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Evaluation of Dietary Inorganic and Organic Selenium Sources on Immune Organ, Plasma Immunoglobulins, Blood Biochemical, and Performance of Broilers: A Meta-Analysis

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ABSTRACT

The current meta-analysis aimed to estimate the effect of different selenium (Se) sources on immune organs, plasma immunoglobulins, blood profiles, and broiler performances. Related studies that met standard presence criteria were identified and mined from the Scopus database. The database was developed from 38 articles. Data were analyzed using the OpenMEE, considering the difference between organic selenium as fixed effects and different studies as random effects. This study showed that organic selenium feed supplementation improved the feed conversion ratio and increased the average daily feed intake and gain of broilers. Furthermore, the mortality of broilers fed organic Se was significantly lower than that of those fed inorganic Se. For the immune organ of the broiler, organic selenium feed supplement enhanced the thymus and spleen organs but did not affect the bursa organ. IgA and IgM were significantly higher in the broilers fed organic selenium feed; meanwhile, IgG of broilers fed organic selenium was lower than those fed inorganic selenium. The total protein blood concentration of broilers fed organic selenium was significantly higher than those fed inorganic Se. Meanwhile, there was no statistically significant difference in the effects of selenium source on cholesterol. Triglyceride concentrations of broilers fed organic Se are significantly lower than those fed inorganic Se. The ratio of heterophile to lymphocyte in broilers fed organic Se is significantly lower than in those fed inorganic selenium. In conclusion, the organic selenium feed supplement can promote production performance and immune parameters of broilers.

Keywords: immune broilers; meta-analysis; selenium; performance

INTRODUCTION

Selenium (Se) is known to be an imperative element in broiler diets. Certainly, the lack of Se remains associated with reduced poultry production and reproductive performance. It can initiate indications, such as pancreatic fiber degeneration, oozing diathesis, pancreatic fiber degeneration, and nutritional muscle atrophy, as well as decreased reproductive performance, thyroid malfunction, reduced immune function, and stress tolerance (Su, 2016). It is well recognized that there are numerous stressors associated with industrial chicken production, and Se, a component of several selenoproteins, can help maintain antioxidant defences and minimize tissue damage. Selenium is a crucial component of glutathione peroxidase (GSH-Px), a powerful antioxidant enzyme that boosts immunity and prevents several diseases in broilers (Wei *et al.*, 2021).

Additionally, it encourages growth and is crucial for maintaining the proper growth and production of broilers. Modern chicken genetics in commercial poultry production is characterized by high egg output and growth rates. However, these performance enhancements make broilers much more vulnerable to stressors (Akinyemi & Adewole, 2021). As a result, there has been a significant shift in modern chicken production from Se deficiency prevention to Se requirement fulfilment and performance optimization. Generally, Se in raw feedstuff is not enough to meet the demands of animals for health and development; external sources should be added. Therefore, Se supplementation in broilers has two advantages. It can affect the health and performance of broiler animals and influence meat quality, thereby improving human health.

Selenium can easily be divided into biological and inorganic materials. The most common type of inorganic Se utilized is sodium selenite (Na_2SeO_3), a major component of broiler diets. However, it adversely affects animals and the environment owing to its high toxicity, limited bioavailability, and oxidation potential. Broilers may directly absorb, process, and utilize organic Se, which often exists in the form of Se yeast. Their physical growth and development are stimulated, and their production, immunity, and anti-stress capacities are increased. Distinct types of Se are absorbed and processed in the body in comparatively distinct ways (Chen *et al.*, 2014). Broilers' water loss can be significantly decreased, and their production performance can be enhanced by 0.1–0.4 mg/kg when organic Se (Se yeast) is added to the diet (Bakhshalinejad *et al.*, 2018).

Supplemental Se dramatically increased serum IgG, IgA, and IgM concentrations as well as immune system indicators. Selenium may be more effective as an immune modulator by boosting antioxidant defenses against degenerative responses under stress (Wang *et al.*, 2016). Increased serum IgG and IgM concentrations have been observed in non-stressed boilers that received organic selenium (Boostani *et al.*, 2015). According to Cai *et al.* (2012), selenium shortage might lead to histopathological alterations in some tissues, including immunological organs such as the bursa, thymus, and spleen. Total cholesterol and triglyceride levels were reduced by organic Se supplementation in commercial broilers (Prakash *et al.*, 2019). In the meantime, supplementation of the diet with either an organic or inorganic Se had no significant effects on the biochemical blood indices of the broilers (Hossein *et al.*, 2018).

The effects of Se sources on the growth performance, immune system, plasma immunoglobulins, and blood biochemical of broilers have been extensively studied; however, the outcomes vary. This study identified and compiled prior research on the effects of various Se sources on broilers using a meta-analysis approach to provide scientific evidence that organic Se can replace inorganic Se as a supplemental additive. This study aimed to clarify the effects of different Se sources on these variables in broilers. Wei *et al.* (2021) performed a meta-analysis on the effects of selenium sources. However, it included only the Chinese region and lacked information on immune organs and immunoglobulin characteristics.

