



Effects of Antimicrobial Peptide Feed Additives on Immune Performance in Broilers: A Meta-analysis

QingXu Zhang^{1,2,3}, Wu Sun^{1,2,3}, Xiayang Jin^{1,2,3}, Shike Ma^{1,2,3}

10.18805/IJAR.BF-2018

ABSTRACT

Background: The effects of antimicrobial peptide (AMP) feed additives on broiler immune performance remain controversial in existing studies. Given the potential of AMPs as antibiotic alternatives in poultry production, a systematic evaluation of their immunomodulatory effects is needed.

Methods: This meta-analysis evaluated the impact of AMP feed additives on broiler immune indicators using data from 14 articles (35 controlled studies), including 35 experimental groups (AMP-supplemented diet) and 14 control groups (basal diet). Sensitivity analysis assessed result stability and funnel plots examined publication bias.

Result: AMP supplementation significantly increased serum IgA, IgG and IgM levels ($P < 0.05$) and enhanced thymus and spleen indices ($P < 0.05$), but did not affect the bursa of Fabricius index ($P > 0.05$). Funnel plots indicated minimal publication bias and sensitivity analysis confirmed robust findings. These results demonstrate that AMP feed additives effectively improve broiler immune performance. The study supports the judicious use of AMPs in broiler production and provides a scientific basis for further research on AMP applications in poultry farming.

Key words: Amps, Broiler, Immune performance, Meta-analysis.

INTRODUCTION

Antimicrobial peptides (AMPs), a class of small-molecule polypeptides widely present in organisms, exhibit broad-spectrum antibacterial, antiviral, antifungal and immunomodulatory properties (Wang *et al.*, 2004; Bu *et al.*, 2005). Characterized by excellent thermal stability, high water solubility and low propensity to induce antimicrobial resistance, AMPs are recognized as promising green alternatives to antibiotic feed additives (Wang 2007; Bao *et al.*, 2009; Du *et al.*, 2010). Previous studies have demonstrated that AMPs not only directly eliminate pathogenic microorganisms but also enhance host immunity by modulating the immune system, thereby improving animal growth performance, intestinal health and immune function (Xiao *et al.*, 2006) (Zhang *et al.*, 2016). However, research on the application of AMPs in broiler production remains limited and existing findings on their immunomodulatory effects are inconsistent. While some studies report significant improvements in immune parameters (e.g., serum IgA, IgG and thymus index), others observed no notable effects (Dierick *et al.*, 2003; Surai *et al.*, 2019). Consequently, a systematic evaluation of AMPs' impact on broiler immune performance is of both theoretical and practical significance.

In livestock production, AMPs have gained increasing attention as feed additives, particularly in the context of antibiotic restriction policies, owing to their efficacy, safety and residue-free advantages (Li *et al.*, 2008; Yang *et al.*, 2009; Thacker 2013; Xiao *et al.*, 2015; Zong *et al.*, 2021). Dietary supplementation with AMPs has been shown to enhance growth performance, disease resistance and intestinal morphology in animals (Shan *et al.*, 2012).

¹Academy of Animal Science and Veterinary Medicine, Qinghai University, Xining, 810016, China.

²Key Laboratory of Livestock and Poultry Genetics and Breeding on the Qinghai-Tibet Plateau, Ministry of Agriculture and Rural Affairs, Xining, 810016, China.

³Plateau Livestock Genetic Resources Protection and Innovative Utilization Key Laboratory of Qinghai Province, Xining, 810016, China.

Corresponding Author: Wu Sun, Academy of Animal Science and Veterinary Medicine, Qinghai University, Xining, 810016, China. Email: sunwufrank@163.com

How to cite this article: Zhang, Q., Sun, W., Jin, X. and Ma, S. (2025). Effects of Antimicrobial Peptide Feed Additives on Immune Performance in Broilers: A Meta-analysis. *Indian Journal of Animal Research*. 1-8. doi: 10.18805/IJAR.BF-2018.

Submitted: 05-05-2025 **Accepted:** 22-09-2025 **Online:** 29-10-2025

Specifically, studies indicate that AMPs improve broiler growth performance, macrophage activity and immune organ development (Wang *et al.*, 2010; Lyu *et al.*, 2011). Nevertheless, the diversity of AMP types and their complex mechanisms of action, coupled with variations in experimental designs (e.g., dosage, source and duration of supplementation), may contribute to inconsistent research outcomes (Han *et al.*, 2014). Thus, a systematic approach is needed to integrate existing data and objectively evaluate the overall effects of AMPs on broiler immune function. Meta-analysis, a statistical method for quantitatively synthesizing independent study results, enhances conclusion reliability by increasing sample size and reducing random error (Hedges *et al.*, 1985). Its key steps include literature screening, data extraction,

heterogeneity testing and effect size pooling and it has been widely applied in evidence synthesis across medical and agricultural research.

