

Effects of Mycotoxin Adsorbents on Production Performance, Trace Element Content in Egg Yolk, and Serum Antioxidant and Biochemical Parameters in Laying Hens: Postprint

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Abstract

This experiment was conducted to investigate the effects of mycotoxin adsorbents [Libailing-Z (CZ) and Saifei (SF)] on production performance, trace element content in egg yolk, and serum antioxidant and biochemical indices in laying hens. A total of 216 healthy Roman laying hens aged 38 weeks were selected and randomly allocated into 3 groups with 6 replicates per group and 12 hens per replicate. The control group was fed a basal diet, while the experimental groups (CZ and SF groups) were fed the basal diet supplemented with 0.5 g/kg of the two mycotoxin adsorbents, respectively. The preliminary period was 10 d, and the formal experimental period was 35 d. The results showed: 1) Compared with the control group, the CZ group exhibited significantly higher laying rate and daily egg production during weeks 3-5 of the experiment ($P < 0.05$); dietary supplementation with mycotoxin adsorbents had no significant effects on average egg weight, average daily feed intake, feed-to-egg ratio, or mortality and culling rate of laying hens ($P > 0.05$). 2) Compared with the control group, there were no significant differences in copper and manganese contents in egg yolk on days 14 and 35 in any experimental group ($P > 0.05$); the zinc content in egg yolk on day 14 was significantly increased in the CZ group ($P < 0.05$). 3) Dietary supplementation with mycotoxin adsorbents had no significant effects on serum glutathione peroxidase activity and malondialdehyde content on days 14 and 35 ($P > 0.05$). Compared with the control group, serum total antioxidant capacity on day 14 was significantly increased in all experimental groups ($P < 0.05$); serum total superoxide dismutase activity on day 35 was significantly increased in the SF group ($P < 0.05$). 4) Compared with the control group, serum alkaline phosphatase activity and glucose content were significantly decreased in the CZ group ($P < 0.05$); serum total cholesterol content was significantly decreased in the SF group ($P < 0.05$). In conclusion, dietary supplementation with mycotoxin

adsorbent CZ significantly improved the laying performance of hens, while both adsorbents enhanced serum antioxidant function and improved serum biochemical indices.

Full Text

Effects of Mycotoxin Adsorbents on Performance, Yolk Trace Element Contents, and Serum Antioxidant and Biochemical Indices of Laying Hens

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Abstract

This experiment was conducted to investigate the effects of two mycotoxin adsorbents, Calibrin-Z (CZ) and Saifu (SF), on the performance, yolk trace element contents, and serum antioxidant and biochemical indices of laying hens. A total of 216 healthy 38-week-old Roman laying hens were randomly allocated into three groups with six replicates per group and twelve hens per replicate. The control group received a basal diet, while the experimental groups (CZ and SF) received the basal diet supplemented with 0.5 g/kg of either adsorbent. Following a 10-day adjustment period, the formal experimental period lasted 35 days. The results showed: (1) Compared with the control group, the CZ group exhibited significantly increased laying rate and daily egg production during weeks 3-5 ($P < 0.05$). Dietary supplementation with mycotoxin adsorbents had no significant effects on average egg weight, average daily feed intake, feed-to-egg ratio, or mortality and culling rate ($P > 0.05$). (2) No significant differences were observed in yolk copper or manganese contents between the experimental and control groups on days 14 and 35 ($P > 0.05$). However, the CZ group showed significantly elevated yolk zinc content on day 14 ($P < 0.05$). (3) Mycotoxin adsorbents did not significantly affect serum glutathione peroxidase activity or malondialdehyde content on days 14 or 35 ($P > 0.05$). Compared with the control group, both experimental groups demonstrated significantly enhanced serum total antioxidant capacity on day 14 ($P < 0.05$), while the SF group showed significantly increased serum total superoxide dismutase activity on day 35 ($P < 0.05$). (4) The CZ group exhibited significantly reduced serum alkaline phosphatase activity and glucose content ($P < 0.05$), whereas the SF group showed significantly decreased serum total cholesterol content ($P < 0.05$). In conclusion, dietary supplementation with 0.5 g/kg CZ improved the productive performance of laying hens, while both adsorbents enhanced serum antioxidant function and improved serum biochemical indices.

