Research Article

Assessing the Ameliorating Effects of Adsorbents on the Health and Performance of Ducklings fed mold (Fungal) Contaminated Diets

Anthony C Mgbeahuruike[1*], Ifeoma Emmanuela Nwoko[2], Chinyere T Nwaoga[3], Onyinye Okorie-Kanu[4]

[1]Department of Veterinary Pathology and Microbiology, Faculty of Veterinary Medicine, University of Nigeria, Nsukka

[2]Department of Human Kinetics and Health Education, Faculty of Education, University of Nigeria, Nsukka

[3]Center for Entrepreneurship Development Research, University of Nigeria, Nsukka

[4]Department of Public Health and Preventive Medicine, Faculty of Veterinary Medicine, University of Nigeria, Nsukka

***Corresponding Author:** Anthony C Mgbeahuruike, Department of Veterinary Pathology and Microbiology, Faculty of Veterinary Medicine, University of Nigeria, Nsukka, Nigeria; Tel: +234-8039253623; E-mail: Anthony.mgbeahuruike@unn.edu.ng

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Abstract

Adsorbents are important feed additives for aflatoxin detoxification in feeds. The study investigated the efficacy of locally available adsorbents in mycotoxin detoxification of duckling feed. Bentonite and fuller's earth were added to aflatoxin contaminated duckling feeds and the level of decontamination of the feeds was measured using High Performance Liquid Chromatography (HPLC). Hematological, serum biochemical and performance parameters of the ducklings were measured. Addition of bentonite resulted in 44% reduction of total aflatoxin levels in the feed while the fuller's earth caused 59% reduction. Both adsorbents reduced the aflatoxin level below 20 µg/kg threshold recommended by the United States Food and Drug Administration (USFDA). The fuller's earth resulted in 13% weight increase in the ducklings that ate the feed treated with adsorbent compared with the control that had no adsorbent treatment. There was

increased white blood cell counts (WBC) in the group treated with bentonite (29%) compared with the untreated group. There was also 20% increase in pack cell volume (PCV) of the ducklings that were given the fuller's earth treated feed compared with the untreated control. In the ducklings that ate the adsorbent treated feeds, the liver enzymes, increased from 27.9 to 62.0IU/L for Aspartate aminotransferase (AST), 20.5 to 55.7IU/L for Alanine aminotransferase (ALT) and 29.4 to 50.7IU/L for Alkaline phosphatase (ALP) respectively, while glutathione peroxidase was reduced from 106.0 to 42.2 IU/L by the fuller's earth. In conclusion, the adsorbents caused a significant reduction of the aflatoxin concentration in the feed and positively improved the performance parameters of the ducklings. The two adsorbents (bentonite and fullers' earth) are potential feed additives that can be incorporated in feed during production to reduce the adverse effects of mycotoxins in poultry.

Keywords: Adsorbents; Aflatoxin; Bentonites; Ducklings; Feed

Introduction

Aflatoxins (AFs) are mycotoxins produced by Aspergillus species (Ali et al., 2005; Alcaide-Molina et al., 2009; Adeniran et al., 2013; Mgbeahuruike et al., 2018). Aflatoxins are carcinogenic, hepatotoxic, teratogenic and mutagenic on human and animal health (Zain, 2011; Mgbeahuruike et al., 2018). However, aflatoxin B1 (AFB1) appears to be the most toxic of all the known fractions of aflatoxin because of its higher hepatotoxic and hepatocarcinogenic properties (Mgbeahuruike et al., 2018). Most avian species including ducklings are highly susceptible to AF toxicity (Monson et al., 2015). In birds, doses of aflatoxin as low as 30µg/kg could negatively affect vital organs, avian physiology and can also depress the immune system of the affected birds (Ezekiel et al., 2012; Cegielska-Radziejewska et al., 2013). In Northern Ireland, aflatoxin was reported to be responsible for the death of over 100,000 Turkeys in 1960 (Blout, 1961). Grains with low concentration of aflatoxin may impair resistance of waterfowl to infectious diseases (Smith et al., 1990). Aflatoxicosis in poultry production is more common in ducks than chickens (Bintvihok, 2001). Low concentrations of deoxynivanelon (1.2mg/kg DON), fumonisin (4.5 mg/kg) and aflatoxin B1 (0.01 mg/kg) caused serious mortality in White Pekin ducklings (Davis et al., 1994). Muscovy ducklings (Cairina muschata) are sensitive to T-2 toxins and diacetoxyscirpenol (Alan et al., 1986). This sensitivity makes them good candidates for mycotoxin (trichothecenes and aflatoxins) bioassay in animals.