To address these inconsistencies, this study employs meta-analysis to systematically assess the effects of AMP feed additives on broiler immune indicators (e.g., serum immunoglobulins and immune organ indices). By rigorously screening literature, evaluating bias risks and conducting sensitivity analyses, we aim to derive robust conclusions that support the scientific application of AMPs in broiler production and guide future research and development efforts.

MATERIALS AND METHODS

Literature search

A comprehensive literature search was conducted primarily in Chinese databases including CNKI, Wanfang, VIP and Chinese Science Citation Database (CSCD) to capture the concentrated body of relevant research published in Chinese journals. We acknowledge that this may limit the generalizability of our findings and thus the conclusions of this meta-analysis should be interpreted as being specific to studies published in Chinese. using the following keywords: "antimicrobial peptides," "broilers," and "immune performance." Immune performance indicators included serum IgA, IgG, IgM levels, thymus index, spleen index and bursa of Fabricius index as outcome measures. The search was limited to publications from 2001 to 2023. Relevant articles were subsequently screened and reviewed for inclusion.

Literature screening

Studies were included based on the following criteria:1) The research investigated the effects of antimicrobial peptide (AMP) additives on broiler immune performance;2) Outcome measures included serum IgA, IgG, IgM levels, thymus index, spleen index and bursa of Fabricius index;3) Two independent researchers screened and extracted data from all retrieved literature, with cross-verification to ensure accuracy. A total of 50 publications were initially identified through database searches. After excluding duplicates, conference papers, meeting abstracts and unpublished studies (n=36), 14 articles met the eligibility criteria and were included in the final analysis.

Data extraction and characteristics

The meta-analysis systematically extracted data from the 14 eligible articles, which comprised 35 controlled studies. For each study, key information was collected including publication title, year of publication, sample size, concentration of antimicrobial peptides in the experimental diet, as well as outcome measures (serum IgA, IgG, IgM levels, thymus index, spleen index and bursa of Fabricius index) with corresponding means and standard deviations for both treatment and control groups. Studies published in the same year by the same author were distinguished

using numerical identifiers (e.g., (1), (2)). The final dataset included 4 studies on serum IgA, 6 on IgG, 6 on IgM and 5 studies each for thymus index, spleen index and bursa of Fabricius index, totaling 35 antimicrobial peptide treatment groups and 14 control groups. All included studies were properly controlled experiments investigating the effects of antimicrobial peptide supplementation.

Statistical analysis

The meta-analysis was performed using R software (version 4.2.1) with the meta package. All immune performance outcome measures were continuous variables and the standardized mean difference (SMD) with 95% confidence intervals (CIs) was selected as the effect size metric, calculated using the Hedges' g method (Hedges *et al.*, 1985) or Cohen' g method (Cohen 1988) to account for potential small sample bias. The analysis was conducted through the following systematic procedures.

Effect size calculation and model selection

The metacont () function was employed to compute effect sizes, incorporating group sample sizes (n1, n2), means (mean1, mean2) and standard deviations (sd1, sd2) for both experimental and control groups. Heterogeneity was assessed using I² statistics and Cochran's Q test (P-value), with the DerSimonian-Laird random-effects model applied when substantial heterogeneity was detected (I² > 50% or Q-test P<0.05); otherwise, a fixed-effects model was used.

Forest Plot Generation

The forest () function generated comprehensive forest plots, visually presenting individual study effect sizes, their 95% CIs and the pooled estimate. Graphical outputs were saved in both high-resolution JPEG (7600×4800 pixels, 360 dpi) and PDF formats for publication-quality reproduction.

Publication bias assessment

Publication bias was systematically assessed using three complementary approaches: visual inspection of funnel plot symmetry generated by the funnel () function, quantitative evaluation through Egger's regression test using metabias () with the "rank" method and trim-and-fill analysis via the trimfill () function to estimate and adjust for potentially missing studies. All graphical outputs from these analyses were exported in publication-ready PDF formats (600 dpi) to ensure high-quality visualization and reproducibility of results.

Sensitivity analysis

The metainf () function performed leave-one-out sensitivity analysis to examine the influence of individual studies on the pooled estimate. Results were visualized through modified forest plots, with all graphical outputs exported in multiple formats (JPEG and PDF).

All statistical tests were two-sided, with P<0.05 considered statistically significant. The comprehensive analytical workflow ensured rigorous assessment of both effect magnitudes and result stability. Data preprocessing

included careful formatting of input variables (text for author/year, integers for sample sizes and numeric with 2-3 decimal places for continuous measures) to ensure computational accuracy.

To explore potential sources of the substantial heterogeneity observed, we planned to perform subgroup analyses or meta-regression based on factors such as AMP type, dosage and trial duration if sufficient data had been available from the included studies. However, due to inconsistent reporting across the limited number of studies, these analyses were not feasible.

