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Research article

Efficacy of mycotoxin binder on broiler performance, organ weight, wishbone weight, and gut length: A meta-analysis

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Abstract

Mycotoxin-contaminated feed is one of the main causes of contamination, which may increase broiler mortality and impair production. The objective of this study was to assess the effects of mycotoxin binders on the performance of broiler chickens using a meta-analysis method. A total of 161 in vivo test data points acquired from 31 scientific papers were used as a baseline for measuring the effectiveness of mycotoxin binders on performance and health, as measured by internal organ weight. To assess the validity of the study findings, the Hedges' d value was used as a measure of the effect size (ES) value in the present meta-analysis. Results revealed that, the addition of mycotoxin binder in feed enhanced BW (ES 0.784; P<0.001), FCR (ES -0.87; P<0.001), and mortality (ES -3.98; P<0.001). In terms of criteria such as ADG and mortality suppression, the finisher phase demonstrated the greatest effectiveness of binder usage compared to the starter and finisher phases. The effectiveness of binders in lowering the incidence of mycotoxin in feed was beneficial in reducing mortality and enhancing broiler performance. In addition, its application into feed may enhance the health condition of broilers by enhancing organ weights and gastrointestinal health.

Keywords: Broiler performance, Feed contaminants, Mycotoxin binders

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INTRODUCTION

Feed is essential for chicken production, particularly in broiler production. Approximately 70% of total expenditure is attributed to the cost of chicken production (Abdurofi et al., 2017). Moreover, because of the expense, it is essential to maintain high-quality feed. Feeding management and hygiene must concentrate on feed contamination in particular. Mycotoxins are often present in the raw materials and end products of feed. Mycotoxins are formed during storage, transportation, and processing of feed. Temperature, humidity, and insects are external factors that may promote the spread and development of fungi and the establishment of mycotoxins (Magnoli et al., 2019).

Mycotoxins are secondary metabolites produced by fungi and are highly toxic to animals. Mycotoxin exposure occurs predominantly via the consumption of susceptible grains, such as maize, wheat, peanuts, sorghum, etc. (Sobrane Filho et al., 2016). Mycotoxins include aflatoxins, ochratoxins, trichothecenes, zearalenone, fumonisins, tremorgenic toxins, and ergot alkaloids. Mycotoxins may affect nutritional value and palatability. Mycotoxins may pose toxicotic harm to animals and reduce their performance (Magnoli et al., 2019). The presence of mycotoxins decreases the quality of feed, and a binder-like chemical is required to minimize contamination.

Mycotoxin binders may impede mycotoxin decontamination. Mycotoxin binder aids in the reduction of contamination and preserves the animal's body from the hazards of mycotoxins. The use of mycotoxin binders is among the most efficient strategies for treating mycotoxin-related disadvantages. Mycotoxin-binding molecules are present in the digestive tracts of animals. The binding ability of mycotoxin binders and organic molecules depends on their molecular size, shape, and relatively strong ionic interactions. Consequently, this interaction may be selective based on the mycotoxin binders and implicated mycotoxins (Kihal et al., 2020).

The impact of mycotoxin binders on broiler chickens has been the subject of several studies. Numerous research cannot be developed as a baseline for the impact of mycotoxin binder on the performance of broiler chickens. However, according to some sources, mycotoxin binders affect broiler mortality. Hedayati et al. (2014c) reported that the mortality of broilers in the finisher phase at the same level reduced to 0%; however, according to Kehinde et al. (2018), the mortality of broilers in the finisher period at the same level rebounded to 3.5%. However, numerous studies have reported inconsistent results.

Using appropriate analytical approaches, this method of generalization can be applied to current studies to establish the implications of mycotoxin binding on broiler performance. According to Cheung and Vijayakumar et al. (2016), meta-analysis is often acknowledged as the optimal approach for synthesizing research results across different fields. In a meta-analysis, researchers direct their attention towards the magnitude of the impact or effect size, rather than the statistical significance of individual investigations. Meta-analysis is a research method that involves the combination and synthesis of data using statistical models. This study used meta-analysis to examine the impact of mycotoxin binding on broiler performance.