MATERIALS AND METHODS

Search Strategy, Inclusion Criteria, and Data Extraction

A thorough search of the literature in the English language was performed to find studies using broiler diets with organic and inorganic Se supplements. Scopus was used for literature search (https://www.scopus.com/). The search was done between January and February of 2023 utilizing phrases with a set of keywords in all searches: "selenium," "broiler," and "feed."

There were 542 possible references as a consequence of these initial searches. Additionally, the following criteria were utilized to select the literature: (1) full-text articles that have been published in English; (2) journals that have undergone peer review; (3) a direct comparison of organic and inorganic Se supplements; (4) broiler feed; and (5) a comparison of performance, including mortality rate, average daily gain, average daily feed intake, feed conversion ratio, and immune organs such as the bursa, spleen, and thymus, as well as immunoglobulins such as IgA, IgM, and IgG. Also, blood biochemical total protein, cholesterol, triglycerides, and heterophile to lymphocyte ratio (H/L ratio).

As many as 429 references were disqualified based on the initial title screening because the subject matter was not pertinent to the study. A total of 113 documents were evaluated after examining their abstracts. Subsequently, 66 publications were removed because there was no comparison of interest (40 documents), irrelevant parameters (26 documents), and 10 documents with inadequate data for statistical meta-analysis. Thirty-eight papers were ultimately found through screening, which was used for later data coding and statistical data analysis. The PRISMA-P flowchart in Figure 1 details the selection procedure, and Table 1 lists the studies used in this meta-analysis.

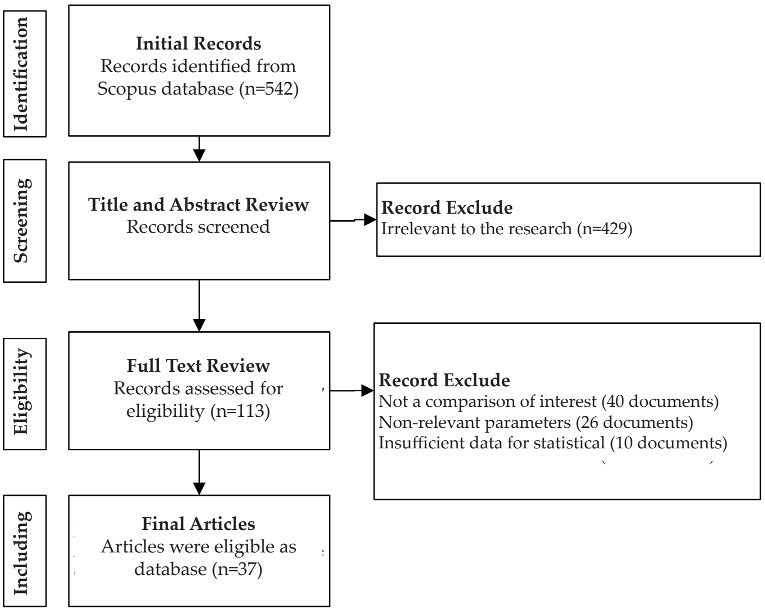

Figure 1. Diagram flow for study selection in the systematic review and meta-analysis study

