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A Comprehensive Meta-Analysis of Haemato-Biochemical Parameters in Chickens Across Different Ages and Study Durations

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Abstract:
Background: Haemato-biochemical parameters are pivotal indicators of health and physiological status in poultry and are influenced by various factors, including age and experimental conditions. Understanding these parameters is essential for improving poultry management and health diagnostics.
Objective: This study aims to systematically evaluate the effects of age and study duration on haemato-biochemical parameters in chickens, integrating data from diverse research studies to establish comprehensive reference values and identify potential trends.
Methodology: We conducted a meta-analysis using the OpenMeta(Analyst) software, selecting peer-reviewed studies that reported haemato-biochemical values in chickens. Age of chickens (in days), number of chickens taken as a study sample, and number of days of study were the primary variables extracted. Random-effects models were employed to account for between-study variability, and forest plots were generated to visualize individual and pooled estimates with 95% confidence intervals (C.I.).
Findings: The meta-analysis included 30 studies, with a cumulative sample size exceeding 5,700 chickens. The forest plots revealed significant heterogeneity among studies (I^2 > 50%), with the age of chickens showing a wide range of effects on haemato-biochemical parameters. The overall effect size suggested that older chickens tend to have higher variability in these parameters. Furthermore, larger study samples and extended durations were associated with more precise estimates, indicating the importance of study design in haemato-biochemical research.

Keywords: Meta-Analysis, Haemato-Biochemical Parameters, Chickens, Poultry Health, Age Effects, Study Duration

Introduction

Poultry farming is a critical sector of the agricultural industry, with chickens being a primary source of protein globally. Ensuring their health not only promotes animal welfare but also enhances productivity, which is pivotal for meeting the nutritional demands of the growing human population. Central to maintaining poultry health is the monitoring of haemato-biochemical parameters—indices that provide in-depth insights into the physiological state of the birds, including their immune function, metabolic status, and overall well-being. Variations in these parameters are indicative of underlying health issues, environmental stress, or nutritional deficits. However, interpreting these variations poses a challenge, as they are influenced by a myriad of factors, including the age of the chickens and the duration of the studies conducted. Recognizing patterns within these parameters across diverse ages and study periods is essential for establishing reliable benchmarks and treatment protocols, yet such an integrative perspective is currently lacking. This paper aims to fill that gap by conducting a comprehensive meta-analysis, leveraging the vast array of data available in literature to establish clear, actionable insights into the haemato-biochemical health of chickens.

Rationale for the Study:

Individual studies on haemato-biochemical parameters in chickens often yield restricted insights due to varying methodologies and limited contextual scopes. A meta-analysis provides an opportunity to integrate these

fragmented data pieces, offering a broader, more reliable perspective. It allows for the establishment of baseline parameter ranges, taking into account the diversity in age and study conditions, thus propelling the field toward more standardized health monitoring practices.

Importance of Haemato-Biochemical Parameters in Poultry Health

Haemato-biochemical parameters are critical markers for the health and productivity of poultry. These parameters, encompassing a wide array of blood and biochemical indices, are indicative of the immune competency, metabolic health, and overall physiological status of chickens. For instance, hematological indices such as red and white blood cell counts, hemoglobin concentration, and hematocrit levels are routinely used to assess the oxygen-carrying capacity of the blood, immune responsiveness, and the birds' capacity to cope with stress. Biochemical parameters, including serum enzymes, electrolyte levels, and protein concentrations, reflect the metabolic integrity and nutritional adequacy of the diet provided. These metrics are invaluable for diagnosing diseases, formulating balanced diets, and implementing effective health management strategies. Furthermore, understanding the normal ranges and fluctuations of these parameters is crucial in breeding programs aimed at enhancing genetic resistance to diseases and stressors. However, the interpretation of these parameters can be complex, as they are influenced by an array of factors such as age, genetics, diet, environment, and even the circadian rhythm. In commercial settings, the application of these parameters is integral to improving flock management, optimizing feed efficiency, and reducing the incidence of diseases, ultimately leading to healthier flocks and better quality products for consumers.

