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Original Article

Saccharomyces Cerevisiae Lysate as an Antimycotoxin Feed Additive for Broilers Previously Contaminated by Deoxynivalenol and Fumonisin: Impact on Animal Health and Performance

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ABSTRACT

We evaluated whether the addition of a commercial product made of *Saccharomyces cerevisiae* lysate (Detoxa Plus®) would be able to minimize the negative effects on performance and health of broilers fed diets contaminated with Deoxynivalenol (DON) and Fumonisin (FB1). A total of 450 male broiler chickens were randomly divided as follows: NC – Negative control diet (without mycotoxin); PC – positive control (diet contaminated with 3 ppm of DON and 30 ppm of FB1); PC+D500 (positive control diet+Detoxa Plus® 500 mg/kg); PC+D750 (positive control diet + Detoxa Plus® 750 mg/kg); PC+D1000 (positive control diet + Detoxa Plus® 1000 mg/kg); NC+D1000 (negative control diet + Detoxa Plus® 1000 mg/kg). Birds fed contaminated diets had lower weight gain (WG) when compared to NC and NC+D1000 at 21 days; however, at 35 and 42 days only birds from the group NC+D1000 showed higher WG. The best feed conversion (FC) was observed in the groups NC and NC+D1000, but birds from the PC+D1000 group showed a similar FC to them. There was an increase in Reactive Oxygen Species and Thiobarbituric Acid Reactive Substances in the liver of PC birds when compared to the other groups. Birds in the NC+D1000 and PC+D1000 groups had the largest intestinal villus size when compared to the other treatments. It is concluded that the consumption of mycotoxins impaired the performance and increased the oxidative stress of the birds. However, the addition of 1000 mg/kg of Detoxa Plus® minimized these negative effects, while also providing larger villus length.

INTRODUCTION

Mycotoxicosis in poultry was first described in 1960 in the United Kingdom, where more than 100,000 turkeys were killed, probably due to the ingestion of feed contaminated with aflatoxin from peanut meal imported from Brazil (Tsiouris *et al*., 2021). Mycotoxins are classified as low molecular weight secondary metabolites produced by fungi, mainly of the genera Aspergillus, Penicillium, and Fusarium (Poloni *et al*., 2020). In 2013, 81% of grains and feed samples were contaminated with at least one type of mycotoxin (Murugesan *et al*., 2015). The appearance of mycotoxins in food is influenced by several factors, including season of the year, place of grain cultivation, drying, storage method, and harvest time.

Deoxynivalenol (DON) and fumonisins are produced by *Fusarium spp*. DON mainly affects young birds by reducing intestinal villi and the expression of transporter peptides, which indicates a decrease in the surface used for nutrient absorption (Santos *et al*., 2021), while also potentially causing immunosuppression (Guo *et al*., 2021). Fumonisins also cause liver damage, oxidative stress, alter protein and

lipid metabolism, and decrease the body weight of birds (Galli *et al*., 2020). Liu *et al*. (2020) found that fumonisins and DON decrease dry matter and energy digestibility, which impairs bird performance.

Several alternatives have emerged to reduce and/or avoid the adverse effects of mycotoxins throughout the gastrointestinal tract, among which are sequestering, adsorbing, or agglutinating agents (Yiannikouris *et al*., 2021). In this context, the cell wall of the yeast *Saccharomyces cerevisiae* (SC) has shown an adsorbent effect, which varies depending on the mannan oligosaccharides (MOS) components or its esterified form β-D-glucan (Čolović *et al*., 2019). Arif *et al*. (2020) found that the addition of 2.5 or 3.75 g/kg of SC could improve the performance of broilers that received mycotoxin-contaminated diets. Live strains of some yeasts have shown the ability to eliminate mycotoxins, and this ability depends on the cell wall amount and mycotoxin removal ability, with β-glucans being the primary involved components (Armando *et al*., 2012). Therefore, the aim of the present study was to evaluate whether the addition of a commercial product composed of selected strains of *Saccharomyces cerevisiae* (Telluris CH 19, CH17 e CH 12) cell wall lysate is able to minimize the adverse effects on zootechnical performance and health of broilers fed diets contaminated with DON and FB1.

MATERIALS AND METHODS

The commercial product

The commercial product used in this study was a lysate based on *S. cerevisiae* (86%) (Detoxa Plus®, Vetanco do Brasil Importação e Exportação Ltda).

