



SYSTEMATIC REVIEW

The effects of dietary seaweed inclusion on growth performance of broiler chickens: a systematic review and meta-analysis [version 1; peer review: 1 approved, 2 approved with reservations]

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Abstract

Background: There has been great interest in the use of seaweed as a functional feed ingredient for poultry in the last decade. This study aimed to assess the effects of dietary seaweed inclusion on growth performance of broiler chickens by using a systematic review and meta-analysis approach.

Methods: A systematic search of published research articles related to seaweed, broiler chickens, and growth performance was conducted using three online databases (Scopus, PubMed, and SciELO). Mean values, standard deviation, and sample size were extracted from each eligible study. The estimated effect size was then quantified using Hedges' *g* with a 95% confidence interval (CI). Data were pooled using a fixed-effect model due to the absence of heterogeneity after being pre-checked using the I^2 statistic.

Results: A total of six studies (nine comparisons) involving 2,257 broiler chickens were accommodated in this study. The seaweed type consisted of seaweed blend, *Laminaria japonica*, *Undaria pinnatifida*, *Hizikia fusiformis*, and *Ulva lactuca*. The inclusion dose ranged from 2 to 30 g/kg, while the intervention duration ranged from 21 to 42 days. No substantial heterogeneity among studies ($I^2 = 0.00\%$) was found for feed intake, body weight gain, and feed conversion ratio. Dietary seaweed had no significant effect on feed intake (Hedges' *g* = 0.19; 95% CI = -0.22 to 0.60; $P = 0.280$). However, broiler chickens fed dietary seaweed had superior body weight gain (Hedges' *g* = 0.64; 95% CI = 0.22 to 1.06; $P = 0.000$) and preferable feed conversion ratio (Hedges' *g* = -0.53; 95% CI = -0.95 to -0.11; $P = 0.004$).

Conclusions: The current investigation highlights that dietary seaweed had growth-promoting potency for broiler chickens.

Open Peer Review

Reviewer Status ? ✓ ?

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	1	2	3
version 1	?	✓	?
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Any reports and responses or comments on the article can be found at the end of the article.

However, more research on this issue is still required to build more comprehensive evidence.

Keywords

alginate, body weight gain, fucoidan, fucoxanthin, functional feed, laminarin, macroalgae, poultry

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Introduction

There has been great interest in the use of seaweed as a functional feed ingredient for poultry in the last decade. The primary functional compounds in seaweed are polysaccharides, peptides, fatty acids, phlorotannins, and carotenoids¹⁻³. These compounds have antimicrobial, antioxidant, and immunomodulatory properties⁴⁻⁷, which are essential to support production performance.

Several reviews have compiled studies regarding the effect of dietary seaweed inclusion on poultry performance⁸⁻¹³. However, those reviews were based on a narrative approach, which mostly led to an inconclusive epilogue due to the contradictory results among studies. The use of systematic review and meta-analysis has become popular in animal science¹⁴⁻¹⁸. This methodology can integrate and determine the overall effect of interventions from several studies to provide more accurate insight than the narrative review. Therefore, this study aimed to assess the effect of dietary seaweed inclusion on the growth performance of broiler chickens using a systematic review and meta-analysis approach.

Methods

This study was reported based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines¹⁹. The PRISMA checklist is presented in *Reporting guidelines*²⁰.

Eligibility criteria

Research articles published in peer-reviewed journals between the years of 2000 to 2020 and written in English were eligible. Additionally, eligible studies also should fulfill the participants, interventions, comparisons, outcomes, and study design (PICOS) criteria given in [Table 1](#).

Searching strategy

The online search was conducted using three databases, namely Scopus, PubMed, and SciELO, with the queries in [Table 2](#). The final search was on 25 June 2020. The references from the included studies were also screened to find additional eligible studies.

Study selection

Firstly, the duplicate reports were removed from the database in Microsoft Excel for Microsoft 365 software. After that, the title and abstract were examined. Irrelevant studies, non-English reports, and review articles were then excluded from the list. The full text was further evaluated according to the eligibility criteria.