Table 1. Studies selected to be included in the meta-analysis

No	Authors	Strain	Age (day)	Percentage of Se content (%)		Selenium source		Pellet/ Mash	Main feed ingredient
				Organic	Inorganic	Organic	Inorganic		
1	(Alian *et al.*, 2020)	Ross	1-42,	0.3	0.3	Seleno-methionine	Sodium selenite, Nanoselenium	N/A	Corn
2	(Arnaut *et al.*, 2021)	Cobb	1-17,	0.08, 0.16. 0.24, and 0.32	0.08, 0.16. 0.24, and 0.32	Selenium yeast	Selenium selenite	mash	Corn
3	(Bakhshalinejad *et al.*, 2018)	Ross	1-10, 11-24, 25-42	0.1	0.1	Selenised yeast and DL-seleno methionine	Sodium selenite	Mash	Maize
4	(Boostani *et al.*, 2015)	Cobb	1-21 and 22-42	0.3	0.3	*Sel-Plex*	Sodium selenite	Mash	Corn
5	(Briens *et al.*, 2013)	Ross	1-42.	0.1, 0.2, 0.3	0.1, 0.2, 0.3	Selisseo, Selenium yeast	Sodium selenite	N/A	Maize
6	(Chen *et al.*, 2014)	Arbor Acres	0-21, 22-42	0.3	0.3	Sel-Plex	Selenium selenite	N/A	Corn
7	(Chen *et al.*, 2022)	Lingnan Yellow	1-21, 22-56	0.2	0.2	Seleno methionine	Sodium selenite	Mash	Corn
8	(Choct *et al.*, 2004)	Bartter	0-38	0.1 and 0.25	0.1 and 0.25	Sel-Plex 50	Selenium selenite	pellet	Soybean, wheat
9	(Couloigner *et al.*, 2015)	Ross	1-11, 11-21. 1-21	0.2	0.2	Selenium yeast, Selisseo (HMSeBA)	Sodium selenite	Pellet	Corn
10	(da Silva *et al.*, 2010)	Ross	1-21 and 22-42	0.3	0.3	Selenium yeast	Sodium selenite	N/A	Corn
11	(Dalia *et al.*, 2017)	Cobb	1-42,	0.3	0.3	*Enterobacter cloacae, Klebsiella pneumoniae, Stenotrophomonas maltophiilia*	Sodium selenite	Pellet	Corn
12	(Deniz *et al.*, 2005)	N/A	0-21, 22-42	0.3	0.3	(Se-enriched yeast,	Selenium selenite	mash	Corn
13	(Dukare *et al.*, 2020)	N/A	1-42.	0.15, 0.20, and 0.25	0.15, 0.20, and 0.25	Green nano selenium	Inorganic	Mash	Maize
14	(Fan *et al.*, 2009)	N/A	1-14,	0.1 and 0.4	0.1 and 0.4	Selenium yeast	Na_2SeO_3	N/A	Maize
15	(Gružauskas *et al.*, 2014)	Cobb	1-8, 8-21, 22-35	0.5	0.15 and 0.5	Seleno methionine	Selenium selenite	N/A	Wheat, soybean
16	(Ibrahim *et al.*, 2019)	Ross	1-38	0.3, 0.4, 0.6	0.3, 0.4, 0.6	Seleno methionine	Sodium selenite	Mash	Corn
17	(Jain *et al.*, 2021)	Cobb	1-21, 22-28, 29-35	0.15 and 0.3	0.3	*Sel-Plex*	Sodium selenite	Mash	Soybean
18	(Kim & Kil, 2020)	Ross 308	7-35	5, 10, 15	5, 10, 15	Yeast	Selenium selenite	Mash	Corn
19	(Li *et al.*, 2018)	N/A	40	0.3	0.3	Selenised yeast and Seleno methionine	Sodium selenite	Mash	Maize
20	(Liao *et al.*, 2012)	N/A	1-42,	0.15 and 0.3	0.15 and 0.3	Selenised yeast	Sodium selenite	Mash	Corn
21	(Mohammadi *et al.*, 2020)	Ross	1-10, 11-24, 25-42	0.3	0.3	Selenised yeast	Sodium selenite	Mash	Corn
22	(Özkan *et al.*, 2007)	Ross	1-7, 8-14, 15-21, 22-28	0.3	0.3	Sel-Plex	Sodium selenite	Mash	Maize
23	(Pardechi *et al.*, 2020)	Ross	0-10, 11-24, 25-42	0.1, 0.2, 0.5	0.1, 0.2, 0.5	Selenium yeast	Sodium selenite	Pellet	Corn
24	(Patel *et al.*, 2021)	Cobb	1-35	0.3	0.3	N/A	N/A	N/A	Maize
25	(Payne & Southern, 2005)	Ross	1-17, 17-35, 35-49	0.3	0.3	Selenium yeast	Sodium selenite	Pellet	Corn
26	(Prakash *et al.*, 2019)	N/A	1-21, 22-42	0.2 and 0.6	0.2, 0.4, 0.6	Selenised yeast	Sodium selenite	Pellet	Maize
27	(Selim *et al.*, 2015)	Arbor Acres	1-10, 11-25, 25-40	0.3 and 0.15	0.3 and 0.15	Se-Yeast and Zinc-L-selenomethionine	Sodium selenite	Mash	Corn
28	(Shabani *et al.*, 2019)	Ross 380	1-42d	0.5, 1.8, and 1.2	0.5, 1.8, and 1.2	Selenomethionine	Nano-selenium	N/A	Corn
29	(Sun *et al.*, 2021)	Cobb	1-42,	0.3	0.3	Selenium yeast	Sodium selenite	N/A	N/A
30	(Sundu *et al.*, 2019)	Cobb	0-42	0.4	0.4	*Sel-Plex*	Sodium selenite	N/A	Corn
31	(Upton et al., 2008)	Arbor Acres	1-42	0.2	0.2	Selenised yeast	Sodium selenite	Mash	Corn
32	(Wang & Xu, 2008)	Ross	1-44.	0.2	0.2	Selenium yeast	Sodium selenite	N/A	Maize
33	(Wang *et al.*, 2021)	Arbor Acres	1-21, 22-42	0.2 and 0.4	0.2 and 0.4	Selenium yeast	Sodium selenite	N/A	Corn
34	(Woods *et al.*, 2021)	Ross	0-21, 22-35	0.465	0.564	Selenised yeast	Sodium selenite	Mash	Wheat
35	(Xu *et al.*, 2022)	ross 308	1-21.	0.3	0.3	Selenium yeast	Na2SeO3	N/A	Corn
36	(Yoon *et al.*, 2007)	Cornish Cross	0-21, 22-42	0.1, 0.2, 0.3	0.1, 0.2, 0.3	Se Yeast A (SelenoSource AF)	Sodium selenite	Mash	Corn
37	(Hossein *et al.*, 2018)	Ross 308	1-14,	0.3	0.3	Availa Se, Selmax, Selenium enriched yeast	Sodium selenite	Mash	Corn