In the United States, the limit of concentration of aflatoxin in domestic chicken feeds is 20 µg/kg (USFDA, 2019) while the threshold level set by the European Union Commission for the same aflatoxin in chicken feed is 10 µg/kg. However, there is lack of information on the limits of concentration of aflatoxins in feeds for duckling production. The global per-capita duck meat consumption is over 600g per year and this figure is increasing at 3.4 per cent per year (Adzitey and Adzitey, 2011). Ducks are fed on mashed feed comprising of different feed ingredients. Feeds of duckling are regularly faced with the problem of aflatoxin contamination. Approaches for reducing aflatoxin concentration in the feed include biological methods and reducing the moisture content in feed by drying grains before storage (Schaller, 2009). Additionally, the use of microbial products which absorb mycotoxins from contaminated feeds has also

been reported (Xiao et al., 1991). Use of feed additives known as adsorbents as detoxifying agents have also been recommended (Oguz et al., 2000; Kana et al., 2006; Mgbeahuruike et al., 2018). These adsorbents prevent the absorption of mycotoxins by binding to them in the gastroinstinal tract. However, many commercially available adsorbents in the market such as aluminosilicates and esterified glucomannan are expensive and are not commonly accessed by local poultry farmers (Girish and Smith, 2008; Mgbeahuruike et al., 2018). Fuller's earth and bentonite which can be locally obtained have therefore become attractive as alternatives to commercial adsorbents. Bentonite is structurally composed of montmorillonit and several other mineral components. Bentonite has been reported as an effective detoxifying agent for aflatoxin contaminated feed (Bhatti et al., 2018; Mgbeahuruike et al., 2018). On the other hand, fuller's earth is a 3-dimensionally structured compound made of successively arranged layers of oxygen (O) and hydroxyl (OH) connected to other minerals like silicon (Si), aluminum (Al) and magnesium (Mg) (Tyagi et al., 2006).

The present study, investigated the efficacy of bentonite and fuller's earth as detoxifying agents for aflatoxin contaminated feed and their ability to reduce the adverse impacts of the aflatoxin contaminated diets on the growth and productivity of ducklings was tested. The results from the experiment are reported below in accordance with the method for reporting in vivo experiments in animals, as outlined in (ARRIVE) guidelines.

Materials and Methods

Duckling management

One hundred and eight 2-weeks old Muscovy ducklings (Cairina moschata) purchased from a farmer at the National Veterinary Research Institute Vom, Plateau State, were used for the study. The ducklings were housed for acclimatization in a 1x1 m2 pen; in a small poultry house domiciled in the Department of Animal Health and Production, Faculty of Veterinary Medicine, University of Nigeria, Nsukka. The pens were laid with wood shavings. During the acclimatization period, the ducklings were provided with freshly prepared uncontaminated commercial starter feeds formulated according to previously prepared protocol (NRC, 1998). Routine treatments were administered to the ducklings before they were moved to 0.5 x 0.5 m2 pens in the same poultry house. The ducklings were divided into 3 treatment groups, with 6 replicates per treatment and 6 ducklings per replicate. The ducklings were allowed free access to water and feed, the pens were well illuminated with proper ventilations. During the period of the experiment, the ducklings were handled with strict compliance with the revised version of the Animals Scientific Procedures Act of 1986 for the care and use of animals for research purposes.

Dietary Treatment

The study area is Nsukka and it is located in the South Eastern part of Nigeria. It has latitude longitude coordinates of 6°51'28.19"N and 7°23'44.77"E respectively. Majority of the rural population in Nsukka are farmers with a reasonable number practicing poultry production. The trial feeds were purchased from Nsukka Enugu State Nigeria. The nutrient content and chemical composition of the feeds were provided and boldly labeled on the feed bags by the producers. Feed treatments were previously described in this species (Mgbeahuruike et al., 2018).

Briefly, feeds were thoroughly mixed and packed into a big dark nylon bag. Feeds were sprinkled with water until they were fully wetted to create enough humidity for mold growth. The nylon bags were tightly closed and the feeds were stored for 3-4 wks in a room with a temperature of about 30°C, until visible growths of mold were observed. The treated feeds were given to 3 groups of ducklings: (1) ducklings fed contaminated but untreated feed (CO), (2) ducklings fed contaminated feed treated with bentonite (CO+B) and (3) ducklings fed contaminated feed treated with fuller's earth (CO+F). Feeding of the birds lasted for 10 weeks.