Data collection

Mean values, standard deviations, and sample sizes were extracted from each included study. The target variables in this study were feed intake (FI), body weight gain (BWG), and feed conversion ratio (FCR). When a study used the standard error of means as a variance measure, it was converted into standard deviation²¹. In the case of more than one seaweed type used in a study, each treatment was coded individually. On the other hand, the treatment was pooled when a study used more than one dose of the same seaweed type²². None of the authors were contacted for further clarification.

Data analysis

Data analysis was performed using Meta-Essential version 1.5²³. The estimated effect size (the difference between seaweed intervention and control) was quantified using Hedges' *g* with a 95% confidence interval (CI)²⁴. Data were pooled using a fixed-effect model due to the absence of heterogeneity after being pre-checked using the I^2 statistic²⁵. A significant effect was declared when the overall estimated effect size had $P < 0.05$. Publication bias was not evaluated because the number of the included studies was fewer than 10²⁶.

Results

The PRISMA flow diagram is shown in [Figure 1](#). The search using three online databases identified 47 records. Of these, five studies met the eligibility criteria. Additionally, one study from reference screening also found to be eligible. Therefore, a total of six studies, with nine comparisons were included in the synthesis.

The details of the included studies are shown in [Table 3](#). A total of 2,257 broiler chickens were involved in this study.

Table 1. PICOS criteria.

Items	Criteria
Participants	Broiler chickens
Interventions	Inclusion of dietary seaweed either as such or fermented product
Comparisons	Diet without seaweed inclusion (control)
Outcomes	Feed intake, body weight gain, and feed conversion ratio
Study design	Controlled trials

Table 2. The search query in Scopus, PubMed, and SciELO databases.

Database	Search query
Scopus	(TITLE-ABS-KEY (seaweed OR macroalgae) AND TITLE-ABS-KEY (growth OR performance) AND TITLE-ABS-KEY (broiler OR chicken))
PubMed	((seaweed[Title/Abstract] OR macroalgae[Title/Abstract]) AND (growth[Title/Abstract] OR performance[Title/Abstract])) AND (broiler[Title/Abstract] OR chicken[Title/Abstract])
SciELO	(ab:(seaweed OR macroalgae)) AND (ab:(growth OR performance)) AND (ab:(broiler OR chicken))