Mycotoxin production

Mycotoxins were produced by the company Micotec (Piracicaba, São Paulo, Brazil). Initially, *Fusarium verticillioides* colonies were obtained from potato-dextrose agar incubated for 15 days at 25°C. For fumonisin B1 production (FB1), *F. verticillioides* was cultured in rice (100 g) moistened with tap water (water activity >0.97) and autoclaved at 121°C for 1 h. The fermentation step was carried out in a 500 mL capacity Erlenmeyer flask using 2 mL of a conidial suspension (1×105 conidia per mL). After inoculation, the flasks were maintained static for 28 days at 25°C. Subsequently, the ferment was dried and grounded to artificially contaminate broiler feed. The concentrations of FB1 and desoxinivalenol (DON) on ground fermented material were measured using HPLC/MS/MS.

Animals and experimental design

A total of 450 one-day-old Cobb male chicks were raised up to 42 days of age. The birds were distributed in a completely randomized design with six treatments, each with five replications of 15 birds each. The birds were kept in pens of 2 m2 with shavings beddings and submitted to a light program in accordance with the Cobb Broiler Management Guide.

The animals were randomly divided as follows: NC – Negative control diet (without mycotoxin); PC – Positive control (diet contaminated with 3 ppm of DON and 30 ppm of FB1); PC+D500 (diet contaminated with 3 ppm of DON and 30 ppm of FB1 + Detoxa® Plus 500 mg/kg); PC+D750 (diet contaminated with 3 ppm of DON and 30 ppm of FB1+Detoxa® Plus 750 mg/kg); PC+D1000 (diet contaminated with 3 ppm of DON and 30 ppm of FB1+Detoxa® Plus 1000 mg/kg); NC+D1000 (negative control diet+Detoxa® Plus 1000 mg/kg). The rations were mixed in a horizontal mixer with a capacity of 150 kg, and then analyzed by liquid chromatography with mass spectrometry detection (HPLC - MS / MS) to detect mycotoxin concentrations (Table 1).

Table 1 – Parameters data from mass spectrometer.

Analyte	MRM transition	Dwell time (s)	Cone voltage (V)	Collision energy (eV)
Aflatoxin B1	313.08>241.23	0.005	30	37
	313.08>285.39			23
IS Aflatoxin B1	330.00>300.90	0.005	30	23
Aflatoxin B2	315.10>259.05	0.005	30	28
	315.10>287.16			25
IS Aflatoxin B2	332.00>303.10	0.005	30	25
Aflatoxin G1	329.09>243.10	0.005	25	26
	329.09>283.00			26
IS Aflatoxin G1	346.00>257.00	0.005	25	26
Aflatoxin G2	331.05>245.05	0.005	25	30
	331.05>257.04			25
IS Aflatoxin G2	348.00>330.00	0.005	25	25
Ochratoxin A	404.20>221.10	0.005	25	30
	404.20>339.10			30
IS Ochratoxin A	424.00>250.00	0.005	25	25
Deoxynivalenol	297.19>231.18	0,037	20	10
	297.19>249.18			10
IS Deoxynivalenol	321.10>263.00	0.039	15	10
Zearalenone	319.20>185.20	0.005	20	19
	319.20>187.20			23
IS Zearalenone	337.00>199.10	0.005	20	19
Fumonisin B1	722.78>334.29	0.005	30	40
	722.78>352.22			35
IS Fumonisin B1	756.10>374.20	0.005	30	40
Fumonisin B2	706.57>318.22	0.005	30	40
	706.57>336.04			40
IS Fumonisin B2	740.20>358.20	0.005	30	36
Toxin T2	484.40>185.10	0.005	10	22
	484.40>215.10			22
IS Toxin T2	508.00>198.10	0.005	25	22

The basal feed was formulated with corn and soybean meal, according to the food compositions and nutritional requirements described in the Brazilian Tables for Poultry and Swine (Rostagno *et al*., 2017). Water and feed were provided *ad libitum* throughout the experimental period through tube feeders and nipple drinkers.

Animal performance

Birds and feed were weighed on days 1, 21, 35 and 42 of the experiment using an electronic scale with a digital output, accurate to 5 g. Mean weight (MW, kg) was determined by dividing the total weight of the birds by the number of animals of each pen; while the weight gain (WG, kg) was determined using the formula: WG = (final weight - initial weight of the group)/number of birds per pen. Feed intake (FI) (g/bird/day) was obtained through the difference between the feed provided at the beginning and the leftovers weighed at the end of each period. Feed conversion (FC) was calculated by the total amount of feed ingested divided by the live weight of the birds.