As a provisional assumption, mycotoxin binders may minimize toxin contamination in feed and promote broiler performance, while simultaneously maintaining organ health and the digestive tract. This study aimed to assess the effect of mycotoxin binders on the performance of broiler chickens using a meta-analysis method

MATERIALS AND METHODS

Database Development

A Database was developed from the literature that used mycotoxin binders to determine the performance of broilers. Several types of literature have been examined using computerized scientific platforms. These include Scopus, Science Direct, and Semantic Scholars. The keywords used were "mycotoxin binder" and "broiler."

The inclusion criteria for articles used as the basis for the meta-analysis were as follows: (1) English publication, (2) the presence of a control treatment in the experiment, (3) the presence of mycotoxin binder in the basal diet or as additives for broiler production, and (4) evaluation of broiler performance in the experiment. This meta-analysis was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) procedure (Liberati et al., 2009).

All relevant literature titles were included in the additional data. Scopus returned 66 references, ScienceDirect returned 303 references, and Semantic Scholar generated 244 references after a literature search based on keywords. Following the application of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol, 32 publications were identified. During the process of data tabulation, all literature will be compiled into a database. The tabulation of data is the arrangement of data from the relevant literature that helps in the computation of the intended analysis. Each piece of literature was examined using meta-analysis, as shown in Table 1. Figure 1 illustrates the procedure for selecting the relevant articles included in the database.

The results of the subgroup analysis facilitated the formulation of reliable conclusions. Subgroup analysis involves the division of participant data within a meta-analysis into subgroups depending on the specific trial or patient characteristics. Subsequently, meta-analysis was performed on one or more subsets. (Richardson et al., 2019). The data pertaining to the impact of mycotoxin binder use on broiler chickens were categorized according to the specific growth phase of broiler chickens. A subgroup analysis is necessary to conduct an analysis based on the maintenance period. The data pertaining to broiler chickens were categorized into subcategories: starter, grower, and finisher.

Table 1 References used for constructing the meta-database

Reference	Broiler strain	Mycotoxin binder	Level (g/kg)	Period
Arafat et al. (2017)	Ross	Humid acid	0-3	Finisher
Awad et al. (2014)	Ross 308	Mycofix	0-2.5	Finisher
Basalan et al. (2006)	-	HSCAS	0-2.5	Finisher
El-Katcha et al. (2017)	-	Detoc and Ochra mat	0-1	Finisher
Farooqui et al. (2019)	-	Zeta plus and Toxfin	0-2	Finisher
Feshanghchi et al. (2022)	Ross 308	Toxofix arka	0-1	Finisher
Sobrane Filho et al. (2016)	Cobb	HSCAS	0-3	Finisher
Ghazalah et al. (2021)	Arbor Acre	NS and Bentonite	0-5	Finisher
García et al. (2003)	Ross	Zeotek and Mycofix	0-2.5	Grower
Hedayati et al. (2014a)	Ross 308	Niltox	0-2	Finisher
Hedayati et al. (2014b)	Ross 308	Niltox	0-2	Finisher
Heidari et al. (2018)	Ross 308	NufotoxPlus	0-2	Finisher
Issad et al. (2022)	Cobb 500	Micotex	0-1	Starter, grower, and finisher
Istiqomah et al. (2017)	Lohman	Toxin binder	0-1.2	Finisher
Kehinder et al. (2018)	Ross	Mycofix	0-4	Finisher
Lee et al. (2018)	Ross 308	Toxin binder	0-0.2	Finisher
Mimoune et al. (2023)	Cobb 500	Micotex	0-1	Starter, grower, and finisher
Nabi et al. (2018)	-	Mycotox and Mycofix	0-2.5	Starter, grower, and finisher
Nalle et al. (2019)	Cobb	Mycosorb	0-0.75	Starter and grower
Nalle et al. (2021)	Lohmann	Mycosorb	0-0.15	Finisher
Nazarizadeh and Pourreza, (2020)	Ross 308	MYC, FMY, and ANZ	0-20	Grower
Ogbonna et al. (2017)	Arbor Acre	Toxin binder	0-2	Finisher
Oliveira et al. (2015)	Cobb	AMA	0-1	Grower
Pappas et al. (2016)	Ross 308	Toxin binder	0-10	Starter, grower, and finisher
Patil et al. (2017)	Vencobb-300	Bantox	0-1	Finisher
Raj et al. (2021)	Cobb 500	Minazel plus and Tixosil	0-2	Finisher
Riahi et al. (2021)	Ross 308	MMDA	0-3	Starter, grower, and finisher
Saleemi et al. (2020)	-	LMB and CMB	0-2	Finisher
Srinual et al. (2022)	-	Toxin binder	0-1	Finisher
Weber et al. (2006)	Ross 308	Toxin binder	0-0.002	Finisher
Zabiulla et al. (2021)	-	Smectite clay	0-0.2	Finisher
Lai et al. (2022)	Arbor Acres	XI	0-2	Grower, finisher