RESULTS AND DISCUSSION

Meta-analysis of antimicrobial peptide additives on broiler immune performance

As shown in Fig 1-6, The meta-analysis results demonstrated significant heterogeneity among studies investigating the effects of antimicrobial peptide additives on broiler immune parameters ($P < 0.001$, $I^2 > 50\%$), including serum IgA, IgG, IgM levels, thymus index, spleen index and bursa of Fabricius index, necessitating the use of a random-effects model for effect size pooling. The high heterogeneity suggests that effects may vary due to

moderating factors such as AMP type or dosage. Unfortunately, as noted in the methods section, the available data were insufficient to robustly investigate these sources through subgroup analysis. The combined effect sizes were consistently located to the right of the null line without intersection, revealing statistically significant improvements in serum IgA ($P < 0.05$), IgG ($P < 0.05$) and IgM levels ($P < 0.05$), as well as thymus index ($P < 0.05$) and spleen index ($P < 0.05$), while no significant effect was observed on the bursa of Fabricius index ($P > 0.05$). Since these immunological markers (serum immunoglobulins and immune organ indices) are well-established indicators of immune competence (Dudley 1992; Dalloul *et al.*, 2006; Dalgaard *et al.*, 2022; Li *et al.*, 2024), these findings collectively indicate that dietary supplementation with antimicrobial peptides can significantly enhance immune performance in broilers.

Sensitivity analyses

The meta-analysis demonstrated that antimicrobial peptide additives significantly influenced broiler immune parameters (Table 1), with high heterogeneity observed across studies ($I^2 > 50\%$, $P < 0.01$), necessitating evaluation of result stability and reliability. Sensitivity analysis,

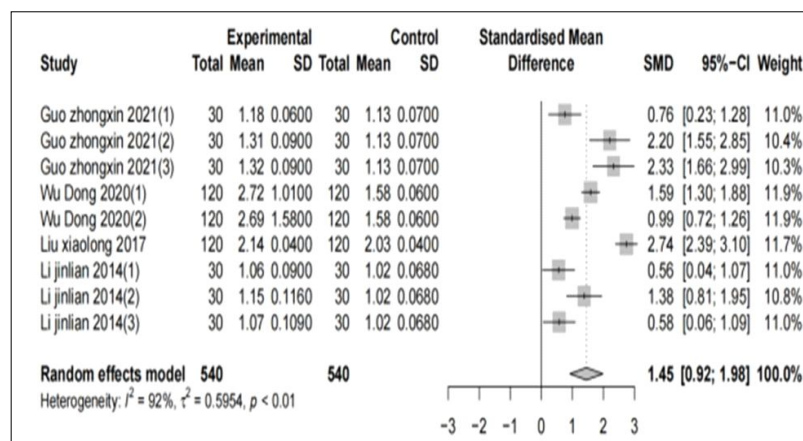


Fig 1: Forest plot for meta-analysis of antimicrobial peptide additives on IgA level in broilers.

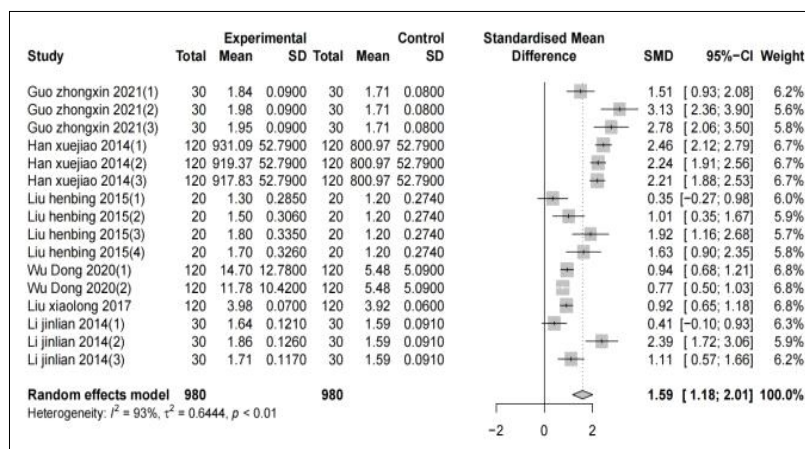


Fig 2: Forest plot for meta-analysis of antimicrobial peptide additives on IgG level in broilers.

performed by sequentially excluding each included study, revealed that the pooled effect sizes of remaining studies consistently remained on both sides of the null line without crossing it, further confirming the robustness and accuracy of our meta-analytic findings regarding the immunomodulatory effects of antimicrobial peptide supplementation in broilers.