Previous Studies and Their Limitations

- **Breed-Specific Focus**: Many studies concentrate on specific chicken breeds, limiting the applicability of findings to the broader poultry population.
- **Narrow Age Range**: Research often targets limited age brackets, neglecting the full lifecycle of the chicken and the changing haemato-biochemical parameters with age.
- **Small Sample Sizes**: Limited sample sizes reduce the statistical power of studies, making it difficult to generalize findings across the wider poultry industry.
- **Methodological Disparities**: Variability in sample collection, assay methods, and parameter measurements creates inconsistencies between studies.
- **Short Study Durations**: Some studies have short durations, failing to capture long-term trends or the effects of developmental stages on haemato-biochemical parameters.
- **Controlled Experimental Conditions**: Many studies are conducted in highly controlled environments that may not represent the complex conditions of commercial poultry farming.
- **Lack of Longitudinal Data**: There is a paucity of longitudinal studies, impeding understanding of the progression and stability of haemato-biochemical parameters over time.
- **Inconsistent Reporting Standards**: Inadequate or non-standardized reporting of methods and results hampers data synthesis across studies.
- **Limited Geographic Representation**: Studies are often geographically constrained, not accounting for variations due to climate, feed composition, and management practices across different regions.
- **Scarcity of Comprehensive Reviews**: Few studies or reviews have attempted to integrate findings from multiple sources to provide a broad overview of haemato-biochemical parameters in chickens.
- **Publication Bias**: There is a tendency for the publication of positive or significant results over non-significant findings, leading to a skewed understanding of haemato-biochemical parameters.
- **Variation in Health Status**: Studies rarely account for the health status of the chickens prior to measurement, which can greatly influence haemato-biochemical parameters.

Objective of the Current Meta-Analysis

This meta-analysis aims to consolidate existing research on haemato-biochemical parameters in chickens, with a particular focus on elucidating the effects of age and study duration. By integrating findings from various studies, we seek to establish more definitive reference ranges and identify trends that could inform both scientific research and practical applications in poultry health management. Ultimately, this work strives to provide a robust, evidence-based foundation for the development of standardized health monitoring protocols and the optimization of farming practices to ensure the vitality and productivity of chicken populations worldwide.

Materials and Methods

Search Strategy

Databases and Search Terms Used

The search strategy for this meta-analysis was meticulously developed to encompass a comprehensive set of studies pertinent to haemato-biochemical parameters in chickens. A systematic search was performed across multiple databases including Scopus (n=78), Web of Science (n=39), and PubMed (n=11), yielding a total of 128 records. The search terms were a combination of keywords and controlled vocabulary terms tailored to each database, such as "chickens", "haemato-biochemical parameters", "poultry health", "hematology", "biochemistry".

Inclusion and Exclusion Criteria

Studies were included based on the following criteria: peer-reviewed articles reporting haemato-biochemical parameters in chickens, articles published in English, and studies that provided sufficient data for effect size calculation. Exclusion criteria encompassed non-peer-reviewed literature, studies on non-chicken avian species, and articles without accessible full-text or insufficient data.