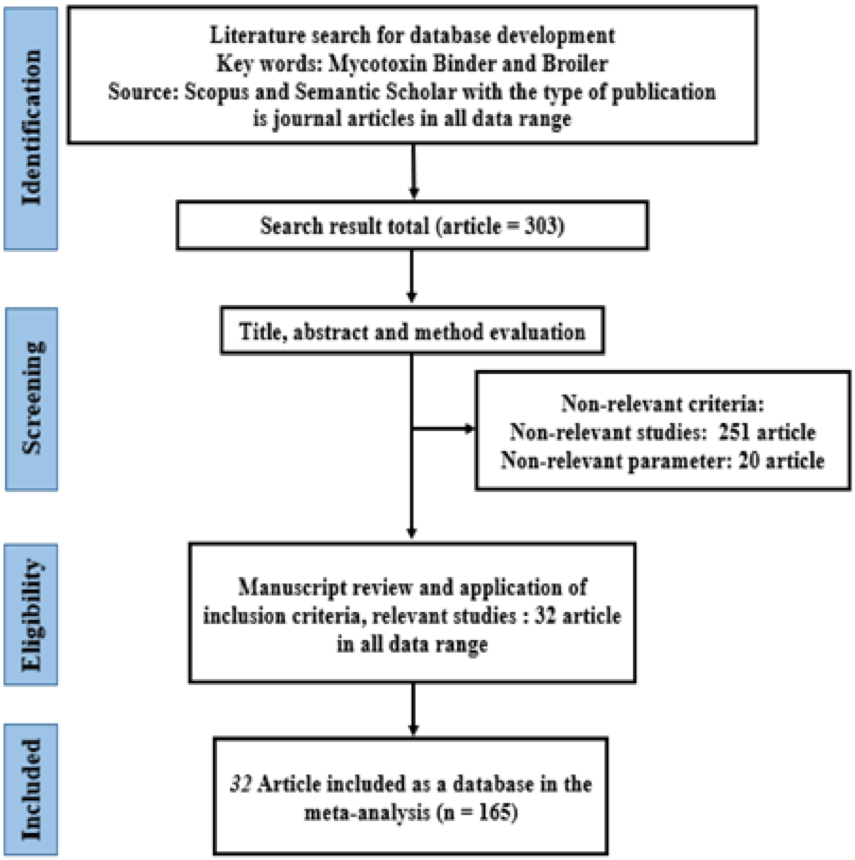

Figure 1 The selection process of the studies

Data Extraction

Meta-analysis refers to the systematic use of statistical methods to analyze effect sizes. The concept of effect size pertains to the quantification and summarization of the impact resulting from an observation of a specific phenomena under investigation. Effect sizes may be categorized as either unstandardized or standardized (Cheung and Vijayakumar, 2016). Data were analyzed using the random-effects meta-analysis method. The effect size (ES) was calculated based on Hedges' d standardized mean difference. The calculation is shown in the following formula (Palupi et al., 2012):