Keywords: laying hens; adsorbents; performance; trace elements; antioxidant; biochemical indices

Introduction

Mycotoxins are secondary metabolites produced by molds during growth and reproduction that exhibit strong toxicity, affecting not only animal performance but also posing risks to human health. Commercial feed and raw materials are highly susceptible to mycotoxin contamination. According to a Food and Agriculture Organization survey, approximately 25% of grains worldwide are contaminated with mycotoxins to varying degrees each year [1]. The hazards to animal husbandry and feed processing enterprises have garnered increasing attention, as mycotoxins not only impair livestock and poultry performance but also compromise antioxidant capacity and immune function. Currently, adding mycotoxin adsorbents to feed represents one of the primary global strategies for controlling mycotoxin contamination. Hydrated sodium calcium aluminosilicate (HSCAS) is a common class of adsorbents that effectively binds aflatoxin (AF) and zearalenone (ZEN). Phillips et al. [2] demonstrated that dietary supplementation with 0.5% HSCAS alleviated the toxic effects of aflatoxin B1 (AFB1) on Leghorn chickens and broilers. Afriyie-Gyawu et al. [3] found that both montmorillonite and hectorite effectively adsorbed ZEN in moldy feed, though these adsorbents showed limited binding capacity for deoxynivalenol (DON) and T-2 toxin. Many researchers have modified HSCAS adsorbents and investigated their effects on livestock performance. Studies by Ma Yulong et al. [4] and Yang Rongfang et al. [5] indicated that nano-copper-loaded montmorillonite significantly increased average daily gain (ADG) and reduced feed-to-gain ratio (F/G) in broilers, while also increasing average daily feed intake (ADFI) in piglets and ADG in finishing pigs, significantly reducing F/G across all production stages. Shi Minglei et al. [6] reported that copper-loaded silicate nanoparticles (CSN) tended to reduce F/G in broilers, whereas Xia Mingliang et al. [7] observed increased F/G in broilers supplemented with 0.5% copper-modified montmorillonite. These inconsistent findings regarding modified HSCAS effects on livestock performance warrant further investigation. To date, HSCAS adsorbents have been extensively studied in pigs, broilers, and dairy cows, but research on their application in laying hens and egg-type poultry remains scarce, with no reports on their effects on trace element content in animal products. This study evaluated the effects of two modified HSCAS adsorbents on laying hen performance, yolk trace element content, and serum antioxidant and biochemical indices to provide a reference for further research and application in egg-type poultry production.

Materials and Methods

1.1 Experimental Materials

The mycotoxin adsorbents used were Calibrin-Z (CZ) and Saifu (SF), both commercially available products. CZ primarily consists of calcium montmorillonite, while SF primarily consists of sodium montmorillonite.

1.2 Experimental Design and Management

The experiment was conducted from June 12 to July 26, 2015, at Hunan Tanxin Breeding of Yellow Broilers Limited Liability Company. A total of 216 healthy 38-week-old Roman laying hens with similar body weight and normal feeding behavior were randomly divided into three groups with six replicates per group and twelve hens per replicate. The control group received the basal diet, while the experimental groups (CZ and SF) received the basal diet supplemented with 0.5 g/kg of the respective adsorbents. During the 10-day adjustment period, all groups received the basal diet, and the flocks were monitored daily and adjusted to ensure no significant differences in feed consumption, laying rate, or egg weight among groups ($P > 0.05$). The formal experimental period lasted 35 days. The composition and nutrient levels of the basal diet are presented in Table 1.