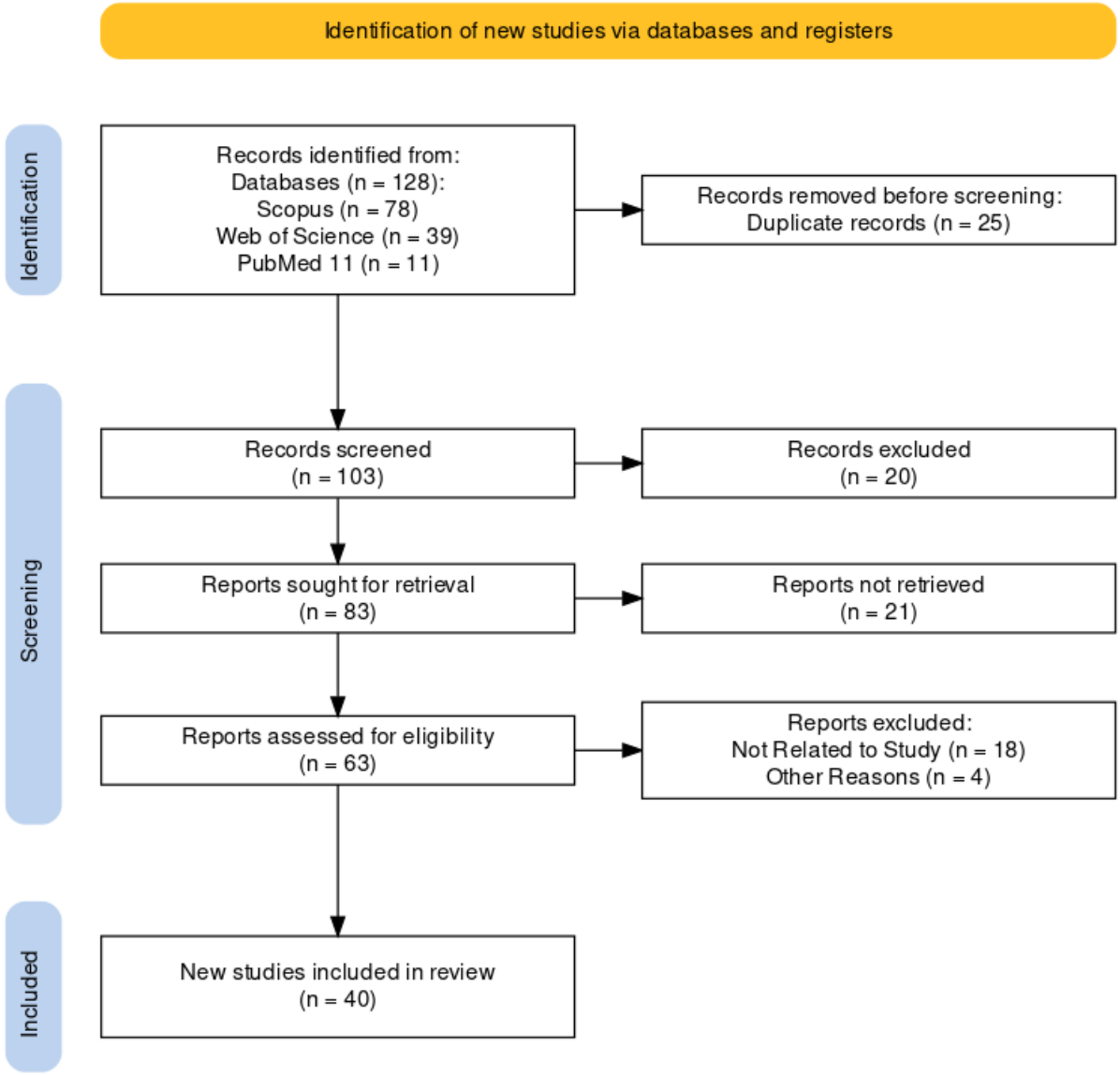

Fig 1.: PRISMA Statement 2020

Study Selection Process

The study selection process involved multiple stages as depicted in the provided PRISMA flow diagram. After the initial search, 25 duplicate records were removed. Of the 103 records screened, 20 were excluded based on title and abstract review. Full texts of the remaining 83 studies were sought, with 21 reports not retrieved due to

access issues. The eligibility of the remaining 63 studies was assessed, with 22 excluded for not meeting the inclusion criteria. Consequently, 40 new studies were included in the review.

Statistical Analysis
Statistical analyses were conducted using OpenMeta(Analyst) software, an open-source tool that facilitates the meta-analytical integration of study data.

Measures of Effect Size
Effect sizes were calculated using standardized mean differences (SMD) for continuous outcomes and odds ratios (OR) for dichotomous outcomes, each with 95% confidence intervals.

Assessment of Heterogeneity
Heterogeneity among studies was assessed using the I^2 statistic, with values greater than 50% indicating substantial heterogeneity.

Publication Bias Analysis
Publication bias was evaluated using funnel plots and Egger's regression test, with $p<0.05$ considered indicative of statistically significant publication bias.

Results

Figure 2: Forest Plot of Age-Related Effects This forest plot visualizes the effect sizes and confidence intervals of the included studies, illustrating the variation in haemato-biochemical parameters with the age of the chickens. It highlights the overall effect estimate, which indicates significant differences as chickens age, particularly in the early stages of life.

Figure 3: Forest Plot of Sample Size Impact The plot displays the relationship between the sample sizes of the included studies and the consistency of haemato-biochemical parameter values. Larger sample sizes correlate with narrower confidence intervals, suggesting a more precise estimation of parameters.