Using predefined criteria such as the type of study (randomized controlled studies), the main experimental parameters (strain, length of the study, selenium concentration, selenium source, feed form, and main feed ingredient) were extracted from each trial and are listed in Table 1.

Statistical Analysis

To measure the difference in the parameters between organic and inorganic Se supplementations, effect size as' Hedges' d' was used. This approach was chosen because of its capacity to estimate the impact of paired treatments and its usefulness in calculating effect size despite variability in sample size, measurement unit, and statistical test results (Sanchez-Meca & Marin-Martinez, 2010). The inorganic group was combined into the experimental group (E), whereas the organic group was pooled into the control group (C). The effect of size (d) was intended as

$$d = \frac{(\dot{x}^E - \dot{x}^C)}{S} J$$

X^E represents the experimental group's mean value, and X^C represents the control group's mean value. Therefore, the experimental parameter is larger in the organic Se group according to the positive impact magnitude and vice versa. J stands for the small sample size adjustment factor, i.e.

$$J = 1 - \frac{3}{(4(N^C + N^E - 2) - 1)}$$

and S stands for the average standard deviation, defined as

$$S = \sqrt{\frac{(N^E - 1)(s^E)^2 + (N^C - 1)((s^C)^2)}{(N^E + N^C - 2)}}$$

Where N^E is the sample size for the experimental set, N^c is the sample size for the control set, S^E is the experimental set's standard deviation, and S^C is the control set's standard deviation. Hedges'd (v_d) variance is defined as

$$V_d = \frac{(N^C + N^E)}{(N^C N^E)} + \frac{d^2}{(2(N^C + N^E))}$$

Cumulative effect size (d++) is formulated as

$$d_{++} = \frac{(\sum_{i=1}^{n} W_i d_1)}{(\sum_{i=1}^{n} W_i)}$$

where w_i is the sampling variance's inverse ($w_i = 1/v_d$). The accuracy of the effect magnitude is given using the 95% confidence interval (CI), or d±(1.96×sd). The sources of equations mentioned above' are Sanchez-Meca & Marin-Martinez (2010). The computed effect size is statistically significant if the confidence interval (CI) does not approach the null effect size. A fail-safe number (Nfs) was produced to identify the publication bias. Nfs > 5N + 10 is considered a reliable meta-analysis model. Using Rosenthal (1979), Nfs was computed. N. Cohen's benchmarks, which serve as the legal judgment bound to determine how large the sample should be, were utilized to determine the smallest sample size from individual investigations. Those benchmarks are 0.8 for large, 0.5 for medium, and 0.2 for small effect size. All the above effect size-related calculations were performed using OpenMEE 2.0.

RESULTS

Profile of the Selected Studies

Because of publication bias, not every meta-analysis result may be considered credible owing to contradictory study findings and small sample sizes. Simply put, the fail-safe number (Nfs) identifies research that should be included in the final firm results. This value indicates the necessary addition of sample research size to reduce the original effect size to a negligible variable. The result can be regarded as the final robust deduction if Nfs > 5N + 10, where N is the study effect size accustomed to deriving the beginning effect size (Rosenthal, 1979). These fail-safe number rules state that mortality, average daily gain (ADG), average daily feed intake (ADFI), and feed conversion ratio (FCR) are resilience parameters. Immune organs were robust, including the bursa, spleen, and thymus. Immunoglobulins, including IgA and IgM, are robust, whereas IgG is a non-robust result parameter. Cholesterol is non-robust in terms of blood. The total protein, triglyceride, and H/L levels were robust. Based on Cohen's benchmarks, the effect sizes of the bursa organ, IgA, IgM, and FCR were categorized as small effects. ADG, ADFI, mortality, and spleen organ were categorized as medium effects, and the thymus had a large effect size. For blood profiles and metabolites, Cholesterol, Total Protein, and Triglycerides were categorized as having a small effect size; meanwhile, H/L had a large effect size.