Bias analysis

The publication bias assessment was visualized using funnel plots (Fig 7). Funnel plot analysis revealed that while most studies on immune performance outcomes were clustered in the upper-middle section of the plot, the distribution showed poor symmetry with several studies

located in the lower or outer regions, indicating the presence of potential publication bias. While the trim-and-fill adjustment confirmed the robustness of the statistical significance, the asymmetric funnel plot suggests that the overall effect size might be overestimated due to the possible absence of small studies with null or negative findings. After applying the trim-and-fill adjustment model, the corrected results (Table 2) demonstrated that the effects of antimicrobial peptide additives on broiler immune performance outcomes remained statistically significant ($P < 0.05$), strongly supporting the reliability of the initial meta-analysis findings. Similarly, for all immune performance indicators examined, the adjusted results

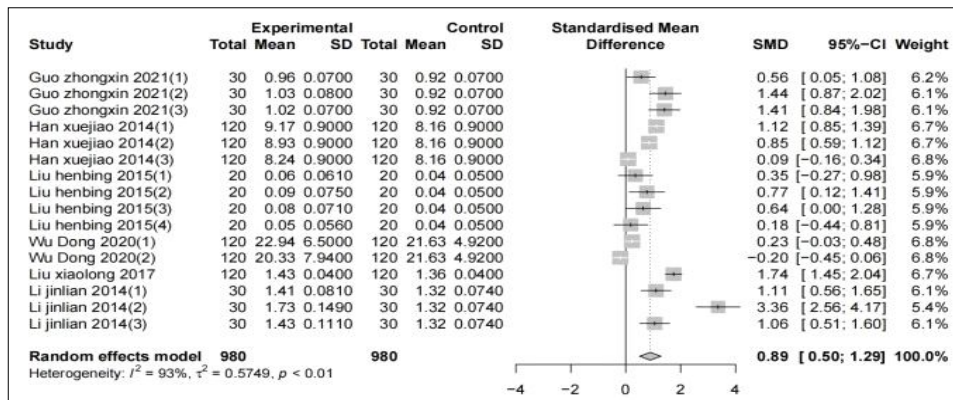


Fig 3: Forest plot for meta-analysis of antimicrobial peptide additives on IgM level in broilers.

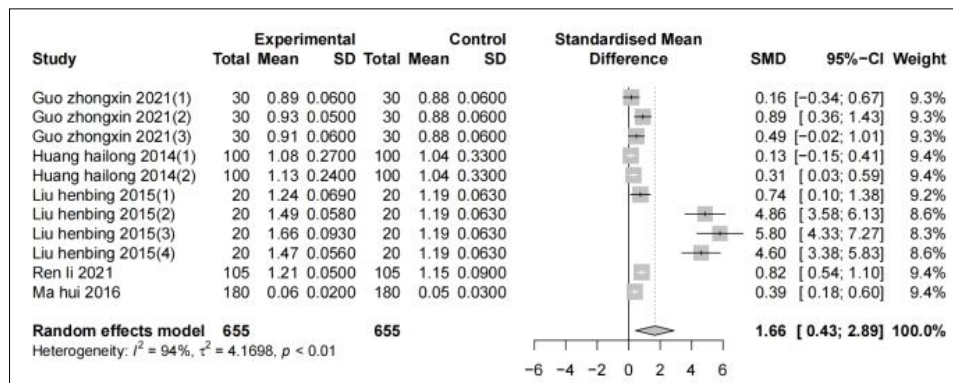


Fig 4: Forest plot for meta-analysis of antimicrobial peptide additives on thymus index in broilers.

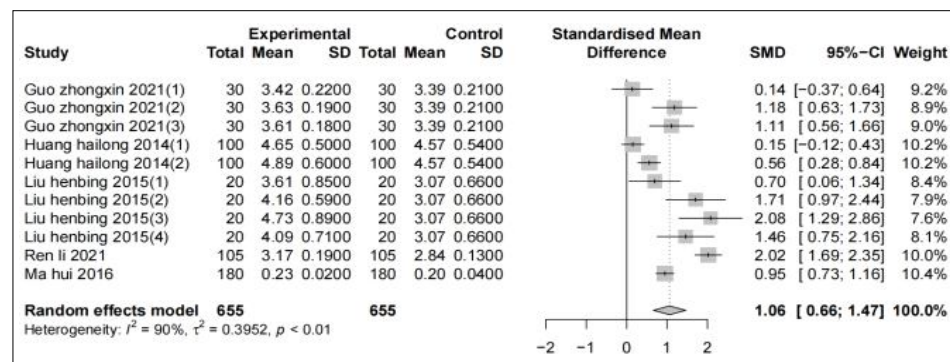


Fig 5: Forest plot for meta-analysis of antimicrobial peptide additives on spleen index in broilers.

maintained statistical significance ($P < 0.05$). These findings provide robust confirmation of the meta-analysis results, further validating the conclusion that antimicrobial peptide supplementation significantly enhances immune parameters in broilers.