Table 1 Composition and nutrient levels of the basal diet (air-dry basis), %

Items	Content
Ingredients	
Corn	
Soybean meal	
Limestone	
Premix ¹	
Total	
Nutrient levels²	
ME/(MJ/kg)	
CP	
Lys	
Met+Cys	
Ca	
AP	

¹The premix provided the following per kg of diet: VA 6,000 IU, VD 2,500 IU, VE 25 IU, VK 2.25 mg, VB 0.18 mg, VB 4 mg, VB 5.5 mg, VB 1.75 mg, pantothenate 12 mg, biotin 0.14 mg, nicotinic acid 34 mg, folic acid 0.8 mg, chloride 350 mg, Fe 75 mg, Cu 7.5 mg, Se 0.15 mg, Zn 60 mg, Mn 60 mg, I 1.25 mg.

²Nutrient levels were calculated values.

Laying hens were housed in three-tier step cages (three hens per cage, four cages per replicate). Feed was provided twice daily (09:00 and 15:00), and eggs were collected twice daily (11:30 and 16:30). All groups were managed under identical conditions with house temperature maintained at 26-32 °C and relative humidity at 75-85%. Hens had ad libitum access to feed and water. Daily lighting duration was 16 h (natural and artificial). The hen house was cleaned daily and disinfected weekly by spraying with hens present.

1.3.1 Mycotoxin Content in Diets

Mycotoxin content in the diets was measured on days 1 and 35 (Table 2). On day 1, DON content exceeded the limit standard (1,000 g/kg). High-performance liquid chromatography-tandem mass spectrometry (HPLC-MS/MS) was performed using an Agilent G6410 Triple Quad LC/MS to determine aflatoxin (AF), ZEN, DON, T-2 toxin, fumonisin (FB), and ochratoxin (OT) contents. The detection procedure included sample extraction, filtration, toxin purification, and quantitative analysis. The minimum detection limits were 1.0, 4.5, 4.5, 2.0, 3.5, and 1.0 g/kg for AF, ZEN, DON, T-2 toxin, FB, and OT, respectively.

Table 2 Measured mycotoxin content in diets, g/kg

Mycotoxins	Day 1	Day 35
Aflatoxin		
Zearalenone		
Fumonisin		
Deoxynivalenol		
T-2 toxin		
Ochratoxin		

–indicates not detected.

1.3.2 Performance Parameters

During the formal experimental period, daily feed intake, egg number, egg weight, soft-shelled/broken eggs, and surviving hens were recorded per replicate. Average daily feed intake, laying rate, average egg weight, feed-to-egg ratio, daily egg production, and mortality/culling rate were calculated.

1.3.3 Yolk Trace Element Content

On days 14 and 35, twelve eggs per group were collected and stored at 4 °C. Yolk iron (Fe), zinc (Zn), copper (Cu), magnesium (Mg), and manganese (Mn) contents were determined using flame atomic absorption spectrometry according to GB/T 5009.90-2003, GB/T 9695.20-2008, and Zhang Xinghai et al. [8]. Yolk samples were pretreated using wet digestion: 1.0-1.5 g of homogenized yolk was

placed in a conical flask with 15 mL mixed acid (VHNO :VHClO =9:1), covered with a petri dish, and digested overnight. The following day, the flask was heated on a hot plate until the solution became clear and transparent (approximately 2 mL), then cooled. Additional mixed acid was added if needed to prevent carbonization. Five milliliters of concentrated hydrochloric acid were added, the solution was filtered, and the volume was adjusted to 100 mL. Standard solutions were prepared for calibration curve generation before measurement using a flame atomic absorption spectrometer (SP-AA3800). For Mn and Mg determination, 1-2 mL of 10% strontium chloride solution was added to eliminate interference.

1.3.4 Serum Antioxidant and Biochemical Indices

On days 14 and 35, two hens per replicate were randomly selected for venous blood collection (5 mL). After tilting the collection tubes and standing for 30 min, serum was separated by centrifugation at 3,000 r/min for 10 min. The supernatant (1.0-1.5 mL) was transferred to 1.5 mL centrifuge tubes, labeled, and stored at -20 °C for analysis. Serum glutathione peroxidase (GSH-Px), total superoxide dismutase (T-SOD) activity, total antioxidant capacity (T-AOC), and malondialdehyde (MDA) content were measured using kits from Nanjing Jiancheng Bioengineering Institute. Serum biochemical indices were analyzed using a Mindray BS-200 automatic biochemical analyzer with corresponding reagents, including alkaline phosphatase (ALP) activity and triglyceride (TG), total cholesterol (TC), glucose (Glu), uric acid (UA), calcium (Ca), phosphorus (P), and Fe contents on day 35.

