Influence of *Saccharomyces cerevisiae* to ameliorate adverse effects of ochratoxin on biochemical profile and immune response in broiler chickens

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**ABSTRACT**

To establish the ochratoxicosis ameliorating efficacy of dietary *Saccharomyces cerevisiae* (SC), day-old broiler chicks (240) were divided into 6 treatment groups (T<sub>1</sub>, control (basal diet); T<sub>2</sub>, T<sub>1</sub> + 200 ppb OTA; T<sub>3</sub>, T<sub>1</sub> + 0.05% SC; T<sub>4</sub>, T<sub>1</sub> + 0.1% SC; T<sub>5</sub>, T<sub>2</sub> + 0.05% SC and T<sub>6</sub>, T<sub>2</sub> + 0.1% SC). Each diet was fed to 5 replicated groups of 8 birds each from 1 to 42 days of age. The total serum protein and haemoglobin (Hb) in T<sub>2</sub> and T<sub>5</sub> were lower than that of control (T<sub>1</sub>). The serum protein and Hb content in group T<sub>6</sub> was higher than that of T<sub>2</sub> and statistically similar to that of control. The serum uric acid, creatinine, ALP, SGOT, SGPT and H/L ratio in ochratoxin fed group (T<sub>2</sub>) was higher than that of T<sub>1</sub>. The serum uric acid, creatinine, ALP, SGOT, SGPT and H/L ratio in T<sub>6</sub> was lower than that of T<sub>2</sub> and statistically similar to that of T<sub>1</sub>. The CMI and HA titre value in ochratoxin fed group (T<sub>2</sub>) was lower than that of T<sub>1</sub>. The CMI and HA titre value in T<sub>5</sub> and T<sub>6</sub> was lower than T<sub>1</sub> but higher than T<sub>2</sub>. It was concluded that ochratoxin contamination at 200 ppb level in broiler diet altered the biochemical parameters and immune response. Inclusion of *Saccharomyces cerevisiae* at 0.1% level to the ochratoxin contaminated diet ameliorated the adverse effects of ochratoxicosis on biochemical parameters and immune response of broiler chickens.

**Key words**: Biochemical, Broiler, Immune response, Ochratoxin, *Saccharomyces cerevisiae*

Ochratoxin A (OTA) is a mycotoxin that is receiving increasing attention worldwide because of the hazard it poses to animal and human health. This mycotoxin was isolated as metabolite of the fungus *Aspergillus ochraceus* from which the toxin acquired its name. However, ochratoxin production is not unique to *Aspergillus ochraceus* as additional several *Aspergillus* species and several *Penicillium* species produce ochratoxins. Ochratoxicosis causes a reduction in production performance, viz. reduced growth rate, decreased feed consumption, poorer feed conversion (Singh et al. 2016b, Singh et al. 2018) and increased mortality (Singh et al. 2015, Singh et al. 2016b, Singh et al. 2018). Ochratoxin impaired both cell mediated and humoral immunity (Singh et al. 2016a). Besides the production of OTA by storage fungi in several different food and feed, the presence of OTA residues in animal products is another concern. Ochratoxin A has also been detected in meat, egg and milk (Jorgensen 1998, Skaug 1999). Moreover, OTA has been frequently found in human plasma, milk and urine indicating a diffuse and continuous human exposure to this mycotoxin in many countries (Rosner et al. 2000, Skaug et al. 2001). Ochratoxin A causes significant losses and reduction in the profitability of poultry industry due to its effects on performance and health (Agawane and Lonkar 2004, Singh et al. 2018). Ochratoxin A is a mycotoxin known to be implicated in a diverse range of toxicological effects in a variety of animal species, its nephrotoxic, hepatotoxic, immunosuppressive, teratogenicity, neurotoxicity, mutagenicity. It causes kidney and liver tumors in poultry and possibly in humans (O’Brien and Dietrich 2005). *S. cerevisiae* has shown considerable binding ability with several commonly occurring mycotoxins (Devegowda et al. 1998, Singh et al. 2018), and is also found effective as a low-inclusion binder to bind mycotoxins present in contaminated feed (Mahesh and Devegowda 1996, Singh et al. 2018). The objective of this investigation was to study the effect of dietary *S. cerevisiae* to ameliorate ochratoxicosis in broiler chickens.