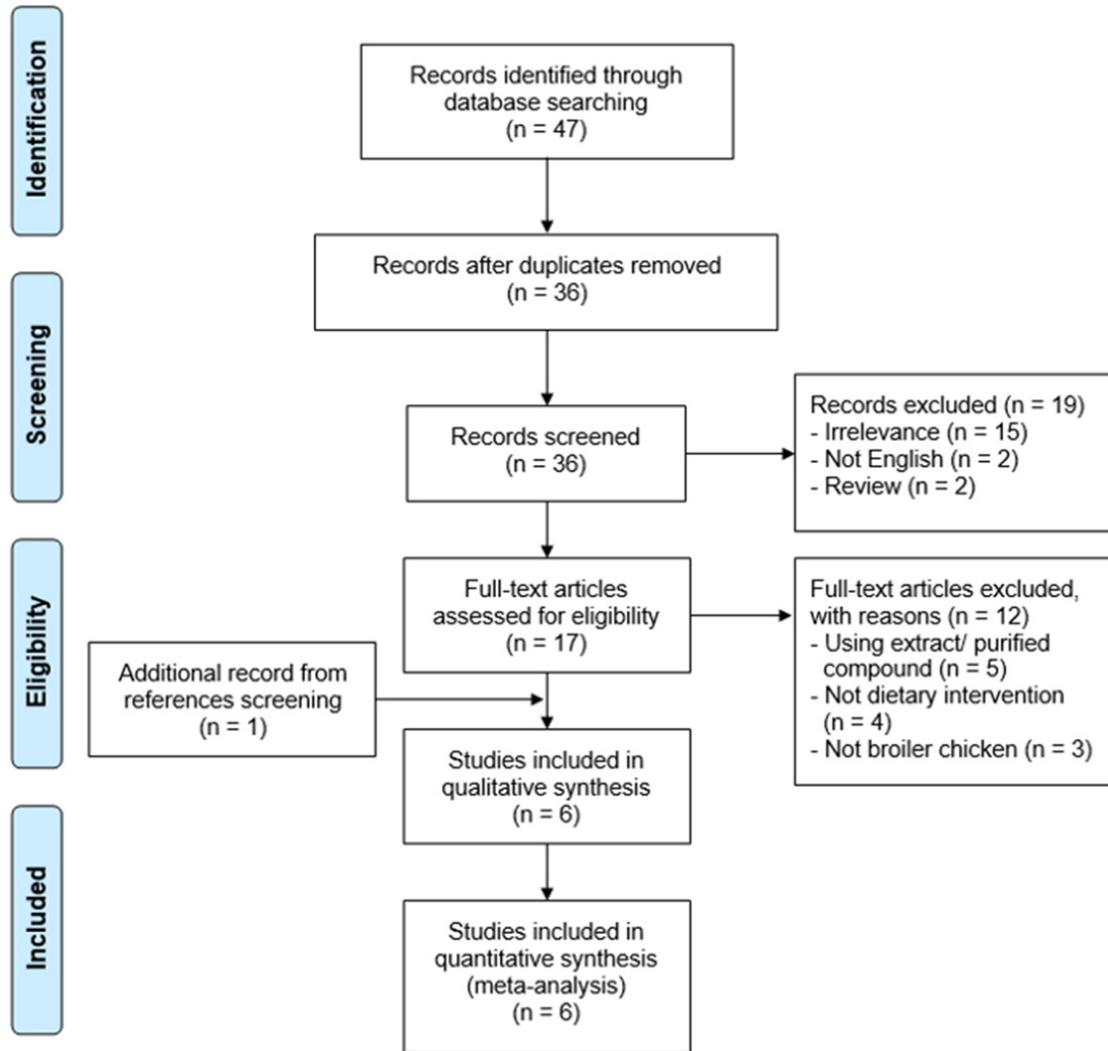


Figure 1. PRISMA flow diagram.

Table 3. Details of the included studies.

Study name	N	Strain	Sex	Diet type	Seaweed type	Dose (g/kg)	Period (d)
Mohammadigheisar <i>et al.</i> ²⁷	864	Ross	Male	Corn-SBM	Blend of brown, green, and red seaweed	5, 10, and 20	1-42
Bai <i>et al.</i> ²⁸	144	Arbor Acres	Mixed	Corn-SBM	<i>L. japonica</i>	10	1-42
Shi <i>et al.</i> ²⁹	384	Ross	Mixed	Corn-SBM	Fermented <i>U. pinnatifida</i>	2	1-35
Ahmed <i>et al.</i> ³⁰	70	Ross	Mixed	Corn-SBM	Fermented <i>L. japonica</i>	5	1-35
Choi <i>et al.</i> ³¹	750	Ross	Male	Corn-SBM	<i>U. pinnatifida</i> (as such and fermented) and <i>H. fusiformis</i> (as such and fermented)	5	1-35
Abudabos <i>et al.</i> ³²	45	Ross	Male	Corn-SBM	<i>U. lactuca</i>	10 and 30	12-33

n: number of broiler chickens, SBM: soybean meal.