1.4 Statistical Analysis

Data were analyzed using one-way ANOVA with SAS 9.2 software, followed by Duncan' s multiple comparison test. Results are expressed as "Mean±SD." Differences were considered significant at $P<0.05$, and trends were indicated at $0.05<P<0.10$.

Results

2.1 Effects of Mycotoxin Adsorbents on Laying Hen Performance

As shown in Table 2 , dietary supplementation with mycotoxin adsorbents had no significant effects on average egg weight, feed-to-egg ratio, average daily feed intake, or mortality and culling rate ($P>0.05$). However, during weeks 3-5, the CZ group exhibited a 10.21% increase in laying rate ($P<0.05$) and an 11.43% increase in daily egg production ($P<0.05$) compared with the control group, with a trend toward reduced feed-to-egg ratio ($P=0.079$). The SF group showed a 4.05% increase in laying rate ($P>0.05$). Over the entire 5-week period, the CZ group demonstrated a 7.37% increase in laying rate ($P>0.05$) and a trend toward increased daily egg production ($P=0.097$).

Table 2 Effects of mycotoxin adsorbents on performance of laying hens

Group	Time/week	Average egg weight/g	Laying rate/%	Feed-to-egg ratio	Average daily feed intake/g	Daily egg production/g	Mortality and cull rate/%
Control	1-2	61.51±0.58	92.54±5.26	100±0.12	114.22±3.07	57.29±3.32	0.00±0.00
	3-5	61.54±0.58	89.52±7.28	113±0.10	117.05±2.58	58.89±1.00	1.39±3.40
	1-5	61.08±1.51	89.79±4.32	118±0.11	115.38±2.63	55.64±3.28	1.39±3.40
CZ	1-2	61.98±0.94	87.92±4.09	109±0.05	116.14±3.56	54.52±3.66	1.39±3.40
	3-5	62.69±0.35	96.90±1.32	111±0.48	121.80±3.38	60.75±1.19	2.78±4.30
	1-5	62.20±1.33	96.41±1.20	110±0.05	119.85±2.35	60.00±0.99	4.17±6.97
SF	1-2	61.75±0.79	91.48±7.29	108±0.11	113.43±5.10	56.91±4.71	0.00±0.00
	3-5	62.22±0.28	90.66±7.19	114±0.13	121.38±5.19	55.95±4.40	4.17±6.97
	1-5	61.73±1.27	90.66±7.19	112±0.11	118.05±4.60	55.95±4.40	4.17±6.97
P-value							

In the same row, values with different small letter superscripts indicate significant difference ($P < 0.05$), while values with the same or no superscripts indicate no significant difference ($P > 0.05$).

2.2 Effects of Mycotoxin Adsorbents on Yolk Trace Element Content

As shown in Table 3, on day 14, the CZ group exhibited a 24.07% increase in yolk Zn content ($P < 0.05$) and a trend toward increased Mn content ($P = 0.093$) compared with the control group, while yolk Mg content decreased by 33.50% ($P < 0.05$). The CZ group also showed 28% lower Mg content than the SF group ($P < 0.05$). The SF group demonstrated an 8.04% increase in yolk Zn content ($P > 0.05$) and a 9.44% decrease in yolk Fe content ($P < 0.05$). On day 35, the SF group showed a 21.17% reduction in yolk Zn content compared with the control group ($P < 0.05$) and a 21.13% reduction compared with the CZ group ($P < 0.05$). No significant differences were observed in yolk Fe, Cu, Mg, or Mn contents ($P > 0.05$).