Sampling

At 42 days of age, blood samples were collected from the ulnar vein using an insulin syringe (1 mL) without anticoagulant to obtain the serum. Subsequently, this material was centrifuged at 3500 rpm for 10 minutes and the serum was separated, collected and frozen (-20°C) for sphinganine/sphingosine (Sa/So) ratio analyses. In addition, one bird per experimental unit (n=5/treatment) was humanely euthanized by cervical dislocation, according to the Animal Welfare and Euthanasia Standards described by the CONCEA Euthanasia Practice Guidelines (Brasil/MCTI, 2013). Liver samples were collected and homogenized in saline solution, centrifuged at 2800 g for 10 min, and the supernatant was frozen at -20ºC until the analysis of oxidative stress markers.

Histopathology

Jejunal samples were collected and preserved in 10% formaldehyde solution. Slides with histological sections were stained with hematoxylin and eosin (H&E). Under a light microscope, their morphological structure was evaluated, and the villi length/crypt depth ratio was determined according to the methodology described by Caruso & Demonte (2005). Histological images were captured using a digital microcamera (Electronic Eyepiece Camera Video) coupled to a biological trinocular microscope (model TNB-41T-PL, OPTON) and a specific software (Images J). The details on the methodology used to measure villus length/crypt depth were described by Galli *et al*. (2020b).

Liver oxidant status

Levels of free radicals (ROS) in the liver were determined according to the technique described by Ali *et al*. (1992). The samples were diluted 1:10 with 10 mM Tris (pH 7.4) and 5 µL of dichlorofluorescein diacetate (DCFH-DA). The results were expressed as U DCF/mg of protein.

Oxidative stability was determined as levels of thiobarbituric acid reactive substances (TBARS) in serum according to the method described by Jentzsch *et al*. (1996). Results were obtained by spectrophotometry at 535 nm and expressed in nmol of malondialdehyde (MDA) /ml of serum.

Sphinganine/sphingosine (Sa/So) ratio

Seric Sa/So ratio was used as a biomarker of exposure to fumonisins. For this, the concentration of sphinganine (Sa) and sphingosine (So) was determined by liquid chromatography with fluorescence detection as described by Riley *et al* (1994), using sphinganine C20 as an internal standard.

Mycotoxins analysis

For mycotoxins analyses, feed samples were ground to particles smaller than 0.85 mm. Grounded material (1g) was transferred to a test tube of 50 mL, diluted into 10 mL of ultrapure water and 10 mL of acetonitrile/acetic acid (CH3CN:CH3COOH) [99.5:0.5, v/v] and shaken in a mechanic shaker for 10 min. A mixture of 4 g of MgSO4 and 1 g of NaCl was added, and the tube was vigorously hand-shaken for 10 s. The solution was then centrifuged for 15 min at 5.000 x g at 25°C, and 2.5 mL of supernatant was transferred to capped glass test tube with 2.5 mL of hexane. The solution was shaken for 2h and then centrifuged at 1.000 x g, at 20°C for 1 min. From the lower phase (acetonitrile), 1 mL was withdrawn and dried with Nitrogen (N2) stream at 40°C. The reconstitution was performed with 75 µL of methanol in ultrasonic bath for 10s, and 10s in a test tube mixer after adding 75 µL of ultrapure water. After centrifugation for 10 min at 14.000 x g, 60 µL was withdraw and transferred to a vial where 140 µL of ultrapure water was added. Ten microlitres were then injected in the chromatographic system.

Detection and quantification of mycotoxins were performed with high-performance liquid chromatography coupled with tandem mass-spectrometry (LC/MS/MS). Chromatographic

separation was carried out using Acquity UPLC System (Waters, Milford, Massachusetts, EUA) equipped with 100 × 2.1 mm, 1.7 µm Acquity UPLC BEH C18 column, (Waters, Milford, Massachusetts, EUA). The column was maintained at 40°C and the injection volume was 10 µL. The mobile phase consisted of 0.1% formic acid in water (A), and 0.1 % formic acid in acetonitrile (B). The acetonitrile (B) concentration was raised gradually from 10 % to 90 % within 12 min, brought back to the initial conditions at 0,1 min, and allowed to stabilize for 3 min. The mobile phase was delivered at a flow rate of 0.4 mL/min. The LC system was coupled with Xevo TQS tandem mass spectrometer (Waters, Milford, Massachusetts, EUA), equipped with a turbo-ion electrospray (ESI) ion source. The mass-spectrometer was operated in scheduled multiple reaction monitoring (MRM) in positive mode. The data acquisition of mass spectrometer are shown in Table 1. Mycotoxins quantification was carried out using matrix-matched calibration curves, using extracts of uncontaminated diets phases.