**MATERIALS AND METHODS**

**Ochratoxin production**: The lyophilised preparation of *Aspergillus westerdijkiae* NRRL 3174 was obtained from US Department of Agriculture, Peoria, Illinois (USA). This lyophilised preparation was revived on potato dextrose agar medium. Ochratoxin was produced as per the method described by Singh et al. (2013). Cracked maize (50 g) was taken in 250 ml conical flasks. The moisture content of substrate was adjusted to have a moisture level of 35%. The flasks were plugged with non-absorbent cotton and sealed with aluminium foil. The flasks were autoclaved for 15 min at 121°C.
20 min at 121°C and inoculated with 1-week old mycelium of *Aspergillus westerdijkiae* NRRL 3174. The inoculated flasks were incubated in a BOD incubator for 14 days. After removal from the incubator, the flasks were dried at 70°C and the ochratoxin assays were performed as per AOAC (1990).

**Experimental design:** Experimental design was completely randomized design (CRD). There were 6 dietary treatments. Each dietary treatment had 5 replicates and each replicate had 8 chicks. The experiment was conducted in broiler chickens from day-old to 6 weeks of age. The various dietary treatments were prepared by mixing the required quantity of mouldy maize to get the desired concentration of 200 ppb OTA in basal diet. The dietary treatments were T1, Control (basal diet free from ochratoxin); T2, T1+ 200 ppb OTA; T3, T1+ 0.05% SC; T4, T1+ 0.1% SC; T5, T2+ 0.05% SC and T6, T2+ 0.1% SC.

**Biological experiment and analysis:** Day-old broiler chicks (240) were obtained from experimental hatchery, CARI, Izatnagar. The chicks were wing banded, weighed individually and distributed randomly into 6 groups. All birds were reared under standard management conditions from 0–6 weeks. All birds were fed with broiler starter ration from 1–21 days and broiler finisher ration from 22 to 42 days. The ingredient and chemical composition of broiler starter and finisher ration are presented in Table 1.

The protein as per AOAC (1990) and calcium contents as per Talapatra et al. (1940) were estimated, while the concentrations of lysine, methionine, available P and metabolizable energy values were calculated. The cell mediated immune response to PHA-P antigen was evaluated by the method described by Corrier and DeLoach (1990). The microtitre haemagglutination procedure as described by Siegel and Gross (1980) was followed to measure total HA antibody titres in chickens. After 6 weeks, the blood samples from each treatment group were collected. The serum was separated and stored at –20°C and analyzed for various biochemical parameters using commercial kit manufactured by Span Diagnostics Ltd, Surat. The haemoglobin concentration in blood was estimated by Sahli’s method. Haemoglobin is converted into acid haematin by addition of 0.1 N HCl. The resultant solution is then matched against a reference solution (Sahli’s Haemoglobinometer). Reading on the graduated tube was expressed as haemoglobin level in g/dl. The heterophili/lymphocyte (H/L) ratio was calculated by dividing the number of heterophil by that of lymphocyte.

**Statistical analysis:** The collected data was subjected to statistical analysis using Software Package for Social Sciences (SPSS Version 16.0). The recorded data were subjected to one-way analysis of variance with comparison among means was made by Duncan’s multiple range test with significance level of P<0.05.

**RESULTS AND DISCUSSION**

**Total serum protein:** The total serum protein in ochratoxin fed group (T2) was lower (P<0.05) than that of control (T1). The serum protein content in groups T3 and T4 was statistically similar to that of T1 (Table 2). The serum protein in T3 was statistically similar to that of ochratoxin fed group (T2) and lower (P<0.05) than that of T1, indicating that supplementation of *S. cerevisiae* at 0.05% level did not improve serum protein content. The serum protein content in group T6 was higher (P<0.05) than that of T2 and statistically similar to that of control, indicating that addition of *S. cerevisiae* at 0.1% level improved the serum protein content equal to that of control. In the present study, contamination of ochratoxin at 200 ppb level in feed caused significant (P<0.05) reduction in serum protein content. The negative effects of ochratoxin on serum protein in the present study were in agreement with the previous investigations (Santin et al. 2002, Hatab 2003, El-Barkouky et al. 2008, El-Barkouky and Abu-Taleb 2008, Singh et al. 2015). Reduction in serum protein is attributed to the decrease in protein absorption and/or utilisation or to the inhibition of protein synthesis by ochratoxin (Kubena et al. 1983, Kubena et al. 1988, Kubena et al. 1989). Similar decrease in serum protein was also reported when ochratoxin was administered to broiler chickens at 130–790 µg/kg (Stoev et al. 2000) and 567 µg/kg (Garcia et al. 2003). They suggested that low serum