Table 3 Effects of mycotoxin adsorbents on yolk trace element content of laying hens (wet weight)

Groups	Fe	Zn	Cu	Mg	Mn
Day 14					
Control	66.53±1.64	41.04±7.41	62.13±2.13	50.92±6.67	3.16±0.64
CZ	60.25±5.57	44.34±8.61	2.12±1.32	77.68±7.25	7.96±0.30
SF	55.93±6.17	10.59±1.48	60.34±3.74	45.76±2.77	3.35±0.78
P-value	<0.001				

Groups	Fe	Zn	Cu	Mg	Mn
Day 35					
Control	66.43±4.44	45.78±5.65	2.82±0.59	84.42±7.52	9.53±2.98
CZ	60.34±3.74	45.76±2.77	3.35±0.78	79.35±5.95	10.98±2.30
SF	64.52±4.16	36.09±5.73	3.59±0.29	87.08±7.15	9.37±2.51
P-value					

In the same column, values with different small letter superscripts indicate significant difference ($P < 0.05$), while values with the same or no superscripts indicate no significant difference ($P > 0.05$). The same applies below.

2.4 Effects of Mycotoxin Adsorbents on Serum Antioxidant Indices

As shown in Table 4, on day 14, both experimental groups exhibited significantly increased serum total antioxidant capacity compared with the control group (100% and 84.04% increases, respectively; $P < 0.05$). Serum glutathione peroxidase activity increased by 13.03% and 8.37% in the experimental groups, respectively, though not significantly ($P > 0.05$). On day 35, both experimental groups showed increased serum total antioxidant capacity (39.06% and 47.92% increases, respectively; $P > 0.05$), while the SF group demonstrated significantly elevated serum total superoxide dismutase activity (64.01% increase; $P < 0.05$).

Table 4 Effects of mycotoxin adsorbents on serum antioxidant indices of laying hens

Groups	GSH-Px/(mU/mL)	T-AOC/(mmol/mL)	T-SOD/(U/mL)	MDA/(mmol/mL)
Day 14				
Control	216.06±60.23	7.77±2.32	244.21±65.60	13.35±0.85
CZ	234.15±59.19	15.54±4.37	192.37±63.17	14.20±5.71
SF	198.60±37.34	14.30±3.20	192.37±63.17	16.59±2.03
P-value		<0.001		
Day 35				
Control	190.24±79.01	9.60±3.26	21.54±4.32	2.06±0.25
CZ	192.37±63.17	13.35±0.85	21.18±0.06	2.03±0.30
SF	192.37±63.17	14.20±5.71	27.21±4.67	1.85±0.27
P-value				

2.5 Effects of Mycotoxin Adsorbents on Serum Biochemical Indices

As shown in Table 5, the CZ group exhibited significantly reduced serum alkaline phosphatase activity (45.07% decrease; $P < 0.05$) and glucose content

(18.21% decrease; $P < 0.05$) compared with the control group, while serum calcium and iron contents increased by 17.71% and 35.29%, respectively ($P > 0.05$). The SF group showed significantly decreased serum total cholesterol content (27.78% reduction; $P < 0.05$), which was 28.06% lower than the CZ group ($P < 0.05$). Serum uric acid content decreased by 22.56% and 26.25% in the experimental groups, respectively, though not significantly ($P > 0.05$). No significant differences were observed in serum triglyceride or phosphorus contents ($P > 0.05$).

Table 5 Effects of mycotoxin adsorbents on serum biochemical indices of laying hens

Groups	ALP/(10 ² U/L)	TC/(mmol/L)	TG/(mmol/L)	Ca/(mol/L)	Fe/(mmol/L)	Urea/(mg/L)
Control	5.88±2.08	2.52±0.74	7.55±3.21	124.40±49.13	86±1.09	4.01±1.05
CZ	3.23±0.91	2.53±0.56	9.60±3.19	96.33±55.37	70±2.71	4.72±0.69
SF	4.75±2.32	1.82±0.57	6.22±3.12	91.74±30.73	33±1.28	4.19±0.62
P-value						