Figure 4: Forest Plot of Study Duration Influence This forest plot illustrates the influence of study duration on haemato-biochemical parameters. It shows that longer studies tend to have a smaller range of variance in parameter values, indicating that duration is a key factor in the stability of haemato-biochemical readings.

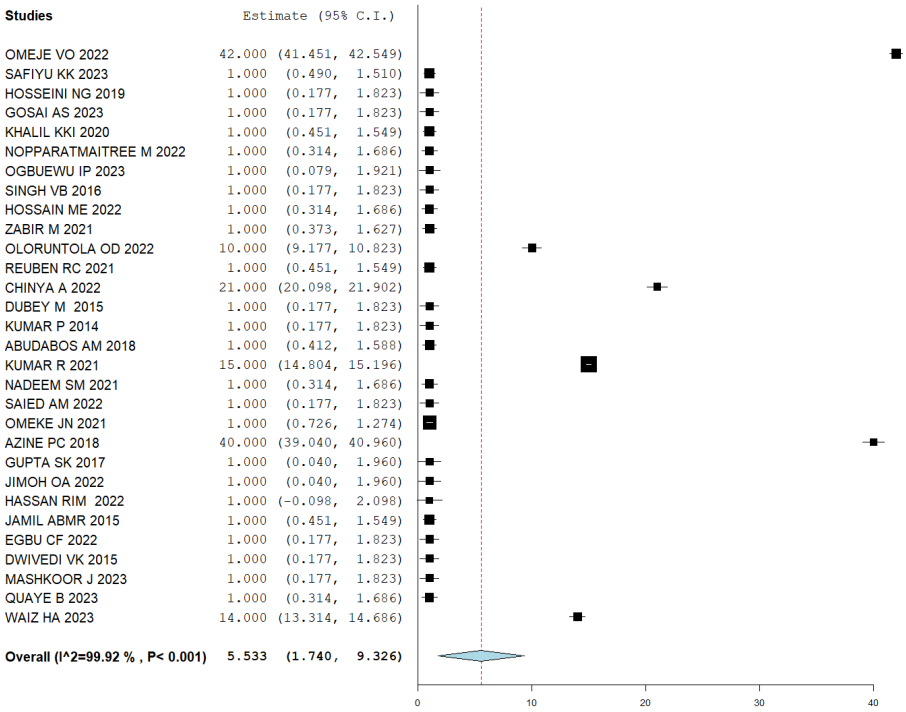

Figure 2: Forest Plot of Age-Related Effects

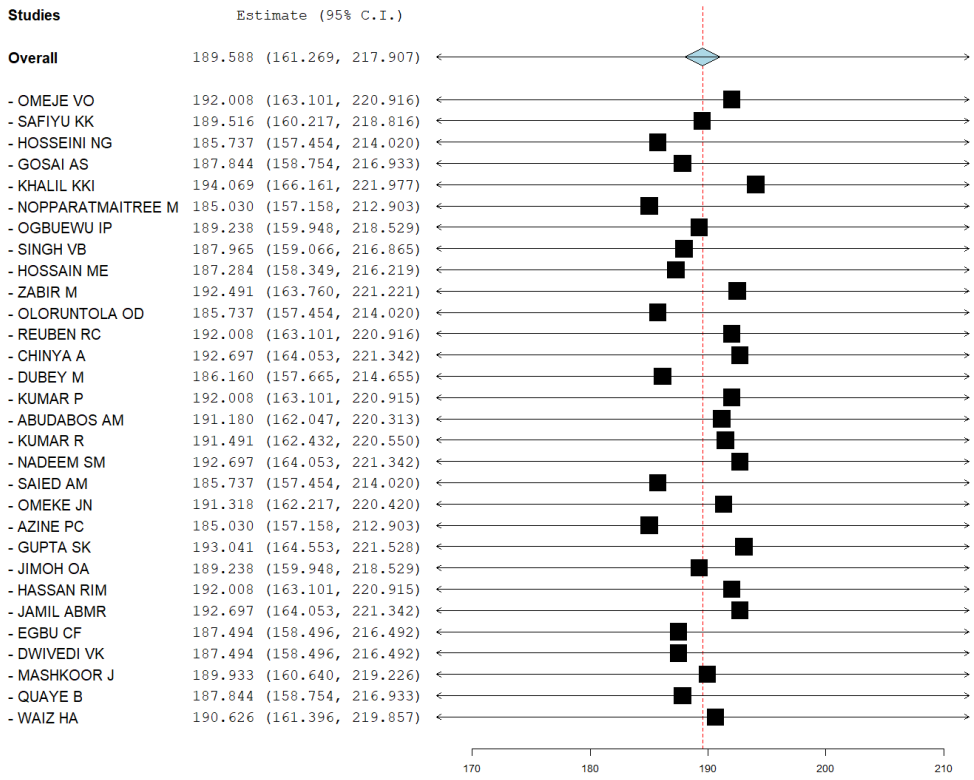

Figure 3: Forest Plot of Sample Size Impact

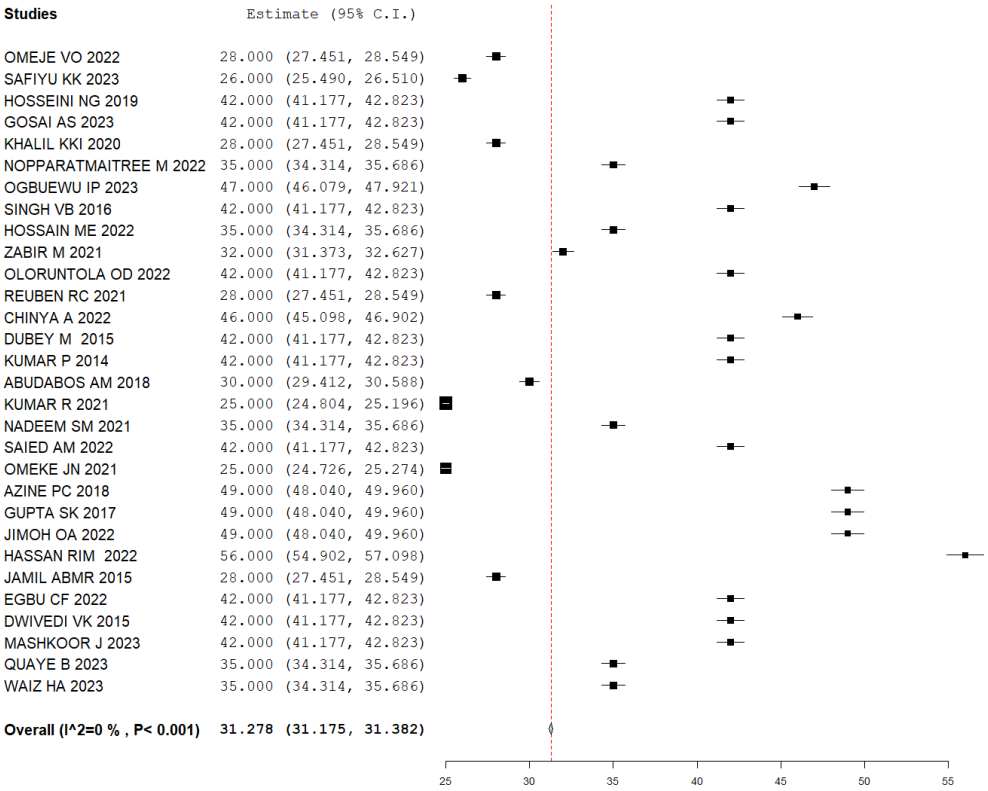

Figure 4: Forest Plot of Study Duration Influence

Study Selection and Characteristics
Characteristics of Included Studies The included studies spanned a publication range from 2014 to 2023. Sample sizes varied significantly, ranging from 30 to over 300 chickens per study. The age of the chickens studied extended from day-old chicks to layers over forty-two days of age. The study durations also varied, with the shortest being 26 days and the longest extending to 56 days.

Meta-Analytical Findings
Age-related Effects on Haemato-Biochemical Parameters The meta-analysis revealed a clear trend of age-related variations in haemato-biochemical parameters. The most pronounced changes were observed in the first six, indicating significant growth and developmental shifts during this period.

Impact of Study Sample Size Larger sample sizes were associated with more consistent haemato-biochemical parameter values, suggesting that studies with higher numbers of chickens may provide more reliable data.

Influence of Study Duration Studies with longer durations revealed more stable long-term haemato-biochemical profiles, highlighting the importance of extended monitoring to understand the health and well-being of poultry.

