RESEARCH ARTICLE AGROBIOLOGICAL RECORDS
ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

EFFECTS OF DIETARY YEAST CELL WALL SUPPLEMENTATION ON BROILER CHICKEN PERFORMANCE AND GUT HEALTH

FM Hayajneh

Department of Animal Production, School of Agriculture, The University of Jordan, 11942, Amman, Jordan

*Corresponding author: firashope@gmail.com

ABSTRACT

This study investigated the effects of dietary yeast supplementation on anticoccidial activity, antioxidant status, performance, and blood parameters in broiler chickens challenged with coccidiosis. A total of 375 one-day-old broiler chicks were randomly assigned to five experimental groups, with three replicates per group (25 chicks per replicate). Treatments included two yeast-supplemented groups (Ty1: 1 g/kg; Ty2: 3 g/kg), two negative control groups (unchallenged, untreated and challenged, untreated), and a positive control group treated with sulphonamide and diaveridine HCl. Birds were raised under standard management conditions for 35 days. Performance parameters, including body weight gain, feed intake, and feed conversion ratio, were recorded. Anticoccidial efficacy was assessed via lesion scoring and oocyst index, while additional evaluations included meat quality traits, blood biochemical profiles, and immune organ development. Yeast supplementation, particularly at 3 g/kg (Ty2), significantly reduced oocyst shedding ($P<0.01$) and mitigated intestinal lesions compared with infected controls. This was supported by histopathological findings in the Ty2 group, which showed preserved intestinal architecture with reduced necrosis. Enhanced meat quality was also observed, including improvements in water-holding capacity, cooking loss, and fillet weight. No adverse effects were noted in blood biochemistry or immune organ weights, indicating systemic safety. It was concluded that dietary yeast, especially at 3 g/kg, effectively improved gut health and meat quality, supporting its potential as a natural alternative for coccidiosis control in broiler production.

Keywords: Yeast supplementation, Coccidiosis, Broiler chickens, Anticoccidial activity, Meat quality, Immune response.

Article History (ABR-26-009) || Received: 07-Jan-2026 || Revised: 15-Apr-2026 || Accepted: 20-May-2026 || Published Online: 01-Jun-2026

This is an open-access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. INTRODUCTION

Coccidiosis remains one of the most economically devastating parasitic diseases affecting global poultry production, caused by protozoan parasites of the genus *Eimeria*. The disease impairs nutrient absorption due to intestinal damage, resulting in reduced growth performance, poor feed conversion, increased morbidity, and mortality (Shivaramaiah et al., 2021). Control strategies have traditionally relied on anticoccidial drugs such as sulphonamides and ionophores. However, growing concerns regarding antimicrobial resistance, drug residues in poultry products, and increasingly stringent regulatory restrictions have intensified the search for natural, sustainable alternatives (Wu et al., 2021; El-Shall et al., 2022; M'Sadeq et al., 2023). Coccidiosis causes intestinal leakage of plasma protein, malabsorption, villous atrophy, interruption of nutrient digestion, decreased weight gain (WG), reduced feed and water intake, increased feed conversion ratio (FCR), increased mortality rates, increased intestinal passage, increased susceptibility to other diseases, and increased medication expenses (Martins et al., 2022).

This search for alternatives has focused on natural agents with immunomodulatory and antimicrobial properties, among which botanical compounds have emerged as a particularly promising frontier. Aromatic plants and their extracts are rich in bioactive compounds with significant therapeutic potential against parasitic diseases (Smith, 2023). This is evidenced by recent studies demonstrating the efficacy of specific botanicals against coccidial infection in poultry. For example, the ethanolic extract of clove (*Syzygium aromaticum*) and the essential oil of *Amomum subulatum* have shown strong anticoccidial activities in broiler chickens, improving health outcomes and reducing parasitic load (Zaheer et al., 2022; Khan et al., 2023a). Similarly, *Linum usitatissimum* (flaxseed) essential oil exhibits growth-promoting, hematological, and anticoccidial potential. The principle of botanical control is effective across species, as shown in ruminants (Iqbal et al., 2023), and the biochemical potential of plants, even under stress, underscores their robustness as a source of bioactive compounds (Ali et al., 2023). The mechanism of action of many botanicals, including the nematocidal effects of *Khaya senegalensis* and *Azadirachta indica* against *Haemonchus contortus* (Idris et al., 2023), often involves disrupting parasite integrity

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

and modulating host immunity, providing a solid rationale for exploring other natural sources, such as yeast.

Yeast and yeast-derived products have garnered considerable interest as multifunctional feed additives in poultry nutrition. Yeast components such as β-glucans, mannan-oligosaccharides (MOS), nucleotides, and enzymes exhibit immunomodulatory, antimicrobial, and antioxidant properties (Alizadeh et al., 2021; Song et al., 2023). These bioactive compounds enhance gut health by promoting beneficial microbiota, improving intestinal integrity, and stimulating both innate and adaptive immune responses (Perricone et al., 2022). As a result, dietary yeast has shown potential to mitigate enteric diseases such as coccidiosis while also enhancing nutrient absorption and performance. Various feed additives—including yeast, probiotics, prebiotics, organic acids, and plant extracts—have been explored to enhance poultry productivity, immunity, and control coccidiosis (Peek & Landman, 2011; Wu et al., 2021; Khan et al., 2023b). *Saccharomyces cerevisiae* yeast cell walls (YCW), rich in β-glucans and mannan-oligosaccharides (MOS), provide immunomodulatory effects and improve gut health by limiting pathogen colonization (Shanmugasundaram et al., 2013a; 2013b; Alizadeh et al., 2021; Magnoli et al., 2024). With strict regulations on chemical anticoccidials in Europe since 2006, natural alternatives like YCW and plant-derived additives are gaining increased use and attention (Hayajneh et al., 2018a; 2018b; El-Shall et al., 2022).