$$d = \frac{(\bar{X}E - \bar{X}C)\,S}{J}$$

Where the mean of the experimental or use mycotoxin binder is ($\bar{X}E$), the control group or without mycotoxin binder is ($\bar{X}C$), the pooled standard deviation is (S), and the correction factor for the small sample size is (J). The mathematical model of one-way random effects is as follows:5

$$y_i = \theta + v_i + \varepsilon_i$$

Suppose the value of the effect size (at hedge d) for the ith observation is (y_i). In that case, the general parameter for the combined effect size is (θ), the actual variation in the effect size is (v_i), and the error of i-th observation is (ε_i). However, the estimate of the between-study variance (τ^2) was based on the DerSimonian and Laird method (DerSimonian and Laird, 1986). The calculation is given by the following formula:

$$\tau^2 = \frac{Q - \mathrm{df}}{C}$$

Where, Q is the weighted sum square, the degrees of freedom are df, and the value is C. The meta-analysis was conducted using the OpenMEE for performance variables and meta-regression. A cumulative forest plot (95% confidence interval [CI]) was constructed using MedCalc.

RESULTS

Table 2 shows a compilation of evidence from meta-analyses regarding the effectiveness of mycotoxin binders on broiler performance and intestinal health. In order to assess the effect of mycotoxin binder in feed on growth performance, relative weight, bone weight, and organ weights of broilers were measured (Table 3). The addition of binder to broilers resulted in substantial increases in BW (ES 0.784; P<0.001; 95% CI: [0.628; 0.939]) and ADG (ES 0.704; P<0.001; 95% CI: [0.336; 1.07]). In contrast, FCR (ES -0.87; P<0.001; 95% CI [-1.09; -0.652]) and mortality (ES -3.98; P<0.001; 95% CI [-4.94; -3.01]) were considerably reduced. In addition, according to Figure 2, the FCR and mortality followed a linearly declining trend. Heart (ES 0.549; P=0.002; 95% CI [0.202; 0.897]), kidney (ES 0.701; P=0.013; 95% CI [0.149; 1.25]), and thymus (ES 1.45; P=0.001; 95% CI [0.527; 2.37]) relative weights increased considerably. In the meanwhile, the pancreas reduced dramatically (ES -0.51; P=0.027; 95% CI [-0.962; -0.054]). Bursa fabricius (ES 2.04; P<0.001; 95% CI [0.985; 3.1]), gizzard (ES 2.62; P<0.001; 95% CI [1.86; 3.37]), wishbone (ES 1.66; P<0.001; 95% CI [1.14; 2.18]), and gut length (ES 0.937; P<0.001; 95% CI [0.557; 1.32]). Figure 3, which compares the position of the mean value per subgroup (starter, grower, finisher, and overall period) to assess the effectiveness of the mycotoxin binder, demonstrates that the varied growth phases of broilers affect its efficacy. The farther the location to the right of the mean, the greater the influence of the mycotoxin binder over the different rearing phases. The value of FCR had the same relative efficacy throughout all phases of rearing, with the grower phase offering the most effectiveness. The ADG was greater during the finisher phase than during the starter and growth phases. Compared to the growing phase, the starter and finisher phases were able to reduce the mortality rate. During the starting stage, gizzard weight was greater than during the grower and finisher periods. The evaluation results of publication bias using the funnel plot test of the FCR parameter are presented in Figure 4. The funnel plot shows a clear asymmetrical image. This indicates the presence of publication bias in the meta-analysis. This condition is due to the different types of mycotoxin binders and strains of broilers used in each study.