Statistical Analysis and Heterogeneity Test

There was considerable heterogeneity ($I^2 > 50\%$) among the data from the 38 articles studied; High heterogeneity due to differences in selenium type, Se level, chicken breeds used, and the number of days chickens were supplemented with Se among articles. Therefore, we combine the effect values using a random-effects model. We mined data on 14 parameters of effects of selenium source on immune organs, plasma immunoglobulins, and performance of broilers (Table 2). Meta-analysis of the immune organ showed that there was no statistically significant difference in the effects of selenium source on bursa ($p>0.05$, $I^2 = 98.72\%$); there was a significant variance in the thymus ($p<0.05$, $I^2 = 98.87\%$) and spleen organ ($p<0.05$, $I^2 = 98.39\%$). Regarding plasma immunoglobulins, there was no difference in IgA between organic and inorganic selenium supplementation ($p>0.05$, $I^2 = 97.65\%$). Meanwhile, IgM significantly increased with organic selenium supplementation based on estimated, lower, and upper effect size ($p<0.05$, $I^2 = 97.53\%$). In contrast, IgG levels

Table 2. Meta-analysis of the effect of organic vs. inorganic selenium supplementation on immune organs, immunoglobulin, and the production performance of broilers

No	Response variables	Doc	Unit	N	Estimate	Lower bound	Upper bound	Std error	p-value	τ^2	Q	Het p-value	I^2
1	ADG	31	g	198	-0.62	-0.789	-0.451	0.086	<0.001	1.439	9.936.348	<0.001	97.94
2	ADFI	30	g	194	-0.758	-0.905	-0.610	0.075	<0.001	1,055	8.221.599	<0.001	97.567
3	FCR	29	ratio	174	0.135	0.059	0.211	0.039	<0.001	0.209	1.620.715	<0.001	89.264
4	Mortality	13	%	35	0.290	0.104	0.476	0.095	0.002	0.282	746.719	<0.001	95.447
5	Bursa	10	%	36	-0.405	-0.957	0.147	0.282	0.15	2.888	2.955.754	<0.001	98.782
6	Thymus	10	%	36	-1.996	-2.603	-1.389	0.310	<0.001	3.000	3.182.648	<0.001	98.869
7	Spleen	10	%	36	-0.527	-0.991	-0.066	0.236	0.026	2.020	2.244.678	<0.001	98.396
8	IgA	6	mg/mL	22	-0.482	-0.991	0.027	0.260	0.063	1.417	934.336	<0.001	97.645
9	IgM	8	mg/mL	22	-3.481	-4.113	-2.850	0.322	<0.001	2.164	891.434	<0.001	97.532
10	IgG	10	mg/mL	41	0.650	0.274	1.025	0.191	<0.001	1.450	1709.71	<0.001	97.602
11	Total protein	5	g/dL	17	-0.549	-1.044	-0.055	0.252	0.03	0.832	72.232	<0.001	77.849
12	Cholesterol	2	mg/dL	11	-0.158	-1.140	0.824	0.501	0.752	2.437	93.852	<0.001	89.345
13	Triglyceride	2	mg/dL	11	0.918	0.329	1.506	0.300	0.002	0.707	36.524	<0.001	72.621
14	H/L ratio	3	ratio	22	1.995	1.510	2.480	0.247	<0.001	1.265	457.108	<0.001	95.406

Note: Doc= document, N= number of data, Std error= standard error, τ2= the variance of the effect size parameters across the population of studies, Q= the weighted sum of squared deviations, Het p-Value= p-value for heterogeneity, I2= heterogeneity level between studies, ADG= average daily gain, ADFI= Average Daily Feed Intake, FCR= Feed Conversion Ratio, H/L= heterophile to lymphocyte ratio.

were significantly lower with organic than inorganic selenium ($p<0.01$, I^2 = 97.64%). Supplementation with organic selenium was significantly higher in ADG ($p<0.01$, I^2 = 97.94%) and ADFI ($p<0.01$, I^2 = 97.56%). In addition, the FCR of organic selenium supplementation was significantly more enhanced than inorganic selenium ($p<0.01$, I^2 = 89.26%). Furthermore, the average mortality of broiler-fed organic Se was significantly lower than that of broiler-fed inorganic Se ($p<0.01$, I^2 = 95.45%). The average total blood protein of broilers fed organic selenium was significantly higher than those fed inorganic Se ($p<0.01$, I^2 = 77.89%). There was no statistically significant difference in the effects of selenium source on cholesterol ($p>0.01$, I^2 = 89.345%). Average triglyceride concentrations of broilers fed organic Se is significantly lower than those of broilers fed inorganic selenium ($p<0.01$, I^2 = 72.62%). Average heterophile to lymphocyte ratios (H/L) of broilers fed organic Se was significantly lower than those of broiler fed inorganic selenium ($p<0.01$, I^2 = 95.40%). Figure 2 shows a forest plot summa¬rizing effects of organic and inorganic selenium sources on broiler performance, while Figures 3-5 show the effects on the immune organ, immunoglobulin, and blood profile of broilers, respectively.