Animal immune function serves as a crucial indicator of health status, directly determining growth performance and economic returns in livestock production status (Liao *et al.*, 2025). Extensive research confirms that levels of immune cytokines and immunoglobulins (particularly IgA, IgG and IgM) accurately reflect immunological status, with these antibodies playing vital roles in host defense mechanisms (Hernández-Castellano *et al.*, 2015). (Lyu *et al.*, 2011) found that adding antimicrobial peptides to feed could increase the spleen coefficient of laying hens, regulate serum immune levels, promote the expression of IL-2 mRNA in the spleen and enhance the immunity of laying hens. In recent years, there have been many studies on the effects of different antimicrobial peptide additives

on the immune performance of broilers, suggesting that antimicrobial peptides are beneficial for improving animal immune performance or function. Multiple studies have demonstrated the immunomodulatory effects of antimicrobial peptides in broilers. Significant improvements in serum IgA levels were observed with 0.5% AMP supplementation (Liu *et al.*, 2017). Doses of 0.05% and 0.1% AMP showed positive effects on both serum IgG and bursa of Fabricius index (Guo *et al.*, 2021). The administration of 500 mg/kg AMP resulted in enhanced serum IgM levels (Li 2014), while the same concentration significantly increased thymus index (Liu *et al.*, 2015). At 200mg/kg, AMP improved both thymus index and bursa of Fabricius index (Ren *et al.*, 2021). Higher concentrations of 600mg/kg and 1200 mg/kg AMP were found to elevate spleen index (Liu *et al.*, 2015). However, conflicting evidence suggests antimicrobial peptides may not consistently enhance immune function, with some studies reporting

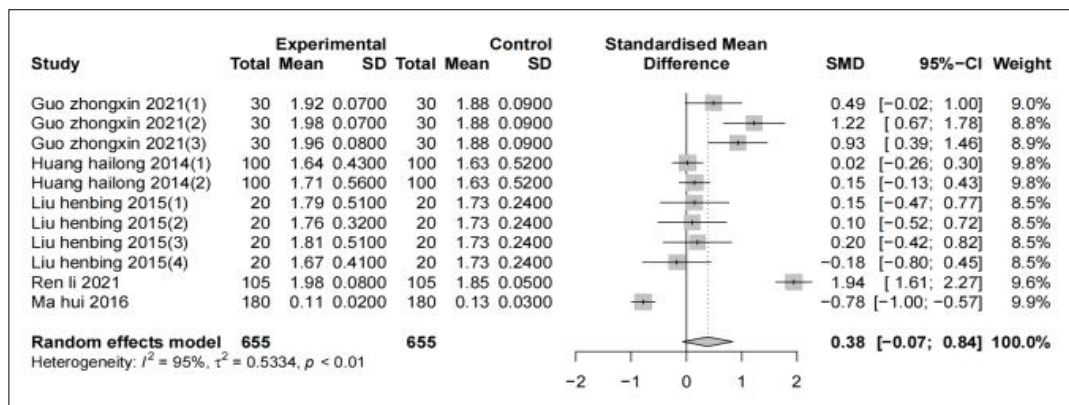


Fig 6: Forest plot for meta-analysis of antimicrobial peptide additives on bursa index in broilers.

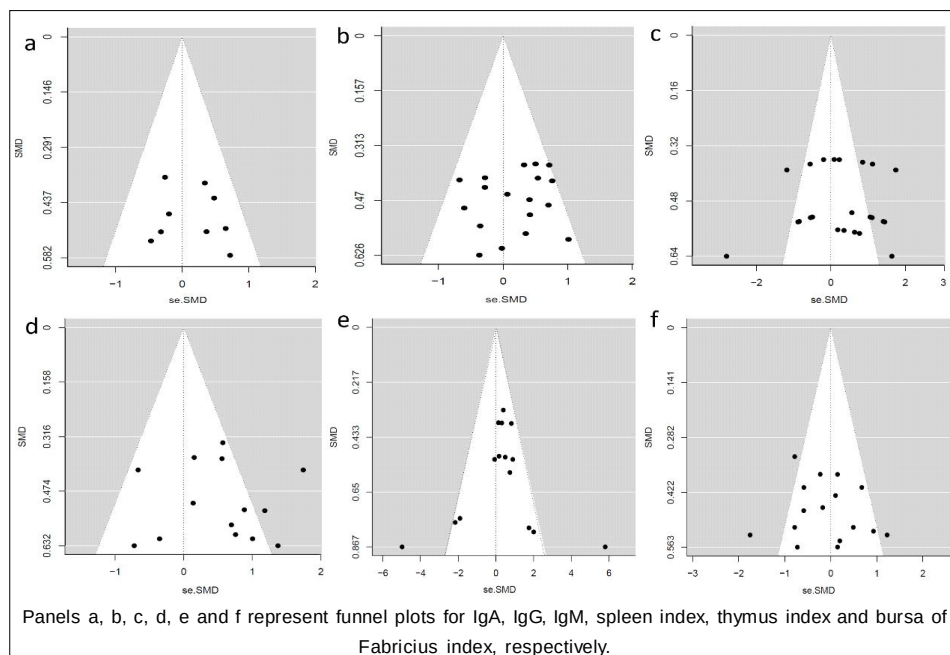


Fig 7: Funnel plots of the effects of antimicrobial peptide additives on broiler immune parameters.

