6 weeks. They were weighed individually and feed consumption was recorded at weekly interval to calculate the feed conversion ratio.

The data obtained on various parameters studied during this experimental trial were subjected to statistical analyses as described by Snedecor and Cochran (1994).

RESULTS AND DISCUSSION

Body weight changes

The broilers fed with aflatoxin B_1 (300 ppb) treated diet started losing BW significantly and consistently as compared to control counterpart from 3rd week onwards (Table 3). At 6th week, there was 43.75% growth depression in aflatoxin-alone fed group as compared to that of control. Significant ($P<0.05$) reduction in body weight of aflatoxin-fed chicken was also reported by Nemati *et al.* (2015) and Kumar *et al.* (2015). The depression of body weight in aflatoxin fed group might be due to inhibition of protein synthesis and reduced feed intake (Yang *et al.,* 2012), reduced nutrient utilization (Ahmed, 2005), increased lipid excretion in droppings, impaired nutrient absorption and reduced pancreatic digestive enzyme production (Marchioro *et al.,* 2013). Shareef and Omar

Table 3. Influence of dietary supplementation of EGM on BW (g), feed intake (g) and FCR of broilers fed with aflatoxin

Treatment	Week 3			Week 6		
	BW	Feed intake	FCR	BW	Feed intake	FCR
T_0	$626.88^{b}\pm12.28$	$488.60^{b}\pm23.22$	$1.57^{ab}\pm0.03$	$2012.56^{de}\pm20.22$	$1119.77^{c}\pm31.62$	$2.02^{a}\pm0.06$
Tx	$405.23^{a}\pm10.85$	$344.61^{a}\pm18.62$	$1.98^{c}\pm0.04$	$1131.87^{a}\pm59.70$	$750.31^{a}\pm26.13$	$2.65^{d}\pm0.05$
TxM_1	$467.55^{ab}\pm9.58$	$402.98^{a}\pm10.13$	$1.92^{c}\pm0.04$	$1355.90^{b}\pm53.24$	$800.72^{a}\pm27.15$	$2.49^{c}\pm0.06$
TxM_2	$570.79^{b}\pm14.15$	$419.05^{b}\pm24.00$	$1.71^{b}\pm0.03$	$1690.56^{c}\pm42.48$	$1031.31^{b}\pm27.36$	$2.27^{b}\pm0.05$
TxM_3	$602.20^{b}\pm19.41$	$495.02^{b}\pm23.75$	$1.70^{b}\pm0.03$	$1850.19^{cd}\pm61.17$	$1049.73^{b}\pm28.52$	$2.10^{b}\pm0.05$
T_0M_2	$639.78^{c}\pm10.72$	$531.55^{b}\pm24.63$	$1.52^{a}\pm0.02$	$2035.89^{e}\pm24.77$	$1132.46^{c}\pm31.86$	$2.05^{a}\pm0.06$

[abcd]Means with different superscripts in a column differ significantly ($P<0.05$).

Table 4. Cost of feeding per kg live weight gain of broilers under different treatment groups

Groups	Feed consumed (kg)		Feed cost per kg (₹)		Cost of feeding (₹)			Total BW gain (kg)	Cost of feeding per kg LW gain (₹)	Cost difference over control (₹)
	Starter	Finisher	Starter	Finisher	Starter	Finisher	Total			
T_o	1.50	1.92	11.76	10.82	17.64	20.77	38.41	1.962	19.58	-
T_x	1.12	1.37	11.76	10.82	13.17	14.82	27.99	1.082	25.87	-6.29
T_xM_1	1.27	1.49	11.76	10.82	14.94	16.12	31.23	1.306	23.91	-4.33
T_xM_2	1.40	1.75	11.76	10.82	16.45	18.94	35.80	1.640	21.83	-2.25
T_xM_3	1.46	1.79	11.76	10.82	17.17	19.37	37.35	1.800	20.75	-1.17
T_0M_2	1.50	1.95	11.76	10.82	17.64	21.10	39.17	1.986	19.72	-0.14

(2012) suggested that reduced appetite during aflatoxicosis could be due to impaired liver metabolism caused by liver damage.