Table 2 Summarize of meta-database from 31 articles

Variable	Unit	NC	Control				Treatment			
			Max	Min	Mean	SD	Max	Min	Mean	SD
Performance										
Body weight	g	145	3528	97	1651	147	3490	104	1783	156
FCR		120	3.88	0.38	1.64	0.183	5.33	0.34	1.63	0.183
Daily feed intake	g	101	3169	21.2	159	22.4	3197	21.1	187	22.5
Total feed intake	g	100	5111	75.5	2169	146	4980	48.6	2204	150
Average daily gain	g	73	410	13.9	62.6	7.38	442	14.9	74.2	7.34
Mortality	%	54	24	1	5.74	1.84	20	0	3.63	1.54
Organ's relative weight										
Liver	g/100g	65	47.8	13.2	32.6	1.29	56.4	31.5	43	1.29
Heart	g/100g	42	5.3	0.32	1.68	0.386	6.2	0.29	1.86	0.39
Spleen	g/100g	41	19.5	0.1	2.27	0.123	2.1	0.1	0.466	0.112
Bursa pancreas thymus	g/100g	40	9.6	0.083	1.1	0.167	9.9	0	1.032	0.185
Gizzard	g/100g	40	19.5	0.097	6.42	1.75	22.1	0.089	6.4	2.04
Kidney	g/100g	40	8.7	0.2	1.84	0.103	71	3	10.4	0.107
Thymus	g/100g	19	6.5	0.196	2.38	0.261	6.6	0.245	2.38	0.31
Pancreas	g/100g	16	3.51	0.251	1.11	0.116	3.61	0.236	1.049	0.092
Organ's weight, wishbone weight, and total gut length										
Bursa fabricius	g	36	23	0.4	4.69	0.284	22	0.9	5.1	0.33
Gizzard	g	32	95	11.5	40.2	3.83	96	30	50.8	4.9
Wishbone	g	24	870	188	538	53.8	1167	205	652	65.1
Gut length	cm	24	221	126	187	18.69	246	155	206	20.6

Note: FCR= feed conversion ratio; Max= maximum value from the data; Min= minimum value from the data; NC= negative control; SD= standard deviation.

Table 3 Effects of mycotoxin binder addition on performance, organ weight, wishbone weight, and gut length of broiler

Variable	Unit	n	Estimate	Std. error	Lower bound	Upper bound	P-Value	τ^2	Q	Het. P-Value	I^2
Performance											
Body weight	g	145	0.784	0.079	0.628	0.939	<0.001	0.579	1313	<0.001	89
FCR		120	-0.856	-1.095	-0.617	0.122	< 0.001	1.079	1144.976	< 0.001	91.703
Daily feed intake	g	101	-0.034	0.113	-0.255	0.187	0.760	0.857	1027	<0.001	90.3
Total feed intake	g	100	-0.058	0.075	-0.205	0.089	0.442	0.283	448	<0.001	77.9
Average daily gain	g	73	0.704	0.188	0.336	1.07	<0.001	1.72	459	<0.001	84.3
Mortality	%	54	-3.98	0.49	-4.94	-3.01	<0.001	11.5	4190	<0.001	98.7
Organ's relative weight											
Liver	g/100g	65	-0.221	0.161	-0.536	0.094	0.169	1.12	320	<0.001	80
Heart	g/100g	42	0.549	0.177	0.202	0.897	0.002	0.795	140	<0.001	70.8
Spleen	g/100g	41	0.034	0.187	-0.332	0.4	0.854	0.859	184	<0.001	78.3
Bursa pancreas thymus	g/100g	40	-0.363	0.256	-0.865	0.139	0.156	1.88	232	<0.001	83.2
Gizzard	g/100g	40	0.044	0.269	-0.484	0.571	0.871	2.13	205	<0.001	81
Kidney	g/100g	40	0.701	0.281	0.149	1.25	0.013	2.26	353	<0.001	89
Thymus	g/100g	19	1.45	0.47	0.527	2.37	0.002	3.4	127	<0.001	85.8
Pancreas	g/100g	16	-0.51	0.231	-0.962	-0.058	0.027	0.448	32.6	0.005	54
Organ's weight, wishbone weight, and total gut length											
Bursa fabricius	g	36	2.04	0.54	0.985	3.1	<0.001	10.3	4169	<0.001	99.2
Gizzard	g	32	2.62	0.385	1.86	3.37	<0.001	4.4	2234	<0.001	98.6
Wishbone	g	24	1.66	0.264	1.14	2.18	<0.001	1.64	1099	<0.001	97.9
Gut length	cm	24	0.937	0.194	0.557	1.32	<0.001	0.872	698	<0.001	96.7

Note: FCR= feed conversion ratio; I^2= heterogeneity level of the meta-analysis model; n= number of observed variables; Q= weight of sum square; Std. error= error within a study; τ^2= absolute value of variance between studies.