inhibitory or null effects. At 100 mg/kg, a significant negative impact on bursa of Fabricius index was observed (Ma *et al.*, 2016). Several studies found no significant effects: 100 mg/kg and 1000 mg/kg AMP showed no influence on serum IgA (Li 2014); 300 mg/kg had no effect on serum IgG or bursa index (Liu *et al.*, 2015); 150 mg/kg Fultai failed to alter serum IgM (Han *et al.*, 2014); 100 g/t and 200 g/t AMP doses did not affect IgM levels (Wu *et al.*, 2020); 0.01% concentration showed no thymus index improvement (Guo *et al.*, 2021); non-induced *Tenebrio molitor* supplementation did not modify spleen index (Huang *et al.*, 2014); and 600 mg/kg AMP demonstrated no bursa index enhancement (Liu *et al.*, 2015).

To address whether antimicrobial peptide additives promote or inhibit animal immune performance or function, this experiment used meta-analysis methods to integrate and analyze recent studies, ultimately proposing our view that antimicrobial peptide supplementation can to some extent improve animal immune performance. These results align with previous research demonstrating the immunostimulatory potential of antimicrobial peptides (Huang *et al.*, 2014; Li 2014; Guo *et al.*, 2021; Ren *et al.*, 2021). This experiment conducted a meta-analysis of 20 controlled studies. Although there was heterogeneity among studies in the changes of outcome indicators represented by serum IgA, IgG, IgM levels, thymus index, spleen index and bursa of Fabricius index, we also performed correction analysis and the results also confirmed the reliability of the meta-analysis results. In addition, sensitivity analysis results showed that after excluding each study one by one, the combined effect size of the remaining results still had statistical significance. In summary, this indicates that the results of this meta-analysis are stable and reliable. Therefore, it can preliminarily

be stated that adding antimicrobial peptides can to some extent improve animal immune performance. The inconsistent conclusions may be related to factors such as animal species, types of herbal additive and different forage-to-concentrate ratios in basal diets. Specifically, the type of antimicrobial peptide (e.g., Cecropin, Defensin), the dosage administered and the duration of supplementation are likely key contributors to the heterogeneous results we observed. Future studies with standardized reporting are needed to allow for quantitative analysis (e.g., meta-regression) of these effect modifiers. In addition, this study included a small number of literatures and there were large differences between studies, which may hinder the drawing of accurate and reliable conclusions. Therefore, more studies should be included in the future to address these limitations.

This study has certain limitations. First, although the overall quality of the literature included in this paper is high, there are still incomplete data and a small amount of publication bias, which may have some impact on the meta-analysis results. In addition, there are differences in basal diets, experimental diet components, pretrial periods, formal trial periods and other experimental manipulation factors among the studies included in this paper. For example, time differences in animal pretrial periods and formal trial periods may easily cause changes in related outcome indicators, thereby having unpredictable effects on the stability of immune indicators. Therefore, differentiated experimental manipulation conditions may be potential sources of heterogeneity. Second, the indicators for evaluating animal immune performance actually include more than those mentioned in this paper, such as IgA, IgG, IgM levels and thymus index. For example, indicators such

Table 1: Results of a meta-analysis of antibacterial peptide additives affecting broiler immune parameters.

Indicators	No. of studies	Standardized mean difference (95% confidence interval)(SMD) (95% CI)		Heterogeneity test	
		Effect size	P-value	I ² %	P-value
IgA	9	1.45[0.92-1.98]	<0.01	92%	<0.01
IgG	16	1.59[1.18-2.01]	<0.01	93%	<0.01
IgM	16	0.89[0.50-1.29]	<0.01	93%	<0.01
Spleen index	11	1.66[0.43-2.89]	<0.01	94%	<0.01
Thymus index	11	1.06[0.66-1.47]	<0.01	90%	<0.01
Bursa of fabricius index	11	0.38[-0.07-0.84]	<0.01	95%	<0.01

Table 2: Summary of results after meta-analysis correction.