Aflatoxin Measurement

The Aflatoxin (AF) content of the feeds was determined using a high-performance liquid chromatography as was previously described (Mgbeahuruike et al., 2018; Bhatti et al., 2018). Briefly, 10g of feed from each treatment group was weighed using a weighing balance (Ana Lab Chemical Laboratories, Gujarat, India), the collected feed samples were ground with mortar and pestle and the AFs were quantitatively extracted with water and acetonitrile (20:80 v/v). The filtrates from the mixture were diluted with deionized water, purified on immunoaffinity columns (VicamAflaTest, Waters Corp.) and the extracts were subjected to reverse phase HPLC (Shimadzu Corp.) with isocratic elution and fluorescence detection after post column derivatization with bromine by KOBRA CELL (Rhone Diagnostics, Glasgow UK). AFs B1, B2, G1 and G2 were analyzed in each feed treatment but for the purpose of convenience, the total AF content (AFB1+AFB2+AFG1+FG2) for each feed is reported.

Performance of Ducklings and Blood sampling

For weight measurements, 6 of the ducklings in each replicate were weighed at each sampling point (days 28, 29, 30 and 31). Ducklings were randomly selected on each day, and the average daily weight gains (ADWG) for each duckling was recorded in each treatment group. The average daily feed intakes (ADFI) were also measured. At day 40, blood samples were collected from the brachial veins of 3 ducklings randomly selected in each replicate into EDTA-treated bottles for hematological analysis. Blood parameters such as red blood cell (RBC), packed cell volume (PCV), white blood cell counts (WBC), hemoglobin (Hb) and total differential counts were analyzed. The packed cell volume (PCV) was determined with a Haematospin 1400® microhaematocrit centrifuge and a Hawksley Microhaematocrit Reader (Hawksley & Sons Ltd. West Sussex, UK) using the method described by (Thrall and Weiser, 2002), The haemoglobin concentration was determined using a CHEM5V3 semi-automated blood analyzer (Erba Diagnostics, Mannheim Germany) following the cyanomethaemoglobin method described by (Higgins et al., 2003). The red blood cell (RBC) and total white blood cell (WBC) counts were manually analyzed following the haemocytometer method as described in (Campbell, 1994). Natt and Herrick's solution was used as the diluting fluid while Neubauer counting chamber (Hawksley & Sons Ltd. West Sussex, UK) and a light microscope (Leica Gallen, New York, USA) were additional instruments used for the analysis.

Similarly, blood samples were collected in anticoagulant free tubes (HMD Healthcare Limited UK) for serum biochemical analysis. Liver enzyme makers such as alanine amino transferase (ALT), alkaline phosphatase (ALP) and aspartate amino

transferase (AST) were analyzed using Randox limited commercial kits (Crumlin, County Antrim, UK). Also, antioxidant enzymes like glutathione peroxidase (GP), superoxide dismutase (SOD) and catalase (CAT) activity were analyzed as described by (Reitman and Frankel, 1957) using Randox limited commercial kits (Crumlin, County Antrim, UK).

Statistical Analysis

Data analysis for variances and power test were performed using the general linear model procedure of SAS software (SAS, 2003). Fisher's method was used for pairwise comparison at 95% significance level. Results were considered significant at $P \leq 0.05$.

Results

Aflatoxin analysis and duckling performance

The feed ingredients with their chemical compositions are shown in (Table 1). The total Aflatoxin concentration of the contaminated feed without adsorbent supplementation was 34 ± 11 µg/kg. This concentration was reduced to 15 ± 5.0 µg/kg in the bentonite treated feed and 20 ± 6.5 µg/kg in the feed treated with fuller's earth. Feed intake was relatively low in the contaminated feed without adsorbent supplementation, however, introduction of the adsorbents resulted in improved feed intake. The group fed fuller's earth supplemented feed had higher feed intake in comparison with the other groups ($P \leq 0.05$, Table 2). Feed intake was relatively low in the contaminated but untreated feed (Table 2). However, the feed intake and the average weight gain were significantly improved by introducing the adsorbents Table 2. Addition of fuller's earth resulted in 13% weight increase in the group fed feed supplemented with the adsorbents (Table 2).

Table 1: Ingredients and chemical composition of the diets given to the birds

CP	19%
Crude fat	5.0%
Crude fibre	6.0%
Calcium	1.0%
Available phosphorus	0.45%
Lysine	0.9%
Methionine	0.38%
Salt	0.3%
ME	2900 kcal/kg

CP= Crude protein, ME= Metabolizable energy. The analysis was done and provided by the feed manufacturer.