Recent studies have reported that yeast supplementation improves weight gain, reduces oocyst shedding, and enhances villus morphology in broilers challenged with *Eimeria* spp. (Chen et al., 2022; Amer et al., 2023). Additionally, improvements in carcass traits, meat water-holding capacity, and oxidative stability have been associated with yeast-derived polysaccharides and antioxidants (Kiczorowska et al., 2020; Hosseini Mansoub et al., 2021). While previous studies have demonstrated the general benefits of yeast supplementation, the novel aspect of this study is the direct, comparative evaluation of two distinct yeast cell wall dosages (1g/kg vs. 3 g/kg) to determine the optimal level for mitigating specific coccidiosis-related pathologies under an experimental challenge model. This precise dosage optimization remains unexplored and is crucial for practical application in the feed industry.

Therefore, we hypothesized that dietary supplementation with YCW would confer dose-dependent protective effects against coccidiosis, with the higher dose (3 g/kg) demonstrating superior efficacy in enhancing growth performance, reducing oocyst shedding and lesion scores, improving antioxidant status, and modulating immune responses compared to the lower dose and the infected, unsupplemented control.

This study is significant because it moves beyond establishing mere efficacy and provides actionable data on optimal dosage. The findings will offer valuable insights for developing effective, natural strategies to control coccidiosis, thereby reducing reliance on anticoccidial drugs and contributing to more sustainable and safe poultry production systems.

2. MATERIALS AND METHODS

2.1. Study Place

This research was conducted at the poultry production unit of the Jordan University Station for Dry Land Research in Al-Muwaqqar, located 45 km southeast of Amman, Jordan. The closed house consisted of 10 rooms. Each room is further divided into 3 chambers, each equipped with stoves, drinkers, feed troughs, and a lighting system.

2.2. Management of Experimental Birds

All chicks had a close initial body weight (48 ± 0.05g). Feed and water were provided ad libitum. Chicks were reared on a floor covered with wood shavings. Nutrient requirements and management practices were applied in accordance with breed guidelines. Chicks were reared according to standard management practices. Light was provided for 24 h throughout the experimental period (as recommended by the Ross 308 rearing guide). All chicks were fed a broiler starter ration until week 2, then a finisher ration (Table 1). The pen temperature was kept at 29-32°C during the first week of age; thereafter, it was reduced by 0.5°C weekly. The birds were assigned to their groups on day 12, and the medications were added to the feed on that day. The birds were vaccinated for infectious bronchitis on day 1 and for Newcastle disease on day 7 (Hayajneh et al., 2024).

2.3. Experimental Design

Chicks were divided into 5 groups, each group composed of three replicates, and each replicate had 25 chicks. Treatments were arranged in a Randomized Complete Block Design (RCBD) with three replicates.

2.4. Drugs and Administration

On day 12 the drugs were given to birds daily: sulfadimidine (320 mg) and diaverdine HCl (10 mg) (Avico, Amman, Jordan) was administered to birds in the T_{+ve} group at a concentration of 100 mg/200L drinking water for three days, followed by plain water /2 days, then the medication was added in water at 100 mg/200L water/2 days). Yeast was given to group T_{y1} at a concentration of 1 g/kg feed/7 days, and to group Ty2 at 3 g/kg/7 days. Nothing

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

was added to T-ve1 and T-ve2 (Table 2). Two yeast concentrations were added to diets at the feed mill.

Table 1: Composition of broiler basal feed (g/kg)

Ingredients	Starter (0-21 d)	Finisher (22-35 d)
Maize	540.0	710.0
Soybean meal (480 g/kg CP)	360	250.0
Dicalcium phosphate	20	20.0
Soybean oil	13	13.0
Fish meal	60	0
DL-Methionine	1.5	0.5
Vitamin-mineral premix[a,b]	3.5	3.5
Sodium chloride	2.0	3.0
Chemical composition (g/kg diet as fed basis)		
MEn (MJ/kg)	12.6	13.0
Crude protein	235.0	182.0
Calcium	12.3	8.0
Total Phosphorus	6.5	5.1
Lysine	17.0	10.0
Methionine	9.0	8.0

[a]Vitamin premix provided per kilogram of diet: Vitamin A = 0.5760; Vitamin K = ?IU; Vitamin B5 = 19.4532mg; Tocopherol = 4.6799mg; Vitamin B1 = 3.5016mg; Vitamin B2 = 1.6994mg; Vitamin B6 = 6.4911mg; Vitamin B12 = 16mg; Biotin = 0.1382mg; Folic Acid = 1.2692mg; Pantothenic = 7.8104mg; Vitamin K3 = 0.9071mg; [b]Trace mineral premix per kg diet were: Iron = 62.0061mg; Zinc = 43.065mg; Copper = 6.8559mg; Iodine = 0.0589mg; Selenium = 1.3466mg. Soybean concentrate and mono-calcium phosphate were also provided.

2.5. Yeast Supplement: Source, Composition, and Preparation

The yeast-based supplement used in this study was a commercial dried yeast cell wall product derived from the fermentation of *Saccharomyces cerevisiae*. The product was sourced from Jordan Bio-Industries Center (JOBIC), Amman, Jordan. The product appeared as a fine, tan-to-beige colored powder. Its typical nutritional composition as provided by the manufacturer (Table 3).

The yeast-based supplement used in this study was a commercial, dried yeast cell wall product derived from the fermentation of Saccharomyces cerevisiae. The product was sourced from Jordan Bio-Industries Center (JOBIC) in Amman, Jordan, a representative supplier of yeast-based feed additives in the region. The product was a fine, tan-to-beige-colored powder. The product was stored in a cool, dry place, protected from direct sunlight until use. For inclusion in the experimental diets, the required amount of yeast powder was first carefully mixed with a small portion of the basal corn-soybean meal diet to form a uniform premix. This premix was then gradually incorporated into the complete feed and thoroughly blended using a horizontal mixer for at least 15 minutes to ensure homogeneous distribution of the supplement. The control diets were prepared using the same procedure, without the addition of yeast.