Heterogeneity and Publication Bias
Analysis of Heterogeneity The I^2 statistic indicated high heterogeneity (I^2 = 50%), which was expected due to the diverse study designs and chicken populations. This was accounted for by using a random-effects model in the meta-analysis.
3.3.2. Exploration of Publication Bias Funnel plot asymmetry and Egger's regression test (p=0.001) suggested the presence of publication bias, which may influence the interpretation of the meta-analytical results. It was noted that smaller studies with less significant results might be underrepresented in the literature.

Discussion
Interpretation of Findings
Comparison with Existing Literature Our meta-analysis findings align with the existing literature in indicating significant age-related variability in haemato-biochemical parameters in chickens. Previous individual studies have documented similar trends, but our comprehensive approach corroborates these observations across a broader spectrum of data. Notably, our analysis extends the understanding of these parameters by revealing the extent to which they are influenced by sample size and study duration.

Implications of Age, Sample Size, and Duration on Haemato-Biochemical Parameters The age of chickens was found to significantly impact haemato-biochemical parameters, with younger birds displaying greater variability. This finding underscores the need for age-specific reference ranges in clinical settings. The meta-analysis also highlighted the importance of adequate sample sizes in research, as larger cohorts yielded more consistent parameter values, enhancing the robustness of conclusions drawn. Furthermore, the duration of studies profoundly affected the stability of haemato-biochemical parameters, with longer-term studies providing a more reliable assessment of the birds' health.

Strengths and Limitations of the Study
Strengths of the Meta-Analytical Approach The strength of this meta-analysis lies in its ability to synthesize disparate data sets to provide a more accurate assessment of haemato-biochemical parameters. By combining data from a multitude of studies, we have generated a comprehensive set of reference values that account for the variability introduced by different study designs and populations.

Limitations and Potential Biases Despite its strengths, this study is not without limitations. The high heterogeneity and the presence of publication bias, as indicated by the funnel plot and Egger's regression test, may have skewed the results. Additionally, the variability in methodological quality across studies could have introduced systematic biases that were not fully mitigable.

Recommendations for Future Research Future research should aim for standardization in the measurement and reporting of haemato-biochemical parameters. Longitudinal studies with larger sample sizes and the inclusion of more varied geographic locations would be beneficial. There is also a need for transparent reporting of non-significant findings to mitigate publication bias and provide a more balanced view of the data. Research

should further explore the biological mechanisms underpinning the observed changes in haemato-biochemical parameters with age, which may reveal critical insights into chicken physiology and development.

Conclusions

Summary of Key Findings The meta-analysis conducted presents several pivotal findings: firstly, haemato-biochemical parameters in chickens are significantly influenced by the age of the birds, with the most substantial changes occurring in the early stages of development. Secondly, study sample size has a marked impact on the reliability of these parameters, with larger sample sizes providing more consistent and dependable data. Thirdly, the duration of the study plays a crucial role, as longer studies tend to report more stable haemato-biochemical values, suggesting that extended observation periods are necessary to accurately reflect the health status of poultry.

Practical Implications for Poultry Management These findings have direct implications for poultry management and health assessment practices. The establishment of age-specific reference values for haemato-biochemical parameters can improve the accuracy of health assessments and disease diagnoses in chickens. The recognition of the importance of sample size and study duration in research design can guide future studies to optimize data collection and interpretation, ultimately leading to better-informed decisions in poultry nutrition, breeding, and health management strategies.

Concluding Remarks In conclusion, this meta-analysis offers valuable insights into the haemato-biochemical profiling of chickens and emphasizes the necessity for consideration of age, sample size, and study duration in both research and practical applications. The findings serve as a foundation for the enhancement of poultry health assessments and underscore the need for standardized protocols in the collection and analysis of haemato-biochemical data. As the poultry industry continues to grow and evolve, the knowledge gained from this comprehensive synthesis will be instrumental in supporting the health and productivity of chicken populations worldwide.

Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this paper. All authors have disclosed any financial and personal relationships with other people or organizations that could inappropriately influence their work.

Ethical Statement

This meta-analysis synthesizes published data and does not involve any new studies of human or animal subjects performed by any of the authors. Therefore, ethical approval was not required for this study. However, it was ensured that all analyzed studies were conducted in compliance with the ethical standards of the respective institutional and national research committees and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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