DISCUSSION

The Performance of Broilers

Selenium is a crucial trace element that serves as a key building block in selenoproteins. Numerous studies have demonstrated that Se is necessary for the development of selenoenzymes such as type I iodothyronine deiodinase and selenoprotein P, both of which are important for the conveyance of Se and the construction of thyroid hormones (Zhan *et al.*, 2014). Chickens supplemented with Se showed improved growth performance, possibly due to the improved energy and protein consumption (Saleh, 2014).

However, there was a difference in the growth performance between organic and inorganic Se supplementation. Not all researchers state that organic selenium provides better growth performance than inorganic Se. The supplemental Selenium Yeast in organic trace minerals can support the highest growth of broiler chicks (Arnaut *et al.*, 2021; Wang *et al.*, 2021; Bakhshalinejad *et al.*, 2018). In addition, Xu *et al.* (2022) reported that a new source of selenium-enriched plants with high levels of organic Se is an acceptable Se source for broilers. In contrast, the average growth performance of broilers supplemented with organic selenium is lower than those supplemented with inorganic selenium.

According to Li *et al.* (2018), organic Se and Nano-Se supplementation did not likely affect the growth performance of broiler chickens compared to inorganic Se. Furthermore, according to Payne & Southern (2005), organic Se enhances tissue Se concentration without affecting growth efficiency. The findings of this meta-analysis demonstrate that broilers fed organic Se performed better than those fed inorganic Se. Based on the analysis of ADG and Feed Intake, it was found that there were greater levels of organic selenium compared to the overall findings. Additionally, organic Se had greater FCR enhancement and lower mortality than inorganic Se.

Organic selenium has greater bioavailability and tissue retention than inorganic selenium. According to Briens *et al.* (2013), broiler hens supplemented with organic selenium at 0.3 g/kg had greater apparent digestibility than those supplemented with inorganic selenium. According to previous research, tissue accumulation is a sensitive indicator of mineral uptake. Dietary organic selenium and nano-selenium treatments may increase the concentrations of selenium in broiler chicken serum, liver, and breast muscles relative to inorganic selenium (Kim & Kill, 2020), most likely leading to an increase in GSH-Px activity.

Additionally, lipid and protein peroxides metabolic byproducts, MDA and carbonyl, are frequently used as

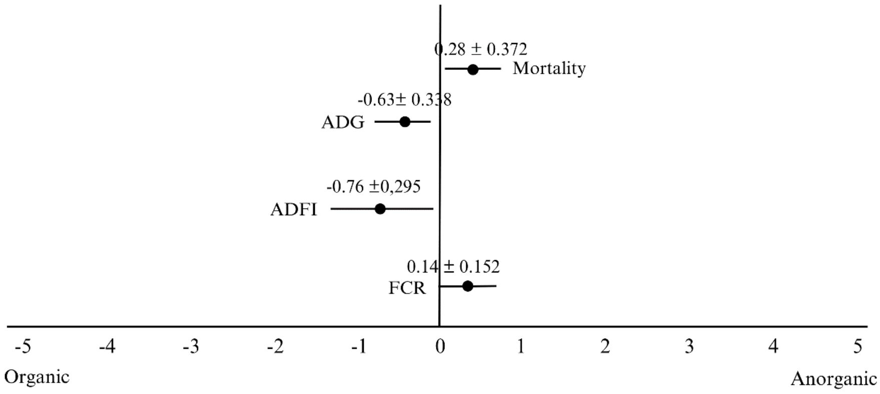

Figure 2. Forest plot of organic and inorganic Se supplement feeds on performance of broilers. ADG= average daily gain; ADFI= average daily feed intake; FCR= feed conversion ratio.

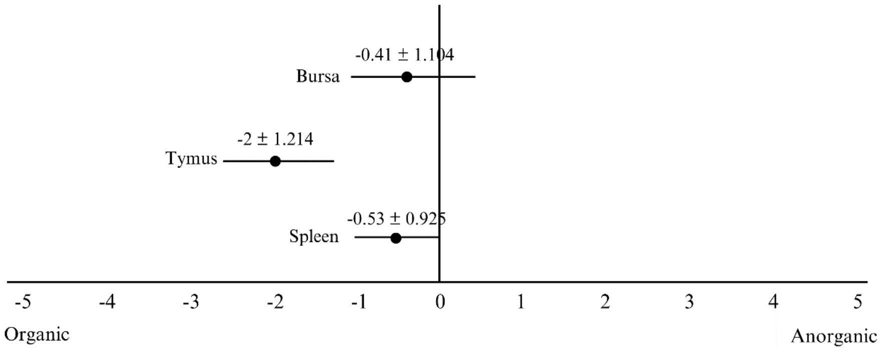

Figure 3. Forest plot of organic and inorganic Se supplement feeds on the immune organ of broilers.