Table 2: Group arrangement in the experiment

Group	Drug Used	Dose	Coccidiosis Introduced
T_{y1}	Infected medicated with yeast at 1 g/kg feed	1 g/kg	Yes
T_{y2}	Infected medicated with yeast at 3 g/kg feed	3 g/kg	Yes
T_{+ve}	sulphadimidine 320 mg and diaverdine HCL 10 mg	100 mg/200l drinking water for three days, followed by plain water/2days, then the medication was added in water 100 mg/200l water/2days	Yes
T_{-ve1}	Infected medicated with bentonite 1.5 mg/kg	1.5 mg/kg	No
T_{-ve2}	None infected; none medicated	None	No

This study was designed to evaluate the prophylactic efficacy of yeast cell wall supplementation against coccidiosis. All medications (yeast and the conventional drug) were initiated on day 12, while coccidiosis challenge was administered on day 14. This two-day pretreatment period reflects commercial practice, in which feed additives are continuously included before disease exposure to prevent outbreaks. Anticoccidial drugs are also commonly used prophylactically in poultry production; therefore, the positive control comparison is valid and appropriate, as all groups received interventions under the same preventive protocol.

Table 3: Analyzed composition of the yeast cell wall supplement (as-fed basis)

Component	Value (%)
Mannan Oligosaccharides (MOS)	22.5
β-Glucans	18.0
Crude Protein	16.0
Crude Fat	5.5
Ash	8.0
Moisture	6.0

2.5. Histopathological Examination

Tissue samples from morbid intestines were collected for histopathological studies. Tissue samples were preserved in 10% buffered formalin and processed for histopathological studies using routine methods of dehydration and paraffin embedding. Sections 4–5µm thick were cut and stained with hematoxylin and eosin (Hayajneh et al., 2020). Slides were examined under a light microscope.

2.6. Evaluation of Sensitivity or Resistance

Seventeen chicks were randomly selected from each group on day 12, weighed, and then reweighed on day 21;

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

the BWT gain difference was calculated between these days. Five chicks from each group were sacrificed on day 21, and the intestinal lesion score was recorded (Raman et al., 2011). The gross lesion scores (GLS) were assessed on a scale of 0 (no gross lesion) to 4 (most severe lesion). After microscopic examination of intestinal scrapings taken from sacrificed birds, the oocyte index was determined (0-5) as described by Arabkhazaeli et al. (2013). The sensitivity of drugs was determined using the global index (GI), and the global index (GI) was calculated (Abbas et al., 2009).

2.7. Coccidiosis Induction

Birds infected with coccidiosis were naturally collected from local farms, and infectious coccidial oocysts were isolated, as described by Hayajneh et al. (2020), according to the site of infection and oocyst morphology, including size, shape, and color after sporulation, five species were identified: *E. acervulina* (10%), *E. brunette* (13%), *E. maxima* (12%), *E. necatrix* (12%), and *E. tenella* (57%). On day 14, coccidiosis was introduced in broiler chicks via the oral route, and each chicken received an infectious coccidian dose of 3 × 10 ^5/bird (Abbas et al., 2011).

2.8. Performance Parameters

Feed intake, body weight gain, and feed conversion ratio (FCR) were calculated on days 21, 28, and 35. Also, oocysts per gram of feces, lesion score, and oocyst scoring were recorded on days 14, 21, and 28. Health aspects and mortality were monitored daily. Efficacy status was calculated as a percentage of the NNC's GI. Meat quality was determined according to Jalal et al. (2023).

2.9. Lesion scoring and Oocyte Index

On days 7, 14, and 21 post-inoculation (experimental days 21, 28, and 35), three birds from each replicate were randomly selected and killed humanely for coccidial lesion scoring. A score of 0 to +4 was recorded for each chicken (Abas et al., 2009; Raman et al., 2011). An Oocyst index of 0 to 5 was determined after examining scrapings from birds sacrificed for lesion scoring. Oocyte index was determined (Abbas et al., 2009; Arabkhazaeli et al., 2013).

2.10. Measurements

Magnesium, creatinine, and uric acid were measured using ELISA kits from Biolab, Jordan. Albumin, cholesterol, magnesium, total protein, bilirubin, and phosphorus were measured using an ELISA kit from Biomed, MDSS GmbH, Germany. Glucose was measured using an ELISA kit from Atlas Medical Jordan. Uric acid using an ELISA kit from ARCOMEX Jordan. Zinc was measured using a spectrophotometry kit from Ita, Italy. Malondialdehyde and total antioxidant capacity were measured using assay kits from Creative Proteomics, USA. To measure Newcastle disease and infectious bursal disease antibodies in serum, a commercial ELISA kit from BioChek Immunoassays (BioCheck, Reeuwijk, Netherlands) was used according to the manufacturer's guidelines. The cut-off used was <0.35. The tests were performed at Feedco Labs in Jordan. Villus surface area was calculated using the formula = (2) × (VW/2) × (VH), in which VW = villus width and VH = villus height (De los et al., 2005). A total of 15 villus areas were calculated for each bird.

2.11. Statistical Analysis

SPSS software was used to analyze the collected data. One-way analysis of variance was used, and the means of the different treatments were compared using Tukey's test and a repeated-measures test. Values were considered statistically different at P≤0.05, and the mean values were compared using Tukey's test.

3. RESULTS

No significant differences were observed in the weights of the liver and bursa among groups (P>0.05), whereas spleen weights differed significantly (P = 0.040), potentially reflecting immune-modulatory effects of the yeast treatment (Table 4). Additionally, blood biochemical parameters, including albumin, glucose, cholesterol, total protein, uric acid, magnesium, phosphorus, and zinc, showed no statistically significant differences between groups (P>0.05; Table 5), suggesting that yeast inclusion at both doses did not adversely affect systemic physiology.

Table 4: Mean weight of liver, spleen and bursa in the different groups

	Sum of Squares	Mean Square	F	P value
Liver	194.889	24.361	0.342	0.948
Spleen	3.824	0.478	2.092	0.040
Bursa	69.142	8.643	1.062	0.392

Based on observed means (df = 8). A significant level was considered at P<0.05.