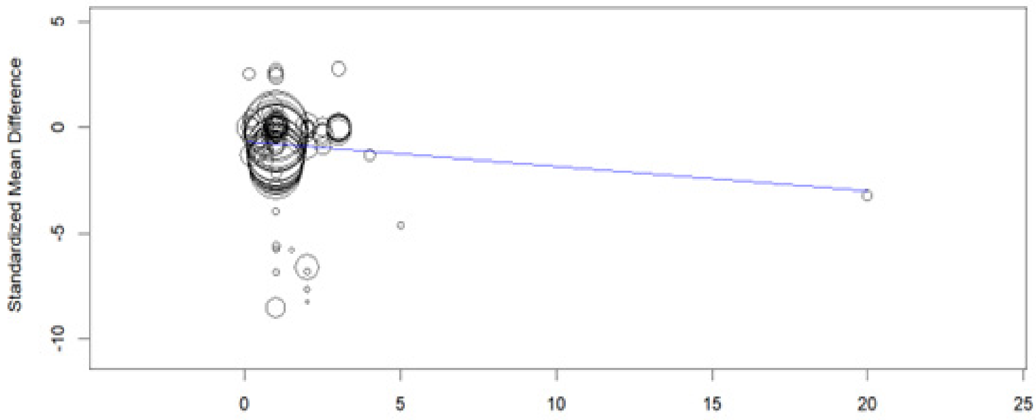

Figure 2 Meta-regression between FCR (ES -0.856; P<0.001; 95% CI -0.617; 0.122]) and level of mycotoxin binder