However, the growth depression was found to be improved when different doses of EGM (0.025, 0.05 or 0.10%) was incorporated in the aflatoxin treated groups from 3rd week onwards. The dose related effect of EGM was more prominent as the age of birds advanced. In 6th week the amelioration was found to be 19.80, 49.43 or 63.57%, respectively for low, medium and high dose of EGM in the diet. Among the toxin binder fed groups, both medium and high doses yielded better result consistently than the other two aflatoxicated groups. Similar findings were observed by Girish and Devegowda (2004) and Basmacoglu *et al.* (2005). Raju and Devegowda (2000) reported that addition of EGM (1 g/kg diet) increased body weight by 2.26% in aflatoxicated broiler chickens. Karaman *et al.* (2005) noted ameliorating effect of yeast glucomannan in broilers during aflatoxicosis. Although the precise mode of action of EGM is not known, it is hypothesized that EGM might trap the mycotoxin molecule in its glucomannan matrix and prevent toxin absorption from the gastrointestinal tract (Raju and Devegowda, 2000). These beneficial effects of EGM might have attributed to its ability to trap the mycotoxins in the gastrointestinal tract (Girish and Devegowda, 2006). There was no significant ($P>0.05$) improvement of BW by the addition of EGM to the control diet as compared to basal diet.

Gain in BW was decreased due to aflatoxicosis as was observed in the aflatoxin fed groups, from the 3rd week onwards and the extent of decrease was more prominent as the age advanced (Table 3). Decreased BW gain in aflatoxin-fed broilers might be due to impaired protein metabolism. Similar finding was observed by Kumar *et al.* (2015). However, addition of EGM at increasing doses could be able to counteract the depressing effect of aflatoxin proportionately. At the 6th week, there was 44.93% reduction in body weight gain in aflatoxin fed group as compared to control group; however, after incorporation of EGM at 0.025, 0.05 or 0.10% the depression effect of weight gain was reduced to 20.71, 34.05 or 39.96%, respectively. Similar findings were observed by Basmacoglu *et al.* (2005) and Yildirim *et al.* (2011)

Feed consumption

The impact of feeding aflatoxin on feed intake was noticed after 3rd week (Table 3). As the age of broiler progressed, the anorexic effect of dietary aflatoxin was more spectacular. In the 5th and 6th weeks the aflatoxin-alone fed group consumed 21.95% and 32.99% less feed as compared to the control group. Similar adverse effects of dietary aflatoxin on appetite were also reported by Sapcota *et al.* (2006), Indresh *et al.* (2013) and Hedayati *et al.* (2014). However, dietary addition of Mycosorb as a counteracting agent in aflatoxin fed groups could improve the anorexic condition reflecting in higher feed consumption. Though ameliorative effect of dietary EGM was varying, the best effect was observed in the groups fed either medium dose (0.05%) or high dose (0.10%). Raju and Devegowda (2000) reported that supplementation of 1 g/kg EGM to the diet containing 0.3 mg aflatoxin/kg caused 1.6% increase in feed intake of broiler chicks. Similar result has been recorded by Girish and Devegowda (2006).

Feed conversion ratio

Dietary inclusion of aflatoxin significantly affected the FCR of broilers from the 3rd week onwards (Table 3). In 6th week significantly poorer FCR was observed in aflatoxin-alone fed group as compared to control group. Similar findings were reported by Sapcota *et al.* (2004, 2005), and Nemati *et al.* (2015). The poor feed efficiency might be due the affect on appetite and negative impact on protein synthesis. However, improvement of feed conversion ratio was observed when aflatoxin added diet was fortified with EGM as counteracting agent. This was gradual and more prominent as the age progressed. On 4th, 5th and 6th week the counteraction was complete, as evident by comparable FCR between the groups fed high dose of EGM (0.10%) with that of control group. This finding is in agreement with the observations of Girish and Devegowda (2004) and Karaman *et al.* (2005). Ghahri *et al.* (2010) observed improved feed efficiency in aflatoxin containing diet, when supplemented with the esterified glulucomannan (1 kg/ton).The beneficial effect might be due to the ability of EGM to trap the aflatoxin irreversibly (Devegowda *et al.,* 1998).