Overall, dietary yeast supplementation, particularly at 3g/feed (Ty2), improved meat quality and reduced coccidial lesions without negatively impacting growth performance or health indicators.

Broiler chickens in the yeast-treated groups (Ty1: 1 g/kg; Ty2: 3 g/kg) exhibited distinct responses across multiple

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

parameters. Lesion scoring and oocyst index were significantly reduced in both yeast-treated groups compared to the infected untreated controls, indicating marked anticoccidial activity (P<0.01; Table 6). Although weight gain and feed intake did not differ significantly among groups (P<0.05), Ty2 showed a numerically higher average weight gain compared to Ty1 (Table 6).

Regarding meat quality traits, both Ty1 and Ty2 exhibited statistically significant differences in meat weight (MWT), fillet weight (FWT), lightness (L), yellowness (B), cooking loss (CL), water holding capacity (WHC), and shear force (SHF) compared to other groups (P<0.001; Table 7). Notably, Ty2 yielded higher meat and fillet weights, whereas Ty1 achieved the highest WHC values, suggesting enhanced juiciness. Redness (a*) and pH values did not differ significantly (P>0.05), indicating that yeast supplementation did not affect meat color stability or acid-base status.

Table 5: Blood parameters in the different groups

	Sum of Squares	Mean Square	F	P value.
Albumin	0.115	0.014	1.306	0.255
Cholesterol	2318.673	289.834	0.857	0.557
Glucose	15030.612	1878.827	1.116	0.363
Total Protein	0.595	0.074	0.198	0.990
Magnesium	17.644	2.205	1.196	0.314
Uric Acid	4.718	0.590	0.344	0.946
Phosphorus	150.839	18.855	1.099	0.374
zinc	24484.425	3060.553	1.693	0.116
IB Titer	1339151.556	167393.944	1.202	0.310
ND concentration	512002.691	64000.336	0.565	0.803

For ND (Newcastle disease virus titer) and IB (infectious bursal disease virus titer), results were based on observed means (df=8). The error term was MSE=113254.756. *. A significant level was considered at P<0.05. For the remaining blood parameters, virus results were based on observed means. The error term is Mean Square (Error)=1808.239. *.

Table 6: Mean values of lesion scoring and performance parameters in the different groups

	Sum of Squares	Mean Square	F	P value
Lesion score	22.519	2.815	5.846	0.001
Oocyte index	70.963	8.870	19.958	0.000
Mortality	15.630	1.954	0.676	0.706
Weight gain	127826.775	15978.347	0.803	0.608
Feed intake	149809.895	18726.237	0.829	0.588

Based on observed means (df = 8). The error term is Mean Square (Error) = 22578.388. A significant level was considered at P<0.05.

Table 7: Meat quality values in the different groups

	Sum of Squares	Mean Square	F	P value
MWT	56671.760	7083.970	19.223	0.000
FWT	49835.920	6229.490	23.645	0.000
L	2234686.667	279335.833	12.569	0.000
A	5343475.728	667934.466	1.316	0.250
B	818197.580	102274.698	4.041	0.001
PH	.003	0.000	.737	0.658
CL	202.552	25.319	12.107	0.000
WHC	399.512	49.939	34.140	0.000
SHF	15.970	1.996	5.766	0.000

Based on observed means (df = 8). The error term is Mean Square (Error) = 0.346. A significant level was considered at P<0.05. MWT: Muscle weight; Fillet weight: weight of the breast fillet; L, A, B: meat color parameters in the CIE Lab system (L = lightness, A = red/green, B = yellow/blue); pH: muscle acidity measured postmortem; CL: cooking loss (%); Water holding capacity (WHC): ability of meat to retain water; Shear force: indicator of meat tenderness.

Histopathological examination of intestinal sections supported the findings of the gross lesion and oocyst index. Severe epithelial damage, extensive schizont stages, and marked necrosis were observed in the infected untreated groups (T-ve1 and T-ve2), indicating heavy coccidial infection. In contrast, birds supplemented with yeast at 1 g/kg (Ty1) showed moderate pathological changes, with partial villus damage, while those receiving 3 g/kg of yeast (Ty2) exhibited relatively preserved intestinal architecture, with reduced necrosis and fewer parasitic stages.

Total antioxidant capacity differed among the experimental groups, as illustrated in Fig. 1. Yeast supplementation significantly enhanced antioxidant status in broiler chickens challenged with coccidiosis, with the highest total antioxidant capacity observed in the Ty2 group (3 g/kg yeast). Lipid peroxidation, as indicated by

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

malondialdehyde levels are presented in Fig. 2. Yeast supplementation reduced malondialdehyde concentrations compared with the infected untreated control, with a more pronounced reduction in birds receiving 3g/yeast, indicating attenuation of oxidative stress.

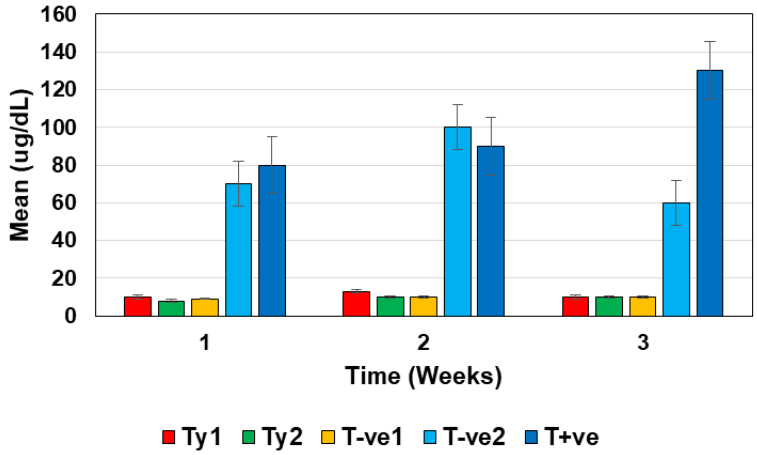

Fig. 1: Total antioxidant capacity (µg/dL) in different experimental groups. Data are based on n = 8. Bars bearing bar errors falling out with others, differing significantly (P<0.05) over time. Ty1 = Infected medicated with yeast at 1 g/kg feed; Ty2 = Infected medicated with yeast at 3 g/kg feed; T+ve = Sulphadimidine 320mg and diaverdine HCL 10mg; T-ve1 = Infected medicated with bentonite 1.5m g/kg; T-ve2 = None infected, none medicated.