Indicators	No. of studies	Standardized mean difference (95% confidence interval) (SMD) (95% CI)		Heterogeneity test	
		Effect size	P-value	I ² %	P-value
IgA	9	1.16[0.92-1.98]	<0.01	94%	<0.01
IgG	16	1.36[1.18-2.01]	<0.01	94%	<0.01
IgM	16	0.64[0.50-1.29]	<0.01	94%	<0.01
Spleen index	11	1.29[0.43-2.89]	<0.01	95%	<0.01
Thymus index	11	1.12[0.66-1.47]	<0.01	92%	<0.01
Bursa of fabricius index	11	0.45[-0.07-0.84]	<0.01	96%	<0.01

as animal diarrhea rate were not included in this analysis due to insufficient literature, which may also have some impact on the experimental results. Therefore, the understanding of the mechanism by which antimicrobial peptides affect broiler immune performance is not yet deep enough, lacking systematic systematicness and comprehensiveness. This experiment did not consider these comprehensive factors and future research will further comprehensively consider these factors to propose systematic and comprehensive conclusions, so as to provide more reasonable scientific basis for the impact of antimicrobial peptides on broiler immune performance.

This study provides the most comprehensive quantitative synthesis to date on AMPs' immunomodulatory effects in broilers, while explicitly acknowledging remaining knowledge gaps that require further investigation through rigorously designed, large-scale trials with standardized protocols.

CONCLUSION

The meta-analysis results demonstrated that dietary supplementation with antimicrobial peptide additives significantly increased serum IgA, IgG and IgM levels ($P < 0.05$), as well as thymus index and spleen index ($P < 0.05$), while showing no significant effect on bursa of Fabricius index ($P > 0.05$). These findings collectively indicate that antimicrobial peptide feed additives can significantly enhance immune performance in broilers.

Funding

This work was supported by Qinghai Youth and Middle-aged Science and Technology Talent Support Project (2023QHSKXRCTJ17).

Author contributions

Qingxu Zhang designed the experiments and drafted the manuscript. Data processing and visualization were performed by Wu Sun, Jin xiayang and Ma shike.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Data availability statement

The datasets generated during and analyzed during the current study are available from the corresponding author on reasonable request. The R code related to the meta-analysis in this article can be obtained by contacting the corresponding author.

Conflict of interest

The authors declare that they have no conflicts of interest.

REFERENCES

- Bao, H., She, R., Liu, T., Zhang, Y., Peng, K.S., Luo, D., Yue, Z., Ding, Y., Hu, Y., Liu, W., Zhai, L. (2009). Effects of pig antibacterial peptides on growth performance and intestine mucosal immune of broiler chickens. *Poultry Science*. **88**: 291-297.
- Bu, G.H., Li, H.J., Yang, G.Y. (2005). Characteristics and application prospects of antimicrobial peptides. *Progress in Veterinary Medicine*. **26**: 26-28.
- Cohen, J. (1988). Statistical power analysis for the behavioral sciences. New York, Lawrence Erlbaum Associates, Inc.
- Dalgaard, T.S., Rebel, J.M.J., Bortoluzzi, C., Kogut, M.H. (2022). Chapter 15 - Factors modulating the avian immune system. *Avian Immunology* (Third Edition). Kaspers, B., Schat, K.A., Göbel, T.W., Vervelde, L. Boston, Academic Press: 419-435.
- Dalloul, R.A. and Lillehoj, H.S. (2006). Poultry coccidiosis: Recent advancements in control measures and vaccine development. *Expert Review of Vaccines*. **5**: 143-163.
- Dierick, N.A., Decuypere, J.A., Degeyter, I. (2003). The combined use of whole cuphea seeds containing medium chain fatty acids and an exogenous lipase in piglet nutrition. *Archives of Animal Nutrition*. **57**: 49-63.
- Du, H.M., Qi, G.Z., Wang, J.J. (2010). Effects of antimicrobial lipopeptide on growth performance and immune function of broilers. *Jiangsu Journal of Agricultural Sciences*. **26**: 1009-1014.
- Dudley, D.J. (1992). The immune system in health and disease. *Baillieres Clin Obstet Gynaecol*. **6**: 393-416.
- Guo, Z.X. and Wang, T.Q. (2021). Effects of antimicrobial peptides on growth performance, slaughter performance, meat quality and immune function of broilers. *Feed Research*. **12**: 37-40.
- Han, X.J., Ma, G.Y., Zhou, Y.Y. (2014). Effects of antimicrobial peptides on growth performance and immune function of broilers. *Chinese Journal of Animal Science*. **50**: 70-74.
- Hedges, L.V. and Olkin, I. (1985). Statistical methods for meta-analysis. New York, Academic Press.
- Hernández-Castellano, L.E., Moreno-Indias, I., Morales-de-laNuez, A., Sánchez-Macías, D., Torres, A., Capote, J., Argüello, A., Castro, N. (2015). The effect of milk source on body weight and immune status of lambs. *Livestock Science*. **175**: 70-76.
- Huang, H.L., Tao, S.X., Jia, Y. (2014). Effects of *Tenebrio molitor* with high expression of antimicrobial peptides on immune function of broilers. *Chinese Journal of Veterinary Science*. **7**: 2000-2004.
- Li, C.P., Chen, A.G., Ding, S.Y. (2008). Application of antimicrobial peptides in broiler production. *Feed Research*. **12**: 31-33.
- Li, C.Y., Xu, L.M., He, H., Huang, Y.Z., Yuan, Y.L., Peng, L.J., Peng, K.J., Wan, K., Zhang, C.S., Cao, L.J., Zhang, J. (2024). Effects of fermented hybrid *broussonetia papyrifera* on the production performance, physiological and biochemical indexes and meat quality of sichuan white goose. *Journal of Southwest University (Natural Science Edition)*. **46**: 71-83.
- Li, J.L. (2014). Effects of different levels of antimicrobial peptides in diet on growth performance and immunity of broilers. *Heilongjiang Animal Science and Veterinary Medicine*. **14**: 87-88.
- Liao, Y.Q., Kang, Y.G., Chang, L.L. (2025). Effects of bacterial enzyme coordinated fermentation of medicinal residue on growth performance, immune indexes and serum biochemical indexes of lambs. *China Feed*. pp-132-137.
- Liu, H.B. and Liu, Y. (2015). Study on the effects of antimicrobial peptides in broiler diets. *Hunan Journal of Animal Science and Veterinary Medicine*. **10**: 6-9.