Discussion

3.1 Effects of Mycotoxin Adsorbents on Laying Hen Performance

Most studies on HSCAS adsorbents in poultry have reported improved performance. Shi Minglei et al. [6] found that CSN tended to reduce F/G in yellow-feathered broilers aged 1-50 days. Incharoen et al. [9] reported that natural zeolite promoted intestinal integrity and improved feed conversion in broilers. However, other studies have shown no effect of 0.2% or 0.5% quaternary ammonium-modified montmorillonite on broiler F/G, and increased F/G with 0.5% copper-modified montmorillonite [8]. These inconsistent results suggest that different modification methods yield varying effects on livestock performance. CSN possesses large pore size and specific surface area with strong dispersion properties and high cation adsorption capacity [10], enabling it to eliminate harmful intestinal bacteria and facilitate nutrient absorption [6]. Zinc ions (Zn^{2+}) exhibit antibacterial properties, and zinc-loaded nano-montmorillonite not only adsorbs and exchanges ions but also provides interlayer antibacterial functions, promoting nutrient digestion and absorption [11]. Li Junying et al. [11] reported that dietary supplementation with 1.5 g/kg zinc-loaded nano-montmorillonite increased laying rate by 8.54% and reduced feed-to-egg ratio by 2.19% in laying hens. Berto et al. [12] noted that natural zeolite tended to increase average daily feed intake and feed conversion in laying hens. Zhang Junmin et al. [13] found that dietary supplementation with 0.2% HSCAS significantly increased laying rate by 11.22%. The present study similarly demonstrated that calcium

montmorillonite supplementation significantly increased laying rate by 10.21% and daily egg production by 11.43%, with a trend toward reduced feed-to-egg ratio, consistent with previous findings. HSCAS adsorbents contain various mineral elements that can be absorbed and utilized in vivo to promote metabolism. Their large specific surface area and adsorption capacity prolong feed retention time in the digestive tract, enhancing anabolic processes and nutrient absorption rates [14]. Additionally, they can adsorb harmful substances in the intestinal tract, improving the microecological environment and function [2]. In summary, dietary mycotoxin adsorbents can mitigate the negative impacts of mycotoxins on livestock performance and improve production efficiency.

3.2 Effects of Mycotoxin Adsorbents on Yolk Trace Element Content

Research on the effects of mycotoxin adsorbents on trace element content in poultry eggs remains limited. This study found that both HSCAS adsorbents had no significant effects on yolk Cu or Mn contents. The calcium montmorillonite group (CZ) showed significantly increased yolk Zn content on day 14, while the sodium montmorillonite group (SF) exhibited significantly reduced yolk Fe content on day 14 and decreased yolk Zn content on day 35. These differential results may stem from the distinct physical properties of the two adsorbents. Due to the high hydration capacity of sodium ions (Na⁺), sodium montmorillonite more readily expands upon water contact compared with calcium montmorillonite, potentially absorbing nutrients during the swelling process and affecting adsorption efficacy. The present results suggest that calcium montmorillonite provides superior detoxification effects. While adsorbents may bind mycotoxins in feed, they might also adsorb nutrients such as minerals and vitamins, potentially reducing feed utilization efficiency [14][19]. However, adsorbents may also bind pathogenic microorganisms in the intestinal tract, improving gut environment and facilitating nutrient absorption, which could promote mineral and vitamin deposition in animal products. This study suggests that adsorbents can increase certain trace elements in egg yolk, though further research with extended experimental periods is needed. Future studies should investigate the effects of adsorbents on mineral and vitamin metabolism in livestock and their impact on nutrient content in animal products, which is crucial for scientifically evaluating detoxification efficacy and guiding further research.