Table 2: Feed intake and average daily weight gain

Experimental Groups[1]	Feed Intake (kg)	Average daily Weight gain (kg)
Group 1 (CO)	0.53 ± 0.11^{a}	0.73 ± 0.10^{a}
Group 2 (CO+B)	0.57 ± 0.15^{a}	0.73 ± 0.03^{a}
Group 3(CO+F)	0.66 ± 0.08^{b}	0.83 ± 0.15^{a}

[1]Experimental groups = CO - contaminated but untreated feed, CO+B - contaminated feed supplemented with bentonite, CO+F - contaminated feed supplemented with fuller's earth. Different letters in the same column expressed as superscript show statistical difference at $P \leq 0.05$.

Hematological parameters

The RBC level was increased in the ducklings fed contaminated but untreated feed when compared with the treated groups ($P \leq 0.05$). The WBC count was higher ($P \leq 0.05$) in the bentonite treated group in comparison with the untreated control. This increment resulted in 14% higher levels of WBC in the ducklings fed bentonite treated feeds. PCV of the ducklings fed fuller's earth treated feed increased by 20% ($P \leq 0.05$) compared with the untreated control (Table 3). For the differential white blood cell counts, hetrophil level was increased by 14% in the ducklings fed fuller's earth treated feed ($P \leq 0.05$). The lymphocyte count was lower in the adsorbent treated group compared with the control (Table 4), but this was not statistically significant. This reduction in lymphocyte level was more pronounced in the fuller's earth treated group (19%). The adsorbent caused 14% higher levels of WBC in the ducklings fed bentonite treated feeds.

Table 3: Haematological indices

Experimental Groups[1]	Haematological Indices[2]			
	Hb (g/dl)	RBC($x10^{6}$/µL)	WBC ($x10^{3}$/µL)	PCV (%)
Group 1 (CO)	12.43 ± 0.56^{a}	151.67 ± 2.89^{a}	25.9 ± 11.51^{a}	40.00 ± 1.00^{a}
Group 2 (CO+B)	14.10 ± 1.71^{a}	98.33 ± 7.64^{b}	29.8 ± 50.49^{b}	47.00 ± 1.00^{a}
Group 3 (CO+F)	12.90 ± 0.75^{a}	105.00 ± 22.91^{b}	27.6 ± 41.12^{ac}	48.00 ± 4.58^{a}

Blood samples were analysed from three randomly selected ducklings in the replicates from each treatment group. Mean values with different letters as superscripts within columns are statistically significant at $P \leq 0.05$. [1]Experimental groups= CO - contaminated but untreated feed, CO+B - contaminated feed supplemented with bentonite, CO+F - contaminated feed supplemented with fuller's earth. [2]Haematological Indices= Hb - Heamoglobin**,** RBC-Red blood cells, WBC-White blood cells, PCV-Packed cell volume.

Table 4: White blood cell indices

Experimental Groups[1]	White Blood Cell Counts				
	Hetrophil	**Lymphocytes**	**Monocytes**	**Eosinophil**	**Basophil**
Group 1 (CO)	56.00±2.00[a]	43.33±1.15[a]	1.33±0.67[a]	0.00±0.00[a]	0.00±0.00[a]
Group 2 (CO + B)	60.67±1.15[ab]	38.67±1.15[a]	0.67±0.06[a]	0.67±0.06[a]	0.00±0.00 [a]
Group 3 (CO+F)	64.00±5.29[b]	35.33±5.03[a]	0.67±0.06[a]	0.00±0.00[a]	0.00±0.00 [a]

Blood samples collected from 3 randomly selected ducklings from the replicates in each treatment group were analysed for differential white blood cell counts. Mean values with different letters as superscripts within columns are statistically significant at $P \leq 0.05$. [1]Experimental groups= CO – contaminated but untreated feed, CO+B - contaminated feed supplemented with bentonite, CO+F - contaminated feed supplemented with fuller's earth.

Serum biochemical analysis

The liver enzyme markers; AST, ALT and ALP increased from 27.9 to 62.0IU/L, 20.5 to 55.7IU/L and 29.4 to 50.7IU/L ($P \leq 0.05$) respectively, in the ducklings fed the adsorbent treated feeds compared with the untreated control (Table 5). The liver antioxidant enzyme, glutathione peroxidase was however reduced from 106.0 to 42.2 IU/L ($P \leq 0.05$) in the adsorbent treated feed (fuller's earth) compared with the control (Table 6). The concentration of the other antioxidant markers; catalase and superoxide dismutase (SOD) remained almost similar across the three treatment groups.