### Table 1. Ingredient and chemical composition of basal feed

| Ingredient                              | Starter (g/kg) | Finisher (g/kg) |
|-----------------------------------------|----------------|-----------------|
| Maize                                   | 555.00         | 624.20          |
| Deoiled rice bran                       | 18.80          | 20.10           |
| Soybean                                 | 280.00         | 205.00          |
| Guar korma                              | 40.00          | 40.00           |
| Rapse seed meal                         | 40.00          | 40.00           |
| Fish meal                               | 40.00          | 40.00           |
| Limestone                               | 5.00           | 5.00            |
| Di-calcium phosphate                    | 16.00          | 16.00           |
| Common salt                             | 2.00           | 2.50            |
| DL-methionine                           | 0.70           | 0.30            |
| Lysine                                  | 1.25           | 0.70            |
| TM Premix*                              | 1.10           | 1.00            |
| Vitamin Premix**                        | 1.50           | 1.50            |
| B complex***                            | 0.15           | 0.15            |
| Choline chloride                        | 0.50           | 0.50            |
| Coccidiostat                            | 0.50           | 0.50            |

### Chemical composition of basal diet

- Crude protein (g/kg): 223; 200.6
- ME (MJ/kg): 11.75; 12.04
- Calcium (g/kg): 10.9; 10.9
- Available phosphorus (g/kg): 5.0; 4.2
- Lysine (g/kg): 12.8; 10.4
- Methionine (g/kg): 5.1; 4.3

*TM premix supplied mg/kg diet: MgSO4.5H2O, 300; MnSO4.5H2O, 55; KI, 0.4; FeSO4.7H2O, 56; ZnSO4.7H2O, 30; CuSO4.5H2O, 4.**Vitamin premix supplied per kg diet: vitamin A (retinol), 8250 IU; vitamin D3 (cholecalciferol), 1200 IU; vitamin K (menadione), 1 mg.***B complex supplied per kg diet: vitamin B1 (thiamine), 2 mg; Vit. B2, 4 mg; vitamin B6 (riboflavin), 10 mcg; niacin (nicotinic acid), 60 mg; pantothenic acid, 10 mg; choline, 500 mg.
protein concentration might have been due to the decrease in albumin and globulin levels or to the degeneration of endoplasmic reticulum that led to pathological changes in the liver that in turn caused a reduction in hepatic protein synthesis, as ochratoxin is known to inhibit hepatic protein synthesis. In the present study, inclusion of *S. cerevisiae* (0.1%) to the ochratoxin contaminated diet increased the serum protein content due to addition of probiotic containing *S. cerevisiae* culture at 10 mg/kg diet to 0.5 ppm ochratoxin supplemented to the ochratoxin contaminated diet ameliorated the adverse effects of ochratoxicosis on creatinine concentration. In the present study, ochratoxin contamination of feed resulted in increased (P<0.05) creatinine content. Increased creatinine content due to ochratoxicosis in broilers was earlier reported in several investigations (Kumar et al. 2003, Koynarski et al. 2007, Sakhare et al. 2007, Hatab 2003, Elaroussi et al. 2008). Increase in creatinine concentration in the ochratoxin fed birds might be due to nephrotoxic action of ochratoxin, which caused renal impairment by destruction of epithelial cells of proximal and distal convoluted tubules and tubular damage (Agawane and Lonkar 2004). In the present study, supplementation of 0.1% *S. cerevisiae* to the OTA contaminated feed reversed the creatinine content equal to that of control. Agawane and Lonkar (2004) also reported significant improvement in creatinine concentration of broilers as a result of addition of probiotic containing *Saccharomyces* yeast culture in ochratoxin intoxicated broiler chickens. Significant improvement in serum protein content due to addition of *S. cerevisiae* in ochratoxin contaminated feed was also reported by El-Barkouky (2008) and Khalil (2008).

**Total serum cholesterol:** The serum cholesterol in various dietary treatment groups varied between 182.87 and 186.60 mg/dl. The cholesterol concentration in the ochratoxin fed birds, indicating impaired renal excretory functions. In the present study, ochratoxin contamination of feed partially reversed the serum uric acid concentration.