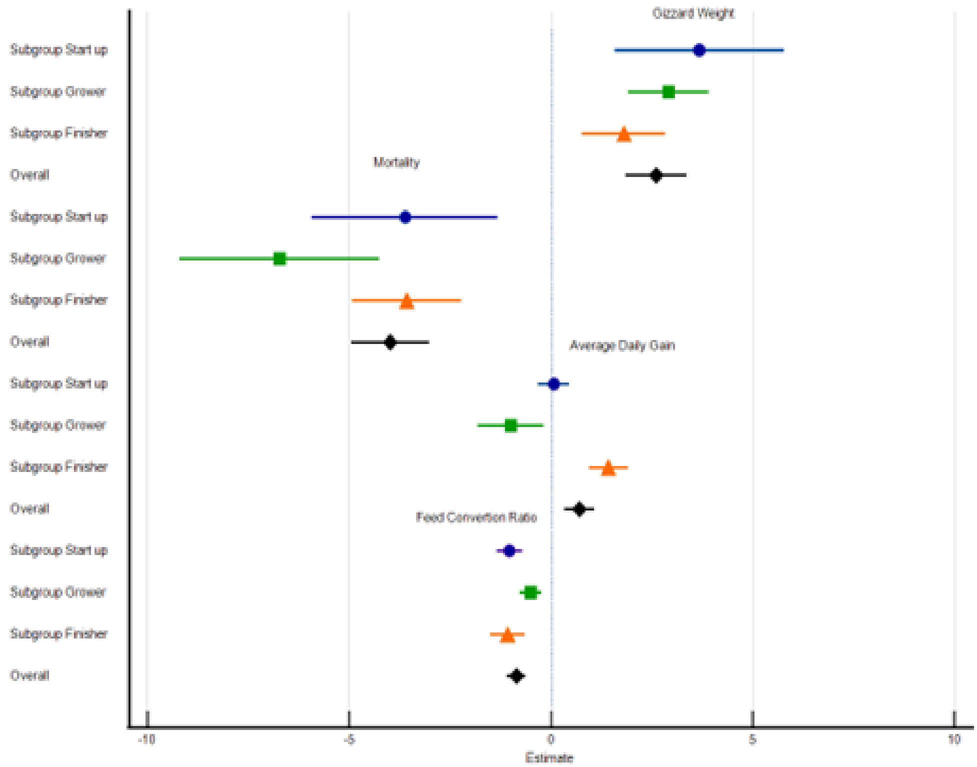

Figure 3 Forest plot of subgroup analysis of different periods for various parameters due to mycotoxin binder addition

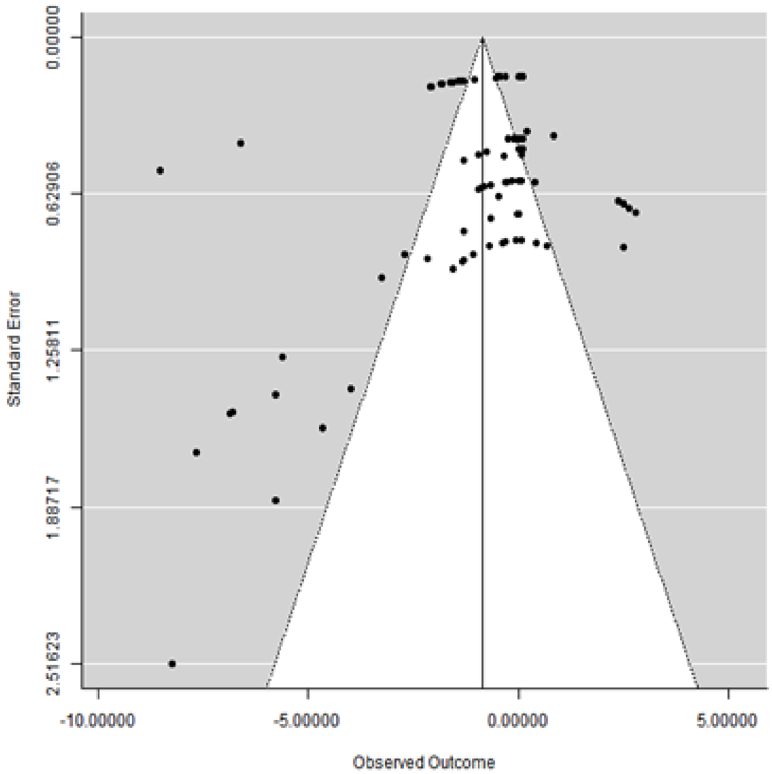

Figure 4 Funnel plot of efficacy of mycotoxin binder addition on the FCR parameter of broiler

DISCUSSION

Mycotoxin binders are added to contaminated diets to decrease mycotoxin effects. According to this hypothesis, the binder decontaminates mycotoxins in the feed by firmly binding them to prevent hazardous interactions. Mycotoxin binders absorb mycotoxins throughout the gastrointestinal tract. Therefore, mycotoxin binder may affect the performance of broiler chicken.

Numerous investigations have been conducted to examine the impact of mycotoxin binding on broiler chickens. Nevertheless, the outcomes observed in each individual study exhibited variations and lacked definitive conclusions. According to Cheung and Vijayakumar et al. (2016), an essential aspect of scientific inquiry is the acquisition and consolidation of information and research discoveries. Meta-analysis is an important research methodology that facilitates the synthesis of study results across several fields. The preferred approach for gathering research results from scientific studies is to use this procedure. Several of these constraints may be mitigated by meticulously designing a systematic review and using suitable statistical meta-analysis methods.

Broiler Performance

Mycotoxins can induce mycocytosis and affect the health and performance of broiler chickens. Mycotoxin management using binders is required to mitigate this threat (Bindhu and Jin, 2010). As a consequence of the meta-analysis-based study, both body weight and weight growth grew in a decent manner, with remarkably different outcomes. The FCR and mortality findings were reduced and negative; hence, they were positive and substantially distinct. The reduction in total and daily feed intake was unfavorable but not statistically significant. A mycotoxin binder facilitates the absorption of mycotoxins in the digestive system. Overall, the performance of broilers was excellent. According to Montagne et al. (2003), a healthy gastrointestinal tract results in improved growth rate and feed efficiency.