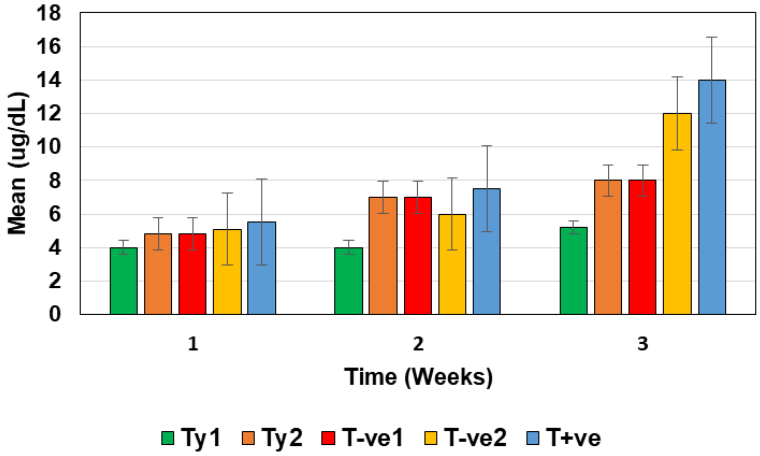

Fig. 2: Malondialdehyde concentration (µg/dL) capacity in different experimental groups. Data are based on n = 8. Bars bearing bar errors falling out with others, differing significantly (P<0.05) over time. Ty1 = Infected medicated with yeast at 1 g/kg feed; Ty2 = Infected medicated with yeast at 3 g/kg feed; T+ve = Sulphadimidine 320mg and diaverdine HCL 10mg; T-ve1 = Infected medicated with bentonite 1.5m g/kg; T-ve2 = None infected, none medicated.

4. DISCUSSION

Supplementation of broiler diets with two distinct yeast doses (Ty1 at 1 g/kg and Ty2 at 3 g/kg) significantly improved meat quality and reduced coccidial lesions without impairing growth performance or systemic health. More importantly, this direct comparative analysis provides crucial, novel insights into the dose-dependent efficacy of yeast supplementation, addressing a key gap in existing literature. These findings align with and extend previous studies highlighting the multifaceted benefits of yeast-derived additives in poultry production (Bortoluzzi et al., 2019; Liu et al., 2023).

Our findings on the efficacy of yeast cell walls (YCW) in reducing oocyst shedding and lesion scores (Fig. 3) are consistent with the growing evidence supporting natural alternatives to chemical anticoccidials. The reduction in pathogenicity observed in our study parallels the effects reported for several plant-derived bioactives. For instance, ethanolic extracts of clove (*Syzygium aromaticum*) and essential oil of *Amomum subulatum* have demonstrated significant anticoccidial activity in broiler chickens, likely through antimicrobial and anti-inflammatory mechanisms (Khan et al., 2023a; Zaheer et al., 2022). Similarly, *Linum usitatissimum* (flaxseed) essential oil has

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

been shown to improve hematological parameters and growth performance, suggesting systemic health benefits comparable to the immunostimulatory effects indicated by increased spleen weight in our YCW-supplemented groups. Although the active components differ—β-glucans and mannan oligosaccharides (MOS) in yeast versus phenolic compounds and essential oils in plants—both approaches share the same objective: strengthening the host's innate immunity and creating a hostile environment for the parasite, without the adverse effects associated with conventional drugs. Collectively, these findings highlight those natural strategies, whether fungal or botanical, offer a promising and sustainable alternative for coccidiosis control.

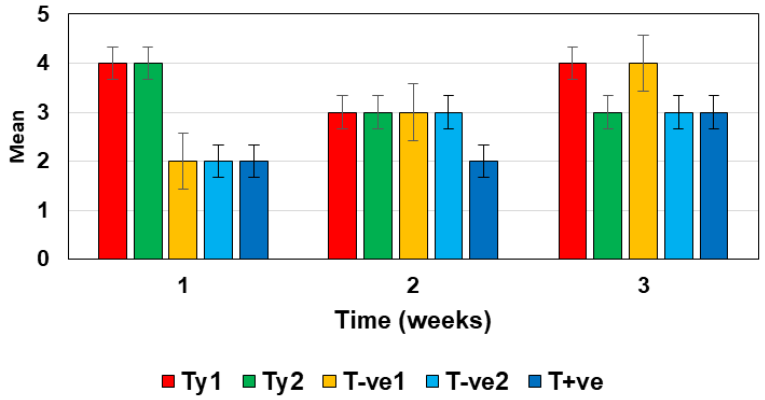

Fig. 3: Coccidia lesion score in different groups. Data are based on n = 8. Bars bearing bar errors falling out with others, differing significantly (P<0.05) over time; Ty1 = Infected medicated with yeast at 1 g/kg feed; Ty2 = Infected medicated with yeast at 3 g/kg feed; T+ve = Sulphadimidine 320mg and diaverdine HCL 10mg; T-ve1 = Infected medicated with bentonite 1.5m g/kg; T-ve2 = None infected, none medicated.

The significant reduction in lesion scores and oocyst shedding observed in both yeast-treated groups supports the established role of yeast cell wall components as effective anticoccidial agents. Giannenas et al. (2023) reported that multi-strain yeast fractions improved intestinal health under challenge. Findings of the present study confirm and further demonstrate that a higher dose (Ty2) elicited a more robust reduction in pathological markers, underscoring the importance of dosage optimization for maximum anticoccidial effect.