Table 5: Activities of liver enzyme markers

Experimental Groups[1]	Liver Enzyme Marker		
	AST[2] (IU/L)	**ALT[3] (IU/L)**	**ALP[4] (IU/L)**
Group 1 (CO)	27.88±0.39[a]	20.50±1.48[a]	29.39±1.46[a]
Group 2 (CO+B)	47.33±14.47[b]	42.00±5.20[b]	43.00±2.00[b]
Group 3 (CO+F)	62.00±7.00[c]	55.67±15.04[c]	50.67±3.79[c]

Serum biochemistry was carried out on blood samples from 3 randomly selected ducklings in the replicates in each treatment group using Randox limited commercial kits (Crumlin, County Antrim, UK). Mean values with different letters as superscripts down the column are statistically significant at $P< 0.05$.

[1]Experimental groups= CO - contaminated but untreated feed, CO+B - contaminated feed supplemented with bentonite, CO+F - contaminated feed supplemented with fuller's earth

[2]AST- Aspartate Aminotransferase

[3]ALT- Alanine aminotransferase

[4]ALP-Alkaline phosphatase

Table 6: Activities of some antioxidant enzymes

Experimental Groups[1]	Antioxidant markers		
	SOD[2] (IU/L)	GPx[3] (IU/L)	Catalase (IU/L)
Group 1 (CO)	10.59±0.72[a]	105.97±4.49[a]	3.53±0.36[a]
Group 2 (CO+B)	10.33±0.06[a]	46.97±12.24[b]	4.10±0.11[a]
Group 3 (CO+F)	10.33±0.73[a]	42.19±14.27[b]	3.26±0.02[a]

Antioxidant enzyme markers determined by analysing blood from 3 randomly selected ducklings in the replicates from each treatment group using Randox limited commercial kits (Crumlin, County Antrim, UK). Mean values with different letters as superscripts down the column are statistically significant at $P< 0.05$.

[1]Experimental groups. CO - contaminated but untreated feed, CO+B - contaminated feed supplemented with bentonite, CO+F - contaminated feed supplemented with fuller's earth

[2]SOD-superoxide dismutase

[3]GPx-Glutathion peroxidase

Discussion

The use of adsorbents as feed additives for mycotoxin detoxification of feeds is a common practice in poultry production (Mgbeahuruike et al., 2018). The adsorbents reduced the aflatoxin in the feed below the 20 µg/kg level recommended by the United States Food and Drug Administration (USFDA). However, the reduction was higher than the 10 µg/kg threshold recommended by the European Commission (EU). Fuller's earth has been effectively used to decontaminate poultry feeds contaminated with aflatoxins (Mgbeahuruike et al., 2018). Sodium bentonite is an excellent detoxifier of contaminated poultry feeds perhaps due to the presence of numerous minerals in its structural composition (Bhatti et al., 2018). Broilers fed 5 mg/kg AFB1 and 0.3% sodium bentonite was able to effectively bind AFB1 (Rosa et al., 2001). Sodium bentonite has also proved to be an effective binding and lubricating agent in pelleted feeds (Grim and Guven, 1978). Addition of 2% bentonite in naturally contaminated raw milk was able to adsorb 89% of aflatoxin M1 (Applebaum and Marth, 1982). Bentonite has also been shown to be an effective adsorbent for aflatoxin B1 in various liquid media (Dvorak, 1989).

The reduced feed intake and weight gain in the group fed contaminated and untreated feed were perhaps as a result of high absorption of AF in the gastrointestinal tract. AF compound produces toxic metabolites that cause liver injury and inhibits protein synthesis, resulting to anorexia (Minami et al., 2004; Yunus et al., 2011). For the group fed adsorbent treated feeds, the adsorbent prevented AF absorption and its circulation, leading to reduction in its bioavailability; and this may have enhanced the growth of the ducklings. A similar result was documented by (Miazzo et al., 2000; Pimukdee et al., 2004) who reported improved feed efficiency in chicken fed feed treated with calcium montmorillonite clay and zeolites. Furthermore, improved feed intake and weight gain were observed in chicken fed feed

supplemented with hydrated sodium calcium aluminosilicate (HSCAS) (Kubena et al., 1998; Ledoux et al., 1999). Additionally, Mgbeahuruike et al. (2018) observed that feeds supplemented with bentonite and fuller's earth-caused 65% and 100% weight increases in broilers when compared with the untreated control (Mgbeahuruike et al., 2018). Supplementing feed with 0.2% bone and 0.4% canarium charcoal improved the body weight of chickens fed 36 and 60 ppb aflatoxin (Kana et al., 2014). Other studies showed that addition of 2% sodium bentonite to AF contaminated feed improved the production parameters of pullets (Oliver, 1989). Furthermore, Li et al. (2012) reported decreased body weight and average daily weight gain in Cherry Valley ducks fed AFB1 (98.73 μg/kg) contaminated feed.