Livability

The highest livability (100%) was observed in control as well as in Mycosorb fed control groups all throughout experimental period (Fig. 1), whereas, the lowest livability was observed in aflatoxin-alone fed group (86.67%). The poor livability due to dietary aflatoxicosis was also reported by Gogoi (2003) and Ahmed (2005). However, livability was improved due to incorporation of Mycosorb in the diet of aflatoxin treated groups. Among these groups, T_XM_2 showed better livability (97.78%) followed by T_XM_3 (95.56%) and TxM_1 (93.33%) groups which might be due to the dose related counteraction of EGM against aflatoxicosis.

Performance index

Among the various treated groups apparently the best performance index (PI) (491.47) was found to be observed in the control group, whereas, the poorest (184.64) was recorded in the toxin-alone fed group (Fig. 2). The lower BW gain, higher FCR as well as poor livability might have contributed for poor PI in toxin-alone fed group. Among the toxin treated groups the performance indices observed were better when the diet was enriched with EGM. Among the toxin-fed groups the response was dose related; the best index was recorded in TxM_3 group (417.20) where the EGM was used at 0.10%. This was followed by TxM_2 (367.83) and TxM_1 (257.08).groups.

Production economy

The lowest cost of feeding/kg LW was observed in the control group whereas, the highest was noted in aflatoxin-alone fed group (₹19.58 vs. ₹25.87; Table 4). The poor weight gain due to the adverse effect of aflatoxin might have contributed for high cost. Similar observations were noted by Gogoi (2003) and Ahmed (2005). However, incorporation of EGM in the aflatoxin treated diets showed improvement in the cost of feeding. This might be due to the reversal effect of EGM against aflatoxicosis.