Relative Organ Weight

Mycotoxin binders affect relative organ weight. Relative organ weight has a negative impact and decreases the relative organ weights of the liver, bursa pancreas, thymus, and pancreas in broiler chickens. Additionally, mycotoxin binders increase the relative organ weights of the heart, spleen, gizzard, kidney, and thymus in broiler chickens. Mycotoxin binder had considerably diverse effects on the heart, kidney, thymus, and pancreas of broiler chickens. The mycotoxin binder had no effect on the liver, spleen, bursa pancreas, thymus, or gizzard of broiler chickens.

Organ Weight

Mycotoxin binders affect organ mass. The lengths of the bursa fabricius, wishbone, gizzard, and pancreas produced drastically varied effects. A mycotoxin binder may cause bursa fabricius, wishbones, and gizzard broiler chickens to gain weight. Mycotoxin binders also lengthen broiler intestines.

Regression Mortality and Level of Mycotoxin Binder

After analyzing the mortality and levels of mycotoxin binders using meta-analysis in the form of meta-regression, a negative trend was discovered. The higher the mycotoxin binder levels administered, the lower the mortality rate. It can be assumed that the amount of mycotoxin binder influences the mortality rate of broiler chickens. This is because mycotoxin binders affect the development of immunity in broiler chickens (Rashidi, 2020).

Regression FCR and Level of Mycotoxin Binder

The meta-analysis used meta-regression to determine a relationship between mycotoxin binder levels and FCR. The data indicated a negative trend, implying that the FCR value decreased as the concentration of the mycotoxin binder increased. It can be inferred that a higher concentration of mycotoxin binder has a greater influence on the FCR value. A low FCR score is desirable because it shows that the addition of a certain quantity of feed may result in a greater percentage of broiler weight increase. In the digestion of broiler chicks, the mycotoxin binder binds to the mycotoxin binder. A healthy digestive system, particularly the gut, boosts growth and feed efficiency (Montagne et al., 2003).

Forest Plot Subgroup Analysis

The chickens were separated into three phases: starter, grower, and finisher. During this time period, the use of mycotoxin binders resulted in a variety of impacts. The gizzard's weight was greatest during the growth phase and lowest during the finisher phase. Nevertheless, the total weight of the gizzard has grown. The growing phase has the lowest death rate, whereas the starter and finisher stages have very high mortality rates. However, the total mortality rate of broiler chicks decreased. The growth phase produced the lowest ADG level, whereas the finisher phase produced the highest. However, overall, the ADG of broiler chicks increased. The FCR level was maximum during the growth phase and very low during the starter and finisher stages. However, the FCR decreased overall.

Publication Bias

The funnel plot shown in Figure 4 had a distinct asymmetrical pattern. The presence of asymmetric findings suggests the possibility of publishing bias. In addition, Susanto et al. (2023) concluded that the presence of an asymmetrical shape in a funnel plot serves as an indication of publication bias. Publication bias might arise because of variations in the mycotoxin binder and broiler strains used in various studies.

CONCLUSIONS

The findings of this study indicate that mycotoxin binders have a more pronounced influence on both broiler production and gastrointestinal health. According to studies on the influence of mycotoxin binders on broiler performance, the body weight, daily body gain, FCR, and mortality of broilers have increased greatly. The relative organ weights of the heart, kidney, thymus, and pancreas were enhanced when the mycotoxin binder was administered. The effect of the mycotoxin binder on the weights of the bursa fabricius, wishbone, and gizzard was notable.

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AUTHOR CONTRIBUTIONS

All authors contributed equally.

CONFLICT OF INTEREST

The authors state that there were no conflicts of interest during the writing of the journal and associated activities.

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