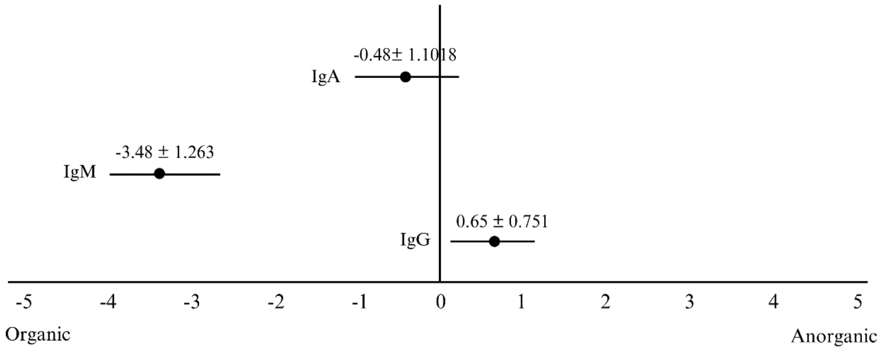

Figure 4. Forest plot of organic and inorganic Se supplement feeds on immunoglobulin of broilers.

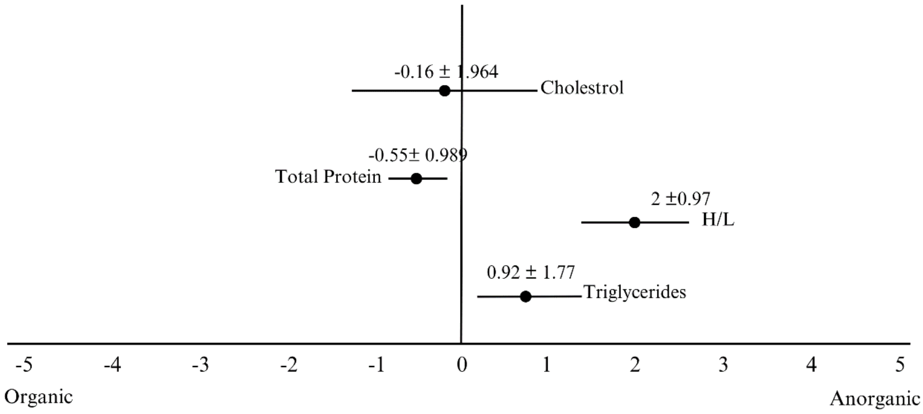

Figure 5. Forest plot of organic and inorganic Se supplement feeds on blood profile of broilers.

indicators of oxidative stress. A lack of selenium may increase the MDA levels in chicken immunological organs (Yang *et al.,* 2012). Furthermore, near the conclusion of fattening, dietary organic selenium supplementation increases protein oxidation in the kidney and lipid peroxidation in the kidney and small intestine (Jasna *et al.,* 2013). Se-yeast, an organic form of selenium given to broiler diets, can help mitigate some of the detrimental effects of cadmium toxicity while maintaining improved growth performance (Al-Waeli *et al.,* 2013). However, it can only partially counterbalance all of these.

In contrast to sodium selenite groups, selenium organic yeast groups had significantly higher serum total superoxide dismutase (T-SOD), glutathione peroxidase (GSH-Px), hydroxyl radical (OH), and total antioxidant capacity (T-AOC) activity. In contrast, the sodium selenite groups had significantly lower MDA contents. This study showed that while various selenium sources had a considerable impact on broiler oxidation resistance, they had no discernible impact on the production performance of broilers (Chen *et al.,* 2014).

Organic selenium has a high absorption and utilization rate, and is most found as selenium yeast or selenomethionine. Like amino acids, it is actively absorbed by the body. The small intestine of animals absorbs selenomethionine using a neutral amino acid transport mechanism. Methionine has the same mechanism of amino acid transport (Gružauskas *et al.,* 2014).

Effect of Selenium Source on the Immune of Broilers

The innate and acquired immune systems are influenced by selenium, which is crucial for maximizing the immunological response. Se deficiency-related thymus and dietary deficits cause the lesion of Fabricius bursa. Previous studies have demonstrated that dietary Se supplementation may enhance organ and humoral immunity in broiler chickens. According to Wang *et al*. (2016), selenium deprivation can lead to histological alterations in various tissues, including immunological organs such as the bursa, thymus, and spleen, reducing the relative weight. Immune response measurements and lymphoid organ weights revealed distinct individual effects of the Se source.