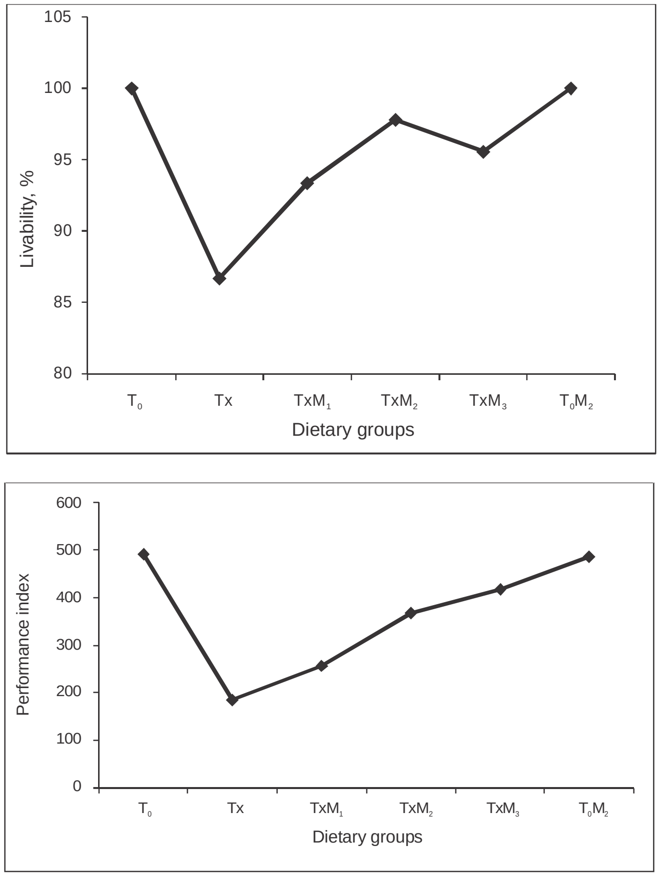

Fig. 1. Livability (%) and performance index of broilers

The cost of production per kg live broiler was found to be highest in aflatoxin-alone fed group (₹ 39.61) whereas, the lowest in control group (₹ 33.11). The highest cost of production might be due to its higher cost factor in aflatoxin fed birds as compared to other groups. However, addition of high dose of EGM showed better result (₹ 34.40) as compared to the lower dose (₹ 37.54) and medium dose (₹ 35.47). On the other hand, addition of EGM in the control diet gave no additional benefit as compared to the group fed basal diet.

CONCLUSIONS

From the above study it could be concluded that feeding of dietary aflatoxin affects important zootechnical characteristics, livability, performance indices and economy. However, addition of esterified glucomannan (Mycosorb) in the diet of broiler could ameliorate these problems. Among the three doses of this counteracting agent (0.25 g, 0.5 g or 1.0 g/kg feed) the highest one has been found to be the best in reversing the various adverse effects of broilers encountered in experimental aflatoxicosis

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REFERENCES

Ahmed, S.U. 2005. *Effect of Garlic (Allium Sativum) in Counteracting the Aflatoxicosis in Broilers*. MVSc Thesis, Assam Agricultural University, Jorhat, India.

Baily, R.H., Kubena, L.F., Harvey, R.B., Buckley, S.A. and. Rottinghaus, G.E. 1998. Efficacy of various inorganic sorbents to reduce the toxicity of aflatoxin and T-2 toxin in broiler chickens. *Poultry Science*, 77: 1623–1630.

Basmacoglu, H., Oguz, H., Ergul, M., Col, R. and Brdane, Y.O. 2005. Effect of dietary esterified glucomannan on performance, serum biochemistry and hematology in broiler exposed to aflatoxin. *Czech Journal of Animal Science,* 50: 31-39.

BIS. 1992. *Nutrient Requirements of Poultry*. Bureau of Indian Standards, New Delhi, India.

Cravens, R.L., Goss, G.R., Chi, F., De Boer, E.D., Davis, S.W., Hendrix, S.M., Richardson, J.A. and Johnston, S.L. 2013. The effects of necrotic enteritis, aflatoxin B_1 and virginiamycin on growth performance, necrotic enteritis lesion scores and mortality in young broilers. *Poultry Science*, 92: 1997–2004

Devegowda, G., Raju, M.V.L.N., Afzali, N. and Swamy, H.V.L.N. 1998. Mycotoxin picture worldwide: novel solutions for their counteraction. In: *Biotechnology in the Feed Industry, Proceedings, of the 14th Annual Symposium* (Eds. T.P. Lyons and K.A. Jacques). Nottingham University Press, Nottingham, England, pp. 291-255.

Diaz, G.J. and Murcia, H.W. 2011. Biotransformation of aflatoxin B_1 and its relationship with the differential toxicological response to aflatoxin in commercial poultry species. In: *Aflatoxins-Biochemistry and Molecular Biology* (Ed. R.G. Guevara-Gonzalez). InTech Europe, Rijeka, Croatia, pp. 3-20.

Edrington, T.S., Kubena, L.F., Harvey, R.B. and Rottinghaus, G.E. 1997. Influence of super activated charcoal on the toxic effects of aflatoxin or T-2 toxins in growing broilers. *Poultry Science*, 76: 1205-1211.

Ghahri, H., Reza, H. and Mehdi, A.F. 2010. Evaluation of the efficacy of esterified glucomannan, sodium bentonite, and humic acid to ameliorate the toxic effects of aflatoxin in broilers. *Turkish Journal of Veterinary and Animal Science*, 34: 385-391

Girish, C.K. and Devegowda, G. 2004. Evaluation of modified glucomannan (Mycosorb) and hydrated sodium calcium aluminosilicate to ameliorate the individual and combined toxicity of aflatoxin and T-2 toxin in broiler chickens. *Proceeding Australian Poultry Science Symposium.* 16: 126–129.