Statistical analysis

The data were submitted to analysis of normality of distribution (Shapiro-Wilk) and then to analysis of variance. In cases of significant differences, the means were compared using the Tukey test (5%). For the mortality variable, a non-parametric test (Kruskal-Wallis test - 5%) was used due to the non-existence of a normal distribution.

Ethics Committee

This experiment was approved by the Institutional Animal Use Ethics Committee (protocol number 6577200720/UDESC).

RESULTS

Mycotoxin level on diets

Table 2 shows the levels of mycotoxins found in feed samples, which were close to the desired levels, enough to challenge the birds.

Animal performance

Table 3 shows that until up to 21 days, the birds that received contaminated rations had lower body weight and weight gain when compared to NC and NC+D1000 (p<0.001). The worst FC was observed in treatments PC and PC+D500 as compared to NC and NC+D1000 (p<0.001). From days 1 to 35, no differences were observed for MW and WG between the NC group and the contaminated groups (p>0.05); however, birds of the NC+D1000 group had higher MW and WG than those of contaminated groups (p<0.001). The FC was similar to that observed in the period from day 1 to 21, with lower numbers observed in the PC and PC+D500 treatments compared to the NC and NC+D1000 ones (p<0.001). For the total period of 1-42 days, similar results to those for 1-35 were observed regarding MW and WG; however, in this rearing phase, the FC for the CP + D1000 treatment did not differ from those of the NC and NC+D1000 groups. There was no difference between treatments for FI in any of the analyzed periods (p>0.05).

Table 2 – Means obtained for the concentrations (ppb) of Deoxynivalenol (DON) and Fumonisin FB1 in the broiler´s feed.

Treatment	DON	FB1
NC	ND	1200
PC	2843	26378
PC+D500	2713	27735
PC+D750	2761	33022
PC+D1000	2730	25291
NC+D1000	ND	1120

Treatments: PC – Contaminated diet (positive control); PC+D500 – Contaminated diet + Detoxa® Plus 500 mg/kg; PC+D750 – Contaminated diet + Detoxa® Plus 750 mg/kg; PC+D1000 – Contaminated diet + Detoxa® Plus 1000 mg/kg; NC+D1000 – negative control + Detoxa® Plus 1000 mg/kg. ND = Not detected.

Table 3 – Mean values for feed intake (FI, kg), mean weight (MW, kg), weight gain (WG, kg) and feed conversion (FC) of birds fed diets containing mycotoxins and yeast cell wall throughout the experimental period.

Treatment		FI	MW	WG	FC
1 to 21 days	NC	1.40	0.998 A	0.951 A	1.47 B
	PC	1.42	0.894 B	0.848 B	1.68 A
	PC+D500	1.46	0.900 B	0.854 B	1.71 A
	PC+D750	1.41	0.923 B	0.878 B	1.61 AB
	PC+D1000	1.40	0.920 B	0.875 B	1.60 AB
	NC+D1000	1.39	1.025 A	0.980 A	1.42 B
	p-Value	0.351	< 0.001	< 0.001	< 0.001
	CV (%)	3.82	3.29	3.47	5.89
1 to 35 days	NC	3.78	2.53 AB	2.48 AB	1.52 B
	PC	3.96	2.47 B	2.42 B	1.63 A
	PC+D500	3.80	2.36 B	2.31 B	1.64 A
	PC+D750	3.79	2.40 B	2.35 B	1.61 AB
	PC+D1000	3.80	2.45 B	2.40 B	1.58 AB
	NC+D1000	3.85	2.65 A	2.60 A	1.48 B
	p-Value	0.673	< 0.01	< 0.01	0.016
	CV (%)	4.71	3.57	3.64	4.75
1 to 42 days	NC	5.18	3.39 AB	3.34 AB	1.55 B
	PC	5.46	3.30 B	3.25 B	1.68 A
	PC+D500	5.25	3.20 B	3.16 B	1.67 A
	PC+D750	5.37	3.27 B	3.22 B	1.67 A
	PC+D1000	5.20	3.28 B	3.23 B	1.61 AB
	NC+D1000	5.30	3.55 A	3.51 A	1.51 B
	p-Value	0.483	< 0.01	< 0.01	< 0.01
	CV (%)	4.32	3.40	3.45	4.30