### Table 2. Certain blood biochemical constituents of broilers fed various dietary treatments (Mean±SEM; n=5)

| Treatment | Protein (g/dl) | Cholesterol (mg/dl) | Uric acid (mg/dl) | Creatinine (mg/dl) | ALP (KA units) | SGOT (IU/L) | SGPT (IU/L) |
|-----------|----------------|---------------------|------------------|-------------------|---------------|-------------|-------------|
| T1        | 6.39±0.35c     | 185.12±4.14         | 5.32±0.33a       | 0.31±0.02a        | 155.20±3.89ab | 171.59±3.98a | 32.30±3.98a |
| T2        | 4.54±0.50a     | 182.88±4.12         | 7.41±0.39c       | 0.37±0.03c        | 191.85±5.81d  | 208.58±5.28d | 42.22±2.26b |
| T3        | 6.49±0.49c     | 185.99±3.97         | 5.35±0.29a       | 0.31±0.01a        | 154.34±3.36a  | 171.10±4.14a | 32.14±2.58a |
| T4        | 6.58±0.42c     | 186.60±5.00         | 5.39±0.29a       | 0.32±0.02ab       | 155.41±3.39a  | 172.10±4.46a | 32.54±2.46a |
| T5        | 4.72±0.42a     | 182.87±4.72         | 6.29±0.40bc      | 0.35±0.03bc       | 181.72±7.25c  | 189.67±3.91c | 42.64±2.13b |
| T6        | 5.56±0.35b     | 185.00±4.83         | 6.70±0.38b       | 0.31±0.02a        | 161.66±2.68b  | 181.47±7.91b | 35.10±3.70a |

Values bearing different superscripts in a column differ significantly (P<0.05).

**Serum creatinine:** The creatinine content in T2 was higher (P<0.05) than that of T1. The creatinine concentration in groups T3 and T4 was statistically similar to that of T1 (Table 2). The creatinine content in group T2 was statistically similar to that of T5. The creatinine content of group T6 was lower (P<0.05) than that of T2, indicating that inclusion of *S. cerevisiae* at 0.1% level to the ochratoxin contaminated diet ameliorated the adverse effects of ochratoxicosis on creatinine concentration. In the present study, ochratoxin contamination of feed resulted in increased (P<0.05) creatinine content. Increased creatinine content due to ochratoxicosis in broilers was earlier reported in several investigations (Kumar et al. 2003, Koynarski et al. 2007, Sakhare et al. 2007, Hatab 2003, Elaroussi et al. 2008). Increase in creatinine concentration in the ochratoxin fed birds might be due to nephrotoxic action of ochratoxin, which caused renal impairment by destruction of epithelial cells of proximal and distal convoluted tubules and tubular damage (Agawane and Lonkar 2004). In the present study, supplementation of 0.1% *S. cerevisiae* to the OTA contaminated feed reversed the creatinine content equal to that of control. Agawane and Lonkar (2004) also reported significant improvement in creatinine concentration of broilers as a result of addition of probiotic containing yeast culture *Saccharomyces bouardi* at 10 mg/kg in diet of broilers intoxicated with ochratoxin.

**Alkaline phosphatase (ALP):** The ALP activities in T1 were lower (P<0.05) than that of T2. The ALP activities in groups T3 and T4 was statistically similar to that of control (Table 2). The ALP activity of groups T5 and T6 was lower (P<0.05) than T2, indicating that addition of *S. cerevisiae* partially ameliorated the ill effects of ochratoxicosis on serum uric acid content. In the present study, ochratoxin contamination resulted in significant (P<0.05) increase in serum uric acid concentration. The significantly increased levels of uric acid in ochratoxin treated birds were in agreement with other reports (Stoev et al. 2000, Ayed et al. 1991, Garcia et al. 2003, Mohiuddin et al. 1993, Patil et al. 2005, Singh et al. 2015). Kubena et al. (1989) indicated that uric acid is the primary product of nitrogen catabolism in chickens and is excreted by the kidney. The elevation in serum uric acid level was accompanied by the increase in kidney weight in the ochratoxin fed birds, indicating impaired renal excretory functions. In the present study, addition of *S. cerevisiae* to ochratoxin contaminated feed partially reversed the serum uric acid concentration.
(Table 2). The ALP activities in group T3 was lower (P<0.05) than that of T2, but higher (P<0.05) than that of T1. The ALP value in T6 was lower (P<0.05) than that of T2 and statistically similar to that of control (T1), indicating that the addition of 0.1% S. cerevisiae to the ochratoxin contaminated diet ameliorated the adverse effects of ochratoxicosis on ALP activities. In the present study, ochratoxin resulted in increased activities of ALP. Khan et al. (2014) also reported increased activities of ALP due to ochratoxin in broiler chickens. In the present study, addition of S. cerevisiae at 0.1% level to ochratoxin contaminated diet ameliorated the adverse effects of ochratoxicosis on ALP activities.