- Liu, X.L., Qiao, J.Y., Fan, H. (2017). Effects of antimicrobial peptides and synbiotics on serum biochemical indexes and intestinal flora of AA broilers. *Heilongjiang Animal Science and Veterinary Medicine*. **12**: 111-114.
- Lyu, Z.Z., Yuan, X.X., Cai, Z.W. (2011). Effects of antimicrobial peptides on serum immune indices and interleukin-2 mRNA expression in spleen of laying hens. *Chinese Journal of Animal Nutrition*. **23**: 2183-2189.
- Ma, H., Yuan, D.L., Qiao, H.X. (2016). Effects of antimicrobial peptides and immunoglobulins in feed on production performance and immune function of broilers. *Animal Husbandry and Veterinary Medicine*. **11**: 67-71.
- Ren, L., Wu, S.Y., Zhao, D.F. (2021). Effects of natto bacteria antimicrobial lipopeptide on growth performance and immune organs of broilers. *Feed Industry*. **42**: 30-34.
- Shan, A.S., Ma, D.Y., Feng, X.J. (2012). Function, research and application of antimicrobial peptides. *Scientia Agricultura Sinica*. **45**: 2249-2259.
- Surai, Kochish, Fisinin, Kidd (2019). Antioxidant defence systems and oxidative stress in poultry biology: An update. *Antioxidants*. **8**: 235-.
- Thacker, P.A. (2013). Alternatives to antibiotics as growth promoters for use in swine production: A review. *J. Anim. Sci. Biotechnol.* **4**: 35.
- Wang, J. (2007). Effects of antimicrobial peptides on growth performance and immune function of broilers. Master's thesis, Shandong Agricultural University.
- Wang, X.Q., Zhu, M.X., Zhang, A.J. (2010). Effects of antimicrobial peptide Cecropin B on growth and immune function of chickens. *Journal of Ningxia Medical University*. **32**: 39-41.
- Wang, Y.Z., Wang, Z.Q., Xu, Z.R. (2004). Comparison of antimicrobial effects between antimicrobial peptides and antibiotics *in vitro*. *Chinese Journal of Veterinary Science*. **24**: 270-273.
- Wu, D., Yang, J.J., Wu, Y.J. (2020). Effects of replacing feed antibiotics with different proportions of antimicrobial peptides on growth performance, serum immune indexes and intestinal flora of broilers. *Cereal and Feed Industry*. **11**: 13-19.
- Xiao, H., Shao, F., Wu, M., Ren, W., Xiong, X., Tan, B., Yin, Y. (2015). The application of antimicrobial peptides as growth and health promoters for swine. *Journal of Animal Science and Biotechnology*. **6**: 19.
- Xiao, Y., Cai, Y., Bommineni, Y.R., Fernando, S.C., Prakash, O., Gilliland, S.E., Zhang, G. (2006). Identification and functional characterization of three chicken cathelicidins with potent antimicrobial activity. *Journal of Biological Chemistry*. **281**: 2858-2867.
- Yang, Y.R., Liang, H.D., Wei, H.L. (2009). Preliminary study on effects of ostrich skin antimicrobial peptides on immune organ indexes and T lymphocyte numbers in chicks. *Chinese Agricultural Science Bulletin*. **25**: 46-48.
- Zhang, L.J. and Gallo, R.L. (2016). Antimicrobial peptides. *Current Biology*. **26**: R14-R19.
- Zong, R., Hu, Z.Z., Zhang, N.F. (2021). Antimicrobial mechanism of antimicrobial peptides and its research progress in ruminants. *Feed Industry*. **42**: 30-35.