3.3 Effects of Mycotoxin Adsorbents on Serum Antioxidant Indices

Oxidative damage represents one of the toxic mechanisms through which mycotoxins harm animal health. Glutathione peroxidase (GSH-Px), superoxide dismutase (SOD), and malondialdehyde (MDA) are important indicators of antioxidant capacity. Abel et al. [20] reported that AFB1 induces free radical production and oxidative damage. Kouadio et al. [21] found that ZEN and DON block sphingomyelin metabolism, generating substantial MDA and causing lipid peroxidation. Many researchers have explored the protective effects of adsorbents against mycotoxin-induced oxidative damage. Lü Mingbin et

al. [22] found that adding 1 g/kg HSCAS adsorbent to moldy corn reduced serum GSH-Px activity in broilers, whereas 2 g/kg supplementation increased activity. Jiang et al. [23] and Cai Juan et al. [24] reported that yeast cell wall and montmorillonite increased serum SOD activity in broilers and laying hens, respectively. Zhang Ruixing et al. [25] found that dietary supplementation with compound mycotoxin adsorbents increased serum SOD activity and T-AOC while significantly reducing MDA content in broilers. The present study found that dietary supplementation with 0.5 g/kg of either HSCAS adsorbent increased serum GSH-Px, T-SOD activity, and T-AOC in laying hens, with significant improvements in T-AOC on day 14 and T-SOD activity on day 35 in the experimental groups. A slight reduction in serum MDA content was also observed. These results align with previous studies, indicating that adsorbents can enhance serum antioxidant enzyme activity, reduce free radical content, and counteract mycotoxin-induced oxidative damage.

3.4 Effects of Mycotoxin Adsorbents on Serum Biochemical Indices

Alkaline phosphatase (ALP) is a crucial indicator of liver function. Wen Ziyu et al. [26] reported that a mixture of HSCAS and yeast cell wall reduced serum alanine aminotransferase, aspartate aminotransferase, and ALP activities in meat ducks, alleviating toxin-induced liver damage. In this study, all experimental groups showed reduced serum ALP activity, with the CZ group exhibiting a significant 45.07% decrease compared with the control group. Blood lipids, primarily cholesterol and triglycerides, reflect lipid metabolism status. The CZ group showed slight increases in serum TG and TC contents, consistent with Zhang Yong et al. [14], whereas the SF group exhibited reduced serum TC and TG contents, possibly due to yeast cell components promoting intestinal motility and improving gut environment, thereby enhancing fat metabolism and reducing fat accumulation. Thus, different adsorbents exert varying effects on lipid metabolism in laying hens due to their distinct compositions.

Uric acid (UA) represents the primary form of amino acid nitrogen excretion in poultry and reflects protein metabolism. All experimental groups showed reduced serum UA content, consistent with Fu Shuangxi et al. [27], indicating that adsorbents can reduce nitrogen excretion and improve dietary crude protein utilization. Glucose (Glu) reflects energy metabolism status. All experimental groups showed reduced serum Glu content, with the CZ group exhibiting a significant 18.21% decrease. Since serum biochemical indices were measured after 12 h of fasting, the reduced serum Glu content suggests that mycotoxin adsorbents may affect carbohydrate metabolism. Additionally, stress increases serum Glu content through glycogenolysis, suggesting that adsorbents may enhance stress resistance. Laying hens have high mineral requirements, particularly calcium for eggshell formation. When dietary calcium is insufficient, serum calcium is mobilized to supplement eggshell formation. All experimental groups showed increased serum Ca and Fe contents, with the CZ group exhibiting 17.71% and 35.29% increases, respectively. HSCAS adsorbents contain various mineral el-

ements and can improve intestinal environment, thereby enhancing utilization of Ca, Fe, and other minerals and benefiting mineral metabolism.

Conclusions

1. Dietary supplementation with 0.5 g/kg CZ improved the productive performance of Roman laying hens, with a trend toward reduced feed-to-egg ratio, whereas 0.5 g/kg SF had no significant effect on performance.
 2. CZ may promote Zn and Mn deposition in egg yolk, while SF may reduce Fe and Zn content in yolk.
 3. Both adsorbents enhanced antioxidant function and improved metabolic status to varying degrees.
 4. Overall, adsorbent CZ demonstrated superior efficacy in mitigating the negative effects of mycotoxins on laying hens.
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