Regarding meat quality, both Ty1 and Ty2 significantly improved meat and fillet weights, WHC, and tenderness. A key novel finding was the differential impact on meat traits: while Ty2 improved overall yield, Ty1 showed superior water-holding capacity. This suggests that moderate yeast supplementation may enhance meat juiciness more effectively, whereas higher doses favor mass, a dose-response relationship that refines the application guidelines for producers. These improvements are consistent with findings from Bai et al. (2022) and Kim et al. (2022), but our study is the first to directly contrast these outcomes at different inclusion levels under a standardized coccidial challenge.

Although growth performance parameters were not statistically different, the trend toward improved average daily gain in Ty2 aligns with previous findings where yeast enhanced nutrient digestibility under stress (Abd El-Hack et al., 2022). Maintaining growth performance, even during a disease challenge, is a significant result, confirming that yeast supplementation does not impose a metabolic cost and protects productivity.

The lack of significant variation in blood biochemical parameters and organ weights confirms the systemic safety of yeast supplementation. The significant increase in spleen weight in yeast-fed groups likely reflects a beneficial immunostimulatory effect, as reported by Song et al. (2021). This finding holds practical significance, as it indicates an enhanced immune readiness without the pathology of inflammation, a valuable trait in disease-prone commercial settings.

Overall, the core novelty of this study—the dose-comparison—reveals that while both doses are beneficial, Ty2 (3 g/kg) provided the most comprehensive anticoccidial protection and improved meat yield, whereas Ty1 (1 g/kg) offered specific advantages for meat quality traits like water retention. This provides the industry with actionable data to select a dosage based on specific production goals, whether for overall health or premium meat quality.

The protective effects of yeast-derived products against coccidiosis are complex, involving both modulation of gut health and immune system priming. The benefits observed in this study—reduced lesion scores, decreased oocyst shedding, and enhanced gut morphology (Fig. 3) are likely driven by yeast's bioactive components, namely mannan oligosaccharides (MOS) and β-glucans. MOS acts as a pathogen-blocking agent by mimicking epithelial receptors that pathogenic bacteria and parasites target. By binding to pathogens such as *Eimeria*, MOS prevents their adhesion and colonization, facilitating their removal from the gut (Spring et al., 2015; Che et al., 2021). β-

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

Glucans serve as potent immunomodulators, recognized by Dectin-1 receptors on macrophages and other innate immune cells (Goodridge et al., 2009). This interaction initiates a cascade of immune responses, enhancing cytokine production and priming the host for a more effective response to coccidial infection. Furthermore, β-glucans may induce 'trained immunity,' a functional reprogramming of innate immune cells that confers enhanced nonspecific protection against subsequent infections (Xiao et al., 2022). Together, these mechanisms—pathogen exclusion and strengthened immune vigilance—likely account for the marked anticoccidial efficacy observed, particularly at the higher dose (3 g/kg), which presumably provided sufficient bioactive compounds to optimally stimulate these protective pathways.

5. CONCLUSION

The findings of this study demonstrate that dietary yeast supplementation provides significant anticoccidial and meat quality benefits in broilers challenged with coccidiosis. Critically, the comparison of two concentrations offers a novel contribution: supplementation at 3 g/kg (Ty2) provided superior overall anticoccidial efficacy and meat yield, while 1 g/kg (Ty1) excelled at enhancing specific meat quality attributes, such as water-holding capacity. This dose-dependent effect provides crucial guidance for its practical application.

While growth performance was maintained, the notable improvements in product quality and animal health highlight the potential of yeast as a natural, effective, and safe alternative to conventional anticoccidial agents. The significance of these results lies in delivering optimized, evidence-based dosage recommendations that can directly contribute to sustainable poultry production by mitigating disease losses and enhancing product value. Future studies should explore the molecular mechanisms behind these differential effects and validate these optimized doses under commercial field conditions.

Declarations

Funding: The research was funded by Jordan University

Acknowledgement: The authors are very thankful to Jordan University for financial support and to all the associated personnel in any reference that contributed in/for the purpose of this research.

Conflicts of Interest: The authors have no conflict of interest.

Data Availability: The supplementary data can be available from the corresponding author on a reasonable request.

Ethics Statement: The Scientific Research Council of the University of Jordan approved the experiment protocols vide number (135/2022). Animals were reared and treated in compliance with the EU Directive 2010/63/EU.

Generative AI Statements: The authors declare that no Gen AI/DeepSeek was used in the writing/creation of this manuscript.

Publisher's Note: All claims stated in this article are exclusively those of the authors and do not necessarily represent those of their affiliated organizations or those of the publisher, the editors, and the reviewers. Any product that may be evaluated/assessed in this article or claimed by its manufacturer is not guaranteed or endorsed by the publisher/editors.

REFERENCES

Abbas, R. Z., Iqbal, Z., Blake, D., Khan, M. N., & Saleemi, M. K. (2011). Anticoccidial drug resistance in fowl coccidia: the state of play revisited. World's Poultry Science Journal, 67(2), 337–350.

Abbas, R. Z., Iqbal, Z., Khan, M. N., Hashmi, N., & Hussain, A. (2009). Prophylactic efficacy of diclazuril in broilers experimentally infected with three field isolates of Eimeria tenella. International Journal of Agriculture and Biology, 11(5), 606–610.