Girish, C.K. and Devegowda, G. 2006. Efficacy of glucomannan-containing yeast product (Mycosorb) and hydrated sodium calcium aluminosilicate in preventing the individual and combined toxicity of aflatoxin and T-2 toxin in commercial broilers. *Asian-Australian Journal of Animal Sciences*, 19: 877–883.

Gogoi, R. 2003. *Studies on the Ameliorating Effect of Curcuma longa on Aflatoxicosis in Broilers*. MVScThesis, Assam Agricultural University, Jorhat, India.

Gholami-Ahangaran, M. and Zia-Jahromi, N. 2013. Nanosilver effects on growth parameters in experimental aflatoxicosis in broiler chickens. *Toxicology and Industrial Health,* 29: 121-125.

Hedayati, M., Manafi, M. and Yari, M. 2014. Aflatoxicosis in broilers: efficacy of a commercial mycotoxin binder on performance and immunity parameters. *International Journal of Ecosystem*, 4: 176-183.

Indresh , H.C., Devegowda, G., Wilfred, R.S. and Shivakumar, M.C. 2013. Effects of high grade bentonite on performance, organ weights and serum biochemistry during aflatoxicosis in broilers, *Veterinary World*, 6: 313-317.

Kamalzadeh, A., Hosseini, A. and Moradi, S. 2009. Effects of yeast glucomannan on performance of broiler chickens. *International Journal of Agricultural Biology*, 11: 49–53.

Karaman, M., Basmacoglu, H., Ortatati, M. and Oguz, H. 2005. Evaluation of the detoxifying effect of yeast glucomannan on aflatoxicosis in broilers as assessed by gross examination and histopathology. *British Poultry Science*, 46: 394-400.

Kumar, C.B., Reddy, B.S.V., Gloridoss, R.G., Prabhu, T.M., Suresh B.N. and Kumar, S.N. 2015. Amelioration of aflatoxicosis through a bio-technologically derived aflatoxin degrading commercial product in broilers. *Pakistan Veterinary Journal*, 35: 217-221.

Kumar Dhanapal, S., Rao, S., Govindaraju, P.K.P., Hukkeri R. and Mathesh, K. 2014. Ameliorative efficacy of citrus fruit oil in aflatoxicosis in broilers: a growth and biochemical study. *Turkish Journal of Veterinary and Animal Sciences*, 38: 207-211.

Liu, Y.L., Meng, G.Q., Wang, H.R., Zhu, H.L., Hou, Y.Q., Wang, W.J. and Ding, B.Y. 2011. Effect of three mycotoxin adsorbents on growth performance, nutrient retention and meat quality in broilers fed on mould-contaminated feed. *British Poultry Science*, 52: 255–263.

Mahesh, B.K. and Devegowda, G. 1996. Ability of aflatoxin B_1 binders to bind aflatoxin B_1 in liquid media - an in vitro study. In: *Proceeding 20th World's Poultry Congress*, New Delhi, India, 4: 295-296.

Marchioro, A., Mallmann, A.O., Diel, A., Dilkin, P., Rauber, R.H., Blazquez, F.J.H., Oliveira, M.G.A. and Mallmann, C.A. 2013. Effects of aflatoxins on performance and exocrine pancreas of broiler chickens. *Avian Disease*, 57: 280-284.

Miazzo, R., Rosa, C.A.R., Queiroz Carvalho, E.C.D., Magnoli, C., Chiacchiera, S.M., Palacio, G., Saenz, M., Kikot, A., Basaldella, B. and Dalcero, A. 2000. Efficacy of synthetic zeolite to reduce the toxicity of aflatoxin in broiler chicks. *Poultry Science,* 78: 1–6.