The adverse role of aflatoxin-contaminated feed on haemostasis and blood system damage has been reported (Abb`es et al., 2006). In the present study, the RBC level increased significantly in the ducklings fed contaminated but untreated feed ($P \leq 0.05$) while the WBC count was higher ($P \leq 0.05$) in the adsorbent (bentonite) treated group. In other studies, (Kana et al., 2014), WBC, RBC and hemoglobin levels did not differ significantly among treatments (adsorbent treated groups and the control). This can be explained by the method of AF exposure to the birds and the sensitivity of the avian species used in the two studies. While Kana et al. (2014) used natural moldy groundnut as the source of AF in their study, in the present study, AF was induced by sprinkling water on the feed and storing for 3-4 wks in closed bags to allow for mold growth. This method may possibly have allowed more growth of molds on the feed and better exposure of the experimental birds to the AF. Furthermore, Kana et al. (2014) used broilers as their experimental birds while ducklings which have been reported to show more sensitivity to AF than broilers (Alan et al., 1986; Bintvihok, 2001) were used in the present study. Consumption of feeds supplemented with activated charcoal, bentonite and fuller's earth resulted in 16%, 13%, and 17% higher WBC levels in broilers respectively, in comparison with the untreated control (Mgbeahuruike et al., 2018). However, other studies reported higher levels of WBC in birds that consumed mould-treated feeds (Che et al., 2011). The reduction of PCV and Hb in the contaminated but untreated feed could be indicative of anemia caused by AF toxicities which altered the hematopoietic process (Birbrair and Frenette, 2016). The 20% increase in PCV caused by the fuller's earth is an indication that the adsorbent had an enhancing effect on the hematopoietic process. In other studies, AF was reported to decrease the PCV level and Hb values of birds fed contaminated feed without adsorbent (Rattanasinthuphong et al., 2017). However, decreased Hb, PCV and RBC counts were reported in ducks fed AFB1 contaminated diets (He et al., 2013a).

Serum biochemical parameters provide information on hepatic injury and function (Abb`es et al., 2006). The increased AST, ALT and ALP in this study is contrary to earlier report by (Mgbeahuruike et al., 2018), where these enzymes were found to be higher in the birds fed contaminated but untreated feeds. The variation in results could be because of species differences. While (Mgbeahuruike et al., 2018) used broilers in their studies, the present study was conducted using ducklings as the experimental birds. Increased levels of AST and ALT were reported in Mule ducklings fed AFB1 (200 μg/kg) contaminated feeds, although the ALP was not affected by the treatment (Cheng et al., 2001). In other studies, feeding Cherry Valley ducks

with AFB1 contaminated feed increased ALP levels but decreased ALT and AST (Li et al., 2012). Liao et al. (2015) reported that AFB1 induces liver cell dysfunction and apoptosis, and increases serum ALT and AST in ducklings. Similarly, elevated levels of AST and ALT were reported in broilers fed AF contaminated feed compared to the control (Azizpour and Moghadam, 2014). The liver antioxidant enzyme, glutathione peroxidase was however lower in the adsorbent treated feed (fuller's earth) compared with the control. This is probably because the adsorbent reduced the level of AF residues in the liver, which in turn resulted in lower free radicals and lower antioxidant enzyme level (Kotan et al., 2011).

Conclusions

In conclusion, the study has successfully dissected the protective effects of the two adsorbents, fuller's earth and bentonite on the adverse effects of AF contaminated duckling feeds. Supplementation of the contaminated duckling feed with bentonite and fuller's earth resulted in 44% and 59% reduction of total aflatoxin concentration in the feed. The two adsorbents can be incorporated in feed during production to reduce aflatoxin contamination. Also, the fuller's earth treated feed caused a remarkable increase (13%) in the body weight of the experimental ducklings; making it a potential candidate for body weight enhancement in ducklings during production.

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Conflicts of interest

There is no conflict of interest.

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