A, B, C: Different letters in the same column indicate a significant difference by Tukey's test (p<0.05). CV = coefficient of variation. Treatments: PC – Contaminated diet (positive control); PC+D500 – Contaminated diet+Detoxa® Plus 500 mg/kg; PC+D750 – Contaminated diet+Detoxa® Plus 750 mg/kg; PC+D1000 – Contaminated diet+Detoxa® Plus 1000 mg/kg; NC+D1000 – negative control+Detoxa® Plus 1000 mg/kg.

Liver oxidant status and sphinganine/sphingosine (Sa/So) ratio

The Sa/So ratio was similar in all samples, with the exception of those from the NC group, whose enzyme concentrations were lower than the detection range of the equipment used in the analysis (Table 4).

Table 4 – Mean values for seric sphinganine/sphingosine (Sa/So) ratio, reactive oxygen species (ROS, U DCF/mg protein) and thiobarbituric acid reactive substances (TBARS, mmol MDA/mg protein) in the liver of broilers fed diets with mycotoxins and yeast cell wall.

Treatment	Sa/So	ROS	TBARS
NC	ND	37.000 B	1.99 B
PC	1.33	108.000 A	8.34 A
PC+D500	1.73	42.000 B	6.92 AB
PC+D750	1.22	25.000 B	1.02 B
PC+D1000	1.34	42.000 B	1.47 B
NC+D1000	0.90	23.000 B	1.44 B
p-Value	0.154	<0.0001	0.0016
CV (%)	44.95	34.13	38.43

A, B: Different letters in the same column indicate a significant difference by Tukey's test ($p<0.05$). CV = coefficient of variation. Treatments: PC – Contaminated diet (positive control); PC+D500 – Contaminated diet+Detoxa® Plus 500 mg/kg; PC+D750 – Contaminated diet+Detoxa® Plus 750 mg/kg; PC+D1000 – Contaminated diet+Detoxa® Plus 1000 mg/kg; NC+D1000 – negative control+Detoxa® Plus 1000 mg/kg. ND= sphingosine not detected (<5ppb).

There was an increase in ROS in the liver of PC birds in relation to the other treatments ($p<0.0001$), while for TBARS there was also an increase in the PC group when compared to the NC, PC+D750, PC+D1000 and NC +D1000 groups ($p=0.0016$).

Histopathology

The NC+D1000 and PC+D1000 groups had the highest intestinal villus height in relation to the other treatments (Table 5). On the other hand, the birds of the NC group had the smallest villus length, with a significant difference from the other treatments ($p<0.0001$).

Table 5 – Villus size, crypt depth and villus:crypt ratio of 42-day-old broilers fed diets with mycotoxins and yeast cell wall.

Treatment	Villus size	Crypt depth	Villus/crypt ratio
NC	1265 D	211.84 B	5.95
PC	1379 C	240.96 AB	6.18
PC+D500	1390 C	232.20 AB	6.24
PC+D750	1389 C	239.76 AB	5.72
PC+D1000	1795 A	279.08 A	6.22
NC+D1000	1732 A	277.66 A	6.16
p-Value	<0.0001	0.0011	0.202
CV (%)	4.85	14.89	16.06

A, B: Different letters in the same column indicate a significant difference by Tukey's test ($p<0.05$). CV = coefficient of variation. Treatments: PC – Contaminated diet (positive control); PC+D500 – Contaminated diet+Detoxa® Plus 500 mg/kg; PC+D750 – Contaminated diet+Detoxa® Plus 750 mg/kg; PC+D1000 – Contaminated diet+Detoxa® Plus 1000 mg/kg; NC+D1000 – negative control+Detoxa® Plus 1000 mg/kg.

DISCUSSION

Broiler chickens that received feed contaminated with DON and FB1 had their intestinal absorption efficiency affected due to a lower duodenal villi length. Important cells such as enterocytes, goblet, and enteroendocrine are found in the villi, and they are responsible for the absorption of nutrients, and mucin and hormone production, respectively (Snoeck *et al*., 2005). In other words, by reducing the villus length, and consequently the number of these important cells, their functions may be impaired, affecting animal performance and health (Weaver *et al*. 2020).