*Serum glutamic oxaloacetic transferase (SGOT):* The SGOT activities in T6 was higher (P<0.05) than that of T1. The SGOT level in groups T3 and T4 was statistically similar to that of control (T1) (Table 2). The SGOT level in groups T3 and T6 was lower (P<0.05) than T2 but significantly higher than control, indicating that the supplementation of S. cerevisiae at any level to the ochratoxin contaminated diet partially ameliorated the adverse effects of ochratoxicosis on SGOT activities. The SGOT level in T6 was lower (P<0.05) than that of T5, suggesting that 0.1% level of S. cerevisiae was more effective than 0.05% level in ameliorating ochratoxicosis. In the present study, ochratoxin resulted in increased activities of SGOT. This result was in agreement with earlier reports (Santin et al. 2002, Kumar et al. 2003, Hatab 2003, Patil et al. 2005, Elaroussi et al. 2008). Rainera et al. (1991) reported that increased level of SGOT in broiler serum was attributed to cellular damage and increased plasma membrane permeability. In present study, inclusion of 0.1% S. cerevisiae to ochratoxin contaminated diet reversed the SGOT value equal to normal. Raju and Devegowda (2000) also reported that inclusion of esterified glucomanan (EG) @ 1 g/kg level in feed resulted in decreased activities of SGOT that were elevated by mycotoxins.

*Serum glutamic pyruvic transferase (SGPT):* The SGPT level in T6 was higher (P<0.05) than that of T1. The SGPT level in groups T3, T5 and T6 was statistically equal to that of control (Table 2). The SGPT level in group T6 was higher (P<0.05) than that of control. The SGPT level in T6 was lower (P<0.05) than that of T5 and statistically similar to that of control, indicating that addition of 0.1% S. cerevisiae to the ochratoxin contaminated feed ameliorated the adverse effects of ochratoxicosis on SGPT activities. In the present study, ochratoxin contamination resulted in increased activities of SGPT. This finding was in agreement with other reports in literature (Kumar et al. 2003, Hatab 2003, Patil et al. 2005, Elaroussi et al. 2008). In the present study, addition of S. cerevisiae (0.1%) to ochratoxin contaminated feed ameliorated the ill effects of ochratoxicosis on SGPT activities. Agawane and Lonkar (2004) also reported that addition of probiotic containing yeast culture S. boulardii @ 10 mg/kg feed to 0.5 ppm OTA contaminated feed showed beneficial effects in decreasing SGPT activities in broiler chickens. They indicated that increased serum concentration of SGPT in broilers fed ochratoxin containing diet may be due to the damage of hepatocytes releasing the enzyme after the damage.

**Effect on haematological parameters:** The haemoglobin content in T1 was higher (P<0.05) than that of T6. The Hb content is T3, T4 and T6 was statistically similar to that of control (Table 3). The Hb value of T5 was higher (P<0.05) than T6 but lower than T2, indicating that inclusion of 0.05% S. cerevisiae may not be sufficient to reverse the haemoglobin concentration however, addition of 0.1% dietary S. cerevisiae reversed the Hb concentration equal to control (Table 3). In the present study, ochratoxin contamination resulted in reduced Hb level in broiler chickens. Similar result was also reported by Agawane and Lonkar (2004), Sakare et al. (2007), El-Barkouky (2008) and El-Barkouky and Abu-Taleb (2008) who found that Hb concentration was significantly reduced due to ochratoxin concentration in feed ranging from 50 to 500 ppb level. Also, Mohiuddin et al. (1992; 1993) reported that addition of ochratoxin at a level of 0.75, 1.5 or 3 μg/g feed for 4 weeks to the diet of 4 week-old broiler chicks resulted in a significant decrease in Hb concentration in blood. In the present study, inclusion of 0.1% S. cerevisiae to the ochratoxin contaminated diet reversed the Hb level which was statistically equal to that of control. These findings were in agreement with Bradley et al. (1994) and Agawne and Lonkar (2004) who reported significant improvement in Hb value as a result of addition of probiotic containing yeast culture to ochratoxin intoxicated broilers. El-Barkouky (2008) also reported that supplementation of broiler diet with S. cerevisiae (200 mg/kg feed) significantly counteracted the deleterious effects of ochratoxin on Hb and PCV values of broilers subjected to ochratoxin intoxication. H/L ratio in control group was 0.51 which increased (P<0.05) to 0.53 in ochratoxin fed group (T2). The H/L ratio in T3, T4, T5 and T6 was statistically similar to that of control, indicating that supplementation of S. cerevisiae at both levels improved (P<0.05) the H/L ratio in ochratoxin intoxicated broiler chicks.