Abd El-Hack, M. E., Alagawany, M., Arif, M., Emam, M., & Tufarelli, V. (2022). Yeast and yeast-derived products in poultry nutrition: A review. World's Poultry Science Journal, 78(3), 567-586. https://doi.org/10.1080/00439339.2022.2033969

Ali, B., Wang, X., Saleem, M. H., Sumaira, Hafeez, A., Al-Ghamdi, A. A., Elshikh, M. S., Moustafa, M., Shah, Z. H., Ahmad, P., & Ali, S. (2023). Physiological and biochemical characterization of sugar beet against salt-stress. Pakistan Journal of Agricultural Sciences, 60(2), 235-247. https://doi.org/10.21162/PAKJAS/23.250

Alizadeh, M., Ouguerram, K., & Bouguermouh, A. (2021). Yeast cell wall and its components: Mode of action and health benefits in poultry. Animal Nutrition, 7(3), 605-614. https://doi.org/10.1016/j.aninu.2020.12.006

Amer, S. A., Mohamed, M. A., & Abdel-Wareth, A. A. (2023). Effects of yeast and its derivatives on broiler chickens challenged with Eimeria tenella. Poultry Science, 102(3), Article 102375. https://doi.org/10.1016/j.psj.2022.102375

Arabkhazaeli, F., Modrisanei, M., Nabian, S., Mansoori, B., & Madani, A. (2013). Evaluating the resistance of Eimeria spp. field isolates to anticoccidial drugs using three different indices. Iranian Journal of Parasitology, 8(2), 234–241.

Bai, K., Huang, Q., Zhang, J., He, J., Zhang, L., & Wang, T. (2022). Effects of dietary yeast culture on growth performance, meat quality, and antioxidant capacity of broiler chickens. Animal Bioscience, 35(6), 837-844. https://doi.org/10.5713/ab.21.0413

Bortoluzzi, C., Pedroso, A., Mallo, J. J., & Ribeiro, A. M. (2019). Feed additives in broiler diets to reduce the effects of coccidiosis on intestinal mucosa. Poultry Science, 98(5), 2198-2205. https://doi.org/10.3382/ps/pey563

Che, T., Song, Y., Wang, W., Li, P., & Liu, L. (2021). Yeast-derived products modulate immune responses and gut health in poultry. Frontiers in Immunology, 12, Article 714014. https://doi.org/10.3389/fimmu.2021.714014

Chen, X., Zhang, M., Zhang, H., Lv, Z., Wei, C., Xin, X., Lv, Z., Zhang, Y., & Yan, A. (2022). Dietary yeast supplementation reduces intestinal lesions and improves immune function in broiler chickens infected with Eimeria maxima. Veterinary Parasitology, 303, Article 109664. https://doi.org/10.1016/j.vetpar.2021.109664

de los, S. F., Donoghue, A. M., Farnell, M. B., Huff, G. R., Huff, W. E., & Donoghue, D. J. (2005). Gastrointestinal development and performance of broilers fed dietary alternative growth promoters. Poultry Science, 84(Suppl. 1), 77.

El-Shall, N. A., Abd El-Ghany, W. A., & Abdel-Latif, H. M. R. (2022). Phytogenic and biological feed additives in poultry: Alternatives to antibiotics. Animals, 12(7), Article 823. https://doi.org/10.3390/ani12070823

Giannenas, I., Tzora, A., Bonos, E., Giannakopoulos, C., & Skoufos, I. (2023). Supplementation with yeast-based products modulates intestinal histomorphology and improves growth in coccidiosis-infected broilers. Tropical Animal Health and Production, 55(1), Article 33. https://doi.org/10.1007/s11250-023-03594-z

Goodridge, H. S., Wolf, A. J., & Underhill, D. M. (2009). Dectin-1 recognition of β-glucans. Immunobiology, 214(7), 551-559. https://doi.org/10.1016/j.imbio.2009.04.003

Hayajneh, F. M. F., Abdelqader, A., Alnimer, M., & Khaza'leh, J. (2020). The role of high-grade bentonite powder in coccidiosis and its effects on feed conversion ratio and blood parameters in broiler chicken. Polish Journal of Veterinary Sciences, 23(1), 97-107. https://doi.org/10.24425/pjvs.2020.132753

Hayajneh, F. M. F., Abdelqader, A., Zakaria, H., Abuajamieh, M., & Araj, S. A. (2024). Drug resistance and coccidiosis affects immunity, performance, blood micronutrients, and intestinal integrity in broiler chickens. International Journal of Veterinary Science, 13(1), 34-41. https://doi.org/10.47278/journal.ijvs/2023.054

Hayajneh, F. M. F., Jalal, M., Zakaria, H., Abdelqader, A., & Abuajamieh, M. (2018b). Anticoccidial effect of apple cider vinegar on broiler chicken: An organic treatment to measure antioxidant effect. Polish Journal of Veterinary Sciences, 21(1), 5-12. https://doi.org/10.24425/122605

Hayajneh, F. M., Araj, S. A., & Mahasneh, Z. (2018a). Anticoccidial effects of medicinal plant extracts in broiler chickens. Veterinary Parasitology, 256, 1-7. https://doi.org/10.1016/j.vetpar.2018.08.008

Hosseini Mansoub, N., Yazdi, F. A., & Rezaei, A. (2021). Impact of Saccharomyces cerevisiae supplementation on growth performance and meat quality of broiler chickens. Italian Journal of Animal Science, 20(1), 808-814. https://doi.org/10.1080/1828051X.2021.1931401

Idris, M., Lawal, I. D., Bello, A. A., Garba, A., Shehu, S., & Raji, A. A. (2023). In vitro nematocidal effects of aqueous extracts of leaves and bark of Khaya senegalensis and Azadirachta indica on the mortality of adults of Haemonchus contortus. Agrobiological Records, 18, 105-112. https://doi.org/10.47278/journal.abr/2023.047

Iqbal, M. S., Ashraf, K., Qudoos, A., Abbas, R. Z., Khan, M. K., Saleemi, M. K., Zaheer, T., Sajid, M. S., & Jabbar, A. (2023). Botanical control of coccidiosis in ruminants. Pakistan Journal of Agricultural Sciences, 60(3), 473-485. https://doi.org/10.21162/PAKJAS/23.267

Jalal, M. A. R., Zakaria, H. A. H., Hayajneh, F. M., & Mehyar, G. M. (2023). Performance, carcass characteristics, and meat quality of broiler chickens fed β-mannanase and two levels of energy. Tropical Animal Science Journal, 46(2), 190–200. https://doi.org/10.5398/tasj.2023.46.2.190

Khan, R. U., Khan, M. I., Fatima, A., Waqas, M., Nawaz, M., Hanif, A., & Shahzad, M. (2023a). Evaluation of anticoccidial activity of ethanolic extract of clove in broiler chicken. Pakistan Veterinary Journal, 44(4), 757-762. https://doi.org/10.29261/pakvetj/2024.250

Khan, R. U., Naz, S., Raziq, F., & Laudadio, V. (2023b). Effect of olive mill wastewater extract on growth performance, antioxidant status and immune response in broiler chicks. Pakistan Veterinary Journal, 43(2), 333-338.