Murthy, T.N.K. and Devegowda, G. 2004. Efficacy of modified glucomannan (Mycosorb) to absorb aflatoxin B_1 in gut conditions of broiler chickens. In: *Proceeding 22nd World's Poultry Congress,* Istanbul, Turkey, p. 471.

Nemati, Z., Karimi, A. and Besharati, M. 2015. Impact of aflatoxin contaminated feed and yeast cell wall supplementation on immune system in broiler chickens. In: *Proceedings of International Conference on Innovations in Chemical & Agricultural Engineering,* February 8-9, 2015, Kuala Lumpur, Malaysia.

Osborne, D.J., and Hamilton, P.B. 1981. Decreased pancreatic digestive enzymes during aflatoxicosis. *Poultry Science*, 60: 1818–1821.

Raju, M.V.L.N. and Devegowda, G. 2000. Influence of esterified glucomannan on performance of organic morphology, serum biochemistry and haematology in broilers exposed to individual and combined mycotoxicosis (aflatoxin, ochratoxin and T2 toxin). *British Poultry Science,* 41: 640-650.

Reddy, A.R., Reddy V.R., Rao, P.V. and Yadagiri, B. 1982. Effects of experimentally induced aflatoxicosis on the performance of commercial broiler chicks. *Indian Journal of Animal Science,* 52: 405-410.

Romer, T.R. 1975. Screening method for the detection of aflatoxins in mixed feed and other agricultural commodities with subsequent confirmation and quantitative measurement of aflatoxins in positive samples. *Journal of the Association of Official Analytical Chemists,* 58: 500-506.

Sapcota, D., Gogoi, R. and Gohain, A.K. 2009. Economic advantages of supplementation of dietary Curcuma longa during induced aflatoxicosis in broilers. *Indian Journal of Animal Sciences,* 79: 942-944.

Sapcota, D., Islam, R and Baruah K.K. 2004. Protective efficacy of vitamin E in experimental aflatoxicosis in broilers. *Indian Journal of Animal Nutrition,* 21: 45-48.

Sapcota, D., Islam, R. and Upadhyaya, T.N. 2006. Dietary supplementation of *Emblica officinalis* for amelioration of experimental aflatoxicosis in commercial broilers. *Animal Nutrition and Feed Technology*, 6: 65-71.

Sapcota, D., Islam, R., Upadhyaya, T.N. and Medhi, A.K. 2005. Efficacy of *Andrographis paniculata* in ameliorating aflatoxicosis. *Indian Veterinary Journal,* 82: 529-532.

Shareef, A.M. and Omar, E.K.S. 2012. Effect of Synertox® on broiler health and performance during aflatoxicosis. *Iraqi Journal of Veterinary Sciences*, 26: 27-34.

Shotwell, O.L., Hesseltine, C.W., Stubblefield, R.D. and Sorenson, W.G. 1966. Production of aflatoxin on rice. *Applied Microbiology*, 14: 425-428.

Smith, J.W. and Hamilton, P.B. 1970. Aflatoxicosis in broiler chickens. *Poultry Science,* 49: 207-215.

Snedecor, G.W. and Cochran, W.G. 1994. *Statistical Methods,* 8th ed. Iowa State University Press, Ames, IA, USA.

Yang, J., Bai, F., Zhang, K., Bai, S., Peng, X., Ding, X., Li, Y., Zhang, J and Zhao, L. 2012. Effect of feeding corn naturally contaminated with aflatoxin B1 and B2 on hepatic functions of broilers. *Poultry Science*, 91: 2792-2801.

Yildirim, E., Yalçinkaya, I., Kanbur, M., Cinar, M. and Oruç, E. 2011. Effects of yeast glucomannan on performance, some biochemical parameters and pathological changes in experimental aflatoxicosis in broiler chickens. *Revue de Medecine Véterinaire*, 162: 413-420.