Liao *et al*. (2012) reported that broilers treated with DL-Se-Met as an organic source had a considerably higher thymus index than those treated with SS as an inorganic source. These effects result in the activation of an immunological response. While broilers were raised under thermos neutral or heat stress settings, Dukare *et al.* (2020) showed that Se supplementation had no appreciable impact on the mass of lymphoid organs. Da Silva *et al.* (2010) noted that the relative weights of the broilers' bursa of Fabricius and spleen were not significantly different due to the varied Se sources. Furthermore, according to Pardechi *et al.* (2020), while the Se source influenced the enhanced thymus yield, the improved spleen yield did not differ between Se sources.

The results of many studies evaluating the impact of selenium sources on immunological organs need to be consistent. Overall, the meta-analysis demonstrated that the spleen and thymus of hens fed organic selenium had heavier weights than those fed inorganic selenium. Bursa, meanwhile, does not discern between selenium that is organic and selenium that is not. Broilers Se deposition and antioxidant capacity are increased by the enhanced bioavailability of DL-Se-Met as organic Se (Wang *et al.,* 2016). Moreover, Bakhshalinejad *et al*. (2018) suggested that supplementing Se with organic sources would strengthen the humoral and cellular immune systems. Compared with dietary selenium supplementation with sodium selenite as an inorganic source, dietary selenium supplementation with nano selenium as an organic source may improve humoral immune responses.

Wang *et al.* (2016) show that selenium sources substantially affected serum IgG, IgA, and IgM contents, with DL-Se-Met as organic Se showing the greatest value. This meta-analysis showed that supplementation with organic versus inorganic selenium did not affect IgA levels. In addition, supplementation with organic selenium significantly increased the IgM levels. Compared with inorganic selenium, IgG levels significantly decreased in the presence of organic selenium. By increasing the supplemental concentration of selenium and employing organic sources of selenium rather than SS, immunoglobulin G (IgG) titers and hypersensitivity improved (Bakhshalinejad *et al.,* 2018). As reported by Cai *et al.* (2012), diets containing 0.3-0.5 mg/kg of organic nano-Se produced the largest improvement in chicken humoral immunity. Supplemental Se may improve serum IgG and IgM levels in broilers. Non-stressed birds that received organic selenium and nano-selenium had the highest blood IgG and IgM concentrations (Boostani *et al.,* 2015).

Effect of Selenium Source on Blood Biochemical

A meta-analysis showed that Se supplementation in organic versus inorganic diets did not affect total cholesterol in the blood of broiler chickens. However, the triglyceride content decreased among the groups supplemented with organic matter in broiler chickens. Triglycerides produced in the liver are the product of *de novo* lipogenesis (Alves & Cohen, 2017). In addition, Hada *et al.* (2013) described lower levels of triglycerides in broiler chickens fed diets enhanced with organic Se. Furthermore, supplementation with organic Se increased the availability of Se by enhancing tissue Se concentration. That supplementation is more proficiently absorbed and reserved in tissues than inorganic Se (Yoon *et al.,* 2007). Se deficiency is important for regulating the mechanism of total cholesterol levels and triglycerides in plasma by regulating the LDL receptor (Zhang *et al.,* 2018).

The total protein levels in the serum were unaffected by selenium supplementation, either organic or inorganic. However, organic selenium supplementation increased within the groups. Similarly, Yang *et al*. (2012) observed that broiler chicks added with 0.3 ppm organic selenium for 42 days showed no significant difference in serum globulin levels associated with the treatment control group. Contrary to our meta-analysis findings, Mohapatra *et al.* (2014) stated that layer chicks supplemented 0.3 ppm nano Se significantly increased total protein for several weeks.

The heterophile to lymphocyte ratio (H/L) is generally considered an independent and robust indicator of stress levels in broilers. The higher the H/L ratio, the higher the stress level experienced. The addition of organic selenium affected H/L. Selenium is an antioxidant that can reduce or even eliminate free radicals, marked by a decrease in H/L; chickens are healthier and more stress-resistant. The H/L ratio may signify a predisposition to resistance to contamination by damage through heterophiles rather than an infectious disease through lymphocytes (Minias *et al.,* 2017). The blood H/L ratio is extensively studied for selecting birds that are resistant to environmental stresses because it reflects the immune system's status.

CONCLUSION

Based on a meta-analysis study, organic sources of Se may increase the deposition of Se in performance (ADG, FI, FCR, and mortality rate). Organic selenium also effectively improves immune organs, blood total protein, IgA, and IgM levels. Furthermore, organic selenium may lower triglyceride and H/L ratio. However, organic and inorganic selenium do not affect cholesterol and IgG. Regarding organic selenium, an appropriate technique to increase the feed efficiency, immunity, and performance of broilers may have a promising future as a feed additive for the poultry industry sector.

CONFLICT INTEREST

Anuraga Jayanegara serves as an editor of the Tropical Animal Science Journal but has no role in the decision to publish this article. The authors also state no conflict of interest.

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