Kiczorowska, B., Samolińska, W., & Andrejko, D. (2020). Effect of dietary yeast extract supplementation on broiler meat quality and antioxidant status. Animals, 10(8), Article 1296. https://doi.org/10.3390/ani10081296

Kim, D. H., Park, S. H., Lee, J. H., & Kim, H. B. (2022). Effects of Saccharomyces cerevisiae on performance, meat quality, and intestinal microbiota in broiler chickens. Animals, 12(1), Article 105. https://doi.org/10.3390/ani12010105

Liu, X., Wu, S., Yang, Q., & Li, J. (2023). Dietary yeast supplementation enhances broiler gut health and immune function under pathogenic challenge. Journal of Animal Science and Biotechnology, 14(1), Article 112. https://doi.org/10.1186/s40104-023-00846-z

Magnoli, A.P., Parada, J., Luna, M. J., Corti, M., Escobar, F.M., FernÃ¡ndez, C., Coniglio, M.V., Ortiz, M.E., Wittouck, P., Watson, S., Cristofolini, L.A., & Cavaglieri, L. (2024). Impact of probiotic Saccharomyces cerevisiae var. boulardii RC009 alone and in combination with a phytase in broiler chickens fed with antibiotic-free diets. Agrobiological Records, 16, 1-10. https://doi.org/10.47278/journal.abr/2024.006

Martins, R. R., Silva, L. J. G., Pereira, A., Esteves, A., Duarte, S. C., & Pena, A. (2022). Coccidiostats and poultry: A comprehensive review and current legislation. Foods, 11(18), Article 2738. https://doi.org/10.3390/foods11182738

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

M'Sadeq, S. A. (2023). Ameliorative effect of yeast cell wall on broiler chickens' performance and gut health under coccidiosis challenge. Czech Journal of Animal Science, 68(8), 346-355. https://doi.org/10.17221/24/2023-CJAS

Peek, H. W., & Landman, W. J. M. (2011). Coccidiosis in poultry: Anticoccidial products, vaccines and other prevention strategies. Veterinary Quarterly, 31(3), 143-161. https://doi.org/10.1080/01652176.2011.586679

Perricone, V., Sandrini, S., Irshad, N., Savoini, G., Comi, M., & Agazzi, A. (2022). Yeast-derived products: The role of hydrolyzed yeast and yeast culture in poultry nutrition—A review. Animals, 12(11), Article 1426. https://doi.org/10.3390/ani12111426

Raman, M., Banu, S. S., Gomathinayagam, S., & Raj, G. D. (2011). Lesion scoring technique for assessing the virulence and pathogenicity of Indian field isolates of avian Eimeria species. Veterinarski arhiv, 81(2), 259-271.

Shanmugasundaram, R., Selvaraj, R. K., Ajithakumar, H. M., Moon, H. W., & Kim, I. H. (2013a). The role of yeast cell wall products in poultry nutrition and health. Poultry Science, 92(9), 2451-2460. https://doi.org/10.3382/ps.2013-03212

Shanmugasundaram, R., Sifri, M., & Selvaraj, R. K. (2013b). Effect of yeast cell product (CitriStim) supplementation on broiler performance and intestinal immune cell parameters during an experimental coccidial infection. Poultry Science, 92(2), 358-363. https://doi.org/10.3382/ps.2013-03212

Shivaramaiah, C., Graat, E. A. M., & Fetterer, R. H. (2021). Epidemiology of coccidiosis in poultry: A review. Poultry Science, 100(8), Article 101478. https://doi.org/10.1016/j.psj.2021.101478

Smith, J. A. (2023). The therapeutic potential of aromatic plants: A new frontier in bioactive compound research. Trends in Animal and Plant Sciences, 4, 112-117. https://doi.org/10.62324/taps/2024.053

Song, Z. H., Cheng, K., Zheng, J., Xu, T., Hu, L., Wang, T., & Zhang, L. (2023). Yeast-based probiotics in poultry production: Benefits and challenges. Frontiers in Veterinary Science, 10, Article 1154321. https://doi.org/10.3389/fvets.2023.1154321

Song, Z., Cheng, K., Zhang, L., Wang, T., & Zhang, J. (2021). The effect of yeast β-glucans on the immune function of broiler chickens. Poultry Science, 100(7), Article 101153. https://doi.org/10.1016/j.psj.2021.101153

Spring, P., Wenk, C., Dawson, K. A., & Newman, K. E. (2015). The effects of dietary mannan oligosaccharide on coccidiosis in broilers. Poultry Science, 94(5), 894-900. https://doi.org/10.3382/ps/pev070

Wu, S., Bai, J., & Yang, Y. (2021). Natural feed additives for the control of coccidiosis in poultry: A review. Animal Nutrition, 7(1), 23-34. https://doi.org/10.1016/j.aninu.2020.08.004

Xiao, J., Wang, L., Wu, S. G., Zhang, H. J., & Qi, G. H. (2022). Effects of β-mannanase supplementation on growth performance, nutrient digestibility, and intestinal morphometry of broiler chickens fed diets with reduced metabolizable energy. Poultry Science, 101(8), 101968. https://doi.org/10.1016/j.psj.2022.101968

Zaheer, T., Abbas, R. Z., Imran, M., Abbas, A., Butt, A., Aslam, S., & Ahmad, J. (2022). Vaccines against chicken coccidiosis with particular reference to previous decade: progress, challenges, and opportunities. Parasitology Research, 121(10), 2749–2767.