Differently from our results, Bortoluzzi *et al*. (2016) found that diets contaminated with mycotoxins increased the villus/crypt ratio, which might be indicative of a lower proliferation rate on rapidly dividing cells. They also reported that the addition of glucomannans decreased these effects on the intestinal morphology of broilers. In this context, pH conditions together with salts and enzymes can cause relaxation in the cell wall structure, which exposes some functional groups such as β-glucans, which are correlated with increased aflatoxin adsorption capacity (Fochesato *et al*., 2020).

It is possible to speculate that the phenomena mentioned above occurred in the present study, since SC lysate reduced the negative effects of mycotoxins on intestinal morphology. Mycotoxins alter the intestinal morphology mainly by greater crypt depth and lower villus height (Souza *et al*., 2020; Luo *et al*., 2021). The addition of 1000 mg/kg of SC lysate increased both the depth of the crypt and the height of the intestinal villi, a mechanism that could explain the improved zootechnical performance. According to Kyoung *et al*. (2023), the effect observed on the villus length is linked to the components of SC lysate (e.g., b-glucan and MOS), which can protect the gut from pathogenic bacteria with type I fimbriae from binding to the villi and allowing fewer antigens to come into contact with the villi. Thus, in the present study, the addition of 1000 mg/kg of SC lysate minimized the adverse effects of mycotoxins on feed conversion, which is the main performance variable considered by commercial poultry operations.

Excess reactive oxygen species can cause changes in intracellular mechanisms that oxidize DNA, proteins and lipids of membranes, as is well-known in mycotoxicoses (Galli *et al*., 2020a). Mycotoxins can overproduce free radicals that negatively affect the function of antioxidant enzymes (Mavrommatis *et al*., 2021). Mavrommatis *et al*. (2021) reported that changes in

antioxidant and oxidant status depend on mycotoxin species, dose, and duration of exposure. Skiepko *et al*. (2020) found that DON and ZEN cause damage to hepatocytes and liver immune/connective tissue cells. Therefore, this explains the increase in ROS and TBARS in the liver of birds challenged with mycotoxins found in the present study. Holanda *et al*. (2020) observed no difference in oxidative stress markers when newly weaned piglets were challenged with mycotoxins and supplemented with yeast wall. This result was different from the one found in the present study, in which the SC wall decreased the concentration of ROS and TBARS in the liver of broiler chickens.

The mechanism of action of the SC lysate in a context of mycotoxin challenge seems to be by adsorption/biodegradation of mycotoxins and/or by acting as a prebiotic for the intestinal microbiota, leading to improved animal performance. In this context, Arif *et al*. (2020) observed that the addition of 3.5 g of SC cell wall per kilogram of feed minimized the negative effects of aflatoxin B1 by acting as a biodegrading agent in broilers. In addition, the yeast wall and derivatives can act as antioxidants, activate enzyme production and increase the absorption of vitamins and minerals (Koc *et al*., 2010). Still in this scenario, Dazuk *et al*. (2020) reported an increase in the activity of the GST enzyme in laying hens that received 500 g/t of SC lysate, and this enzyme has a detoxifying action in the body. Therefore, it appears that the wall of SC can minimize the oxidative stress caused by different mycotoxins by a possible antioxidant effect. On the other hand, more studies regarding the mechanisms/pathways used are necessary. In the present study, SC wall reduced the levels of oxidative stress markers in the liver and improved feed conversion in the group that received 1000 mg/kg, suggesting a lower production or a scavenging mechanism of free radicals in the organism challenged with mycotoxins.

CONCLUSION

The consumption of diets contaminated with deoxynivalenol and fumonisins at the evaluated levels was able to impair broilers' performances, as well as to affect their oxidative status. However, the addition of 1000 mg/kg of SC lysate led to increased intestinal villi and minimized the oxidative stress and the negative effects of mycotoxins on feed conversion.

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AUTHOR CONTRIBUTIONS

Conceptualization, CP, FLB, FM and MMB; methodology, EMG, REM, EMG, JVS, PVO and MSM; investigation, ASS, MMB, LMS and EMG; resources, FLG and FM; data curation, MMB; writing—original draft preparation, MMB, CP, EMG and LMS; writing—review and editing, MMB and LMS; supervision, MMB; project administration, MMB and CP; All authors have read and agreed to the published version of the manuscript.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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