**Immune response:** The data pertaining to CMI response to PHA-P measured as foot web index and humoral immune response measured as haemagglutination titre (HA) against SRBC’s in broiler chickens fed various dietary treatments is presented in Table 3. One of the most profound effects of ochratoxicosis is its ability to impair immune system functions.

**Effect on cell mediated immunity (CMI):** The CMI of group T1 was higher (P<0.05) than that of T2. The results revealed that contamination of dietary ochratoxin in feed reduced (P<0.05) the CMI response as compared to that of control. The CMI in T1 and T6 was statistically similar to that of control, indicating that the addition of S. cerevisiae to the basal feed did not produce any effect on CMI response. The CMI in group T5 was lower (P<0.05) than that of T1 but higher than that of T2, however, the CMI in group T6 was higher (P<0.05) than T5. These findings indicated that supplementation of S. cerevisiae at both levels...
(0.05 and 0.1%) partially ameliorated the ill effect of ochratoxin on CMI response; however, the higher level (0.1%) was more efficacious in ameliorating the adverse effect of ochratoxin. The present study indicated that ochratoxin inclusion in the diet of broiler chickens caused significant (P<0.05) reduction in CMI response to PHA-P. This result was in agreement with those of Singh et al. (2015), Singh et al. (2016b), Singh et al. (2018). Also, Singh et al. (1990) showed suppression of CMI response in chicken due to ochratoxicosis and described the significant reduction of T-lymphocyte count and phagocytic ability of splenic macrophages after feeding 0.5 and 2.0 ppm ochratoxin. These findings were also supported by Verma et al. (2004) in broilers fed with 1–4 ppm ochratoxin for 47 days from one day of age. Reduction in CMI response was also observed by Wang et al. (2009). In the present study, inclusion of S. cerevisiae to the ochratoxin contaminated feed partially ameliorated the ill effects of ochratoxin on CMI response. However, 0.1% inclusion of S. cerevisiae was more efficacious in ameliorating the adverse effect of ochratoxin. Khalil (2008) also observed that dietary inclusion of S. cerevisiae at 2 g/kg ameliorated all the negative effects of ochratoxin in growing quails.

Humoral immune response: The HA titre in T2 was lower (P<0.05) than that of T1. The HA titre of T3 and T4 was statistically similar to that of control. The HA titre in T3 and T5 was lower (P<0.05) than T1 but higher than T2 indicating that addition of S. cerevisiae at both levels partially ameliorated the adverse effect of ochratoxicosis on humoral immune response. The HA titre of group T5 was higher than that of T3, indicating that 0.1% level of S. cerevisiae was more efficacious than 0.05% level in ameliorating ill effect of ochratoxicosis. In the present study, dietary ochratoxin reduced (P<0.05) the HA titre against sheep RBC’s. Ochratoxin interferes with protein, DNA and RNA synthesis through competitive inhibition of phenylalanine-t-RNA synthetase by phenylalanine moiety of ochratoxin that leads to decrease plasma proteins and immunoglobulin (Hsieh 1987, Marguardt and Frohlich 1992). Also, leucocytopenia (lymphocytopenia and monocytopenia) that is noticed during ochratoxicosis can adversely affect immunoglobulin production (Campbell M L, May J D, Huff W E and Doerr J A 1983). Evaluation of immunity of young broiler chickens during simultaneous aflatoxicosis and ochratoxicosis. Poultry Science 62: 2138–44.

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