The seaweed type used included seaweed blend²⁷, *Laminaria japonica*^{28,30}, *Undaria pinnatifida*^{29,31}, *Hizikia fusiformis*³¹, and *Ulva lactuca*³². The inclusion dose ranged from 2 to 30 g/kg,

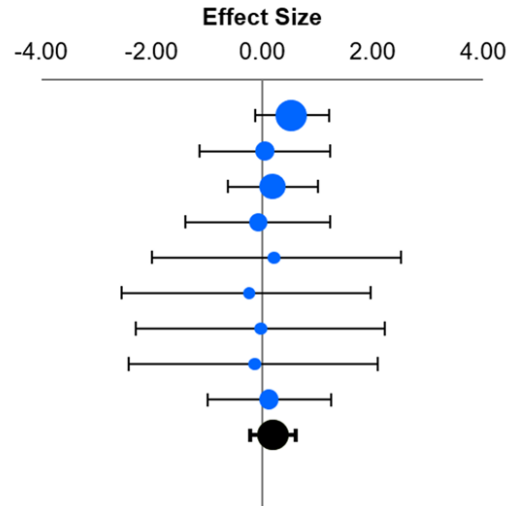
while the intervention duration ranged from 21 to 42 days. The extracted data of target variables is presented as *Extended data*³³.

As shown in Figure 2, no substantial heterogeneity was found for any variables ($I^2 = 0.00\%$). Dietary seaweed had no significant

effect ($P > 0.05$) on FI. However, this intervention significantly improves ($P < 0.05$) the BWG and FCR of broiler chickens. The

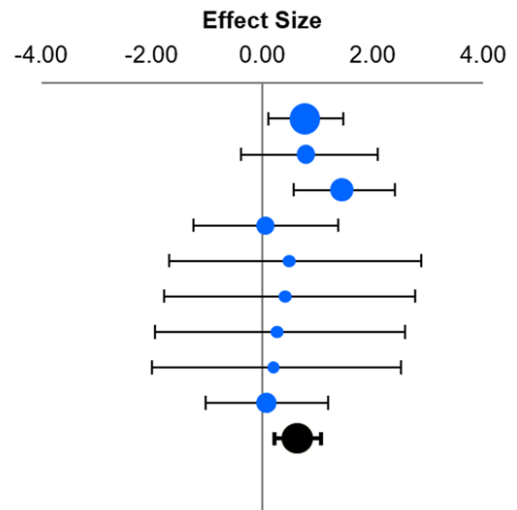
(FI)

Study name	Hedges' g (95% CI)
Mohammadigheisar <i>et al.</i> ²⁷	0.53 (-0.13 to 1.21)
Bai <i>et al.</i> ²⁹	0.05 (-1.14 to 1.24)
Shi <i>et al.</i> ³¹	0.19 (-0.63 to 1.01)
Ahmed <i>et al.</i> ²⁸	-0.08 (-1.40 to 1.23)
Choi <i>et al.</i> ³⁰⁻¹	0.21 (-2.00 to 2.52)
Choi <i>et al.</i> ³⁰⁻²	-0.24 (-2.55 to 1.96)
Choi <i>et al.</i> ³⁰⁻³	-0.03 (-2.29 to 2.22)
Choi <i>et al.</i> ³⁰⁻⁴	-0.14 (-2.42 to 2.09)
Abudabos <i>et al.</i> ³²	0.12 (-0.98 to 1.25)
Overall ($P = 0.280$)	0.19 (-0.22 to 0.60)
Heterogeneity ($I^2 = 0.00\%$)	



(BWG)

Study name	Hedges' g (95% CI)
Mohammadigheisar <i>et al.</i> ²⁷	0.78 (0.11 to 1.47)
Bai <i>et al.</i> ²⁹	0.79 (-0.38 to 2.10)
Shi <i>et al.</i> ³¹	1.44 (0.56 to 2.41)
Ahmed <i>et al.</i> ²⁸	0.06 (-1.25 to 1.38)
Choi <i>et al.</i> ³⁰⁻¹	0.49 (-1.68 to 2.89)
Choi <i>et al.</i> ³⁰⁻²	0.41 (-1.77 to 2.78)
Choi <i>et al.</i> ³⁰⁻³	0.26 (-1.93 to 2.59)
Choi <i>et al.</i> ³⁰⁻⁴	0.21 (-2.00 to 2.51)
Abudabos <i>et al.</i> ³²	0.08 (-1.03 to 1.19)
Overall ($P = 0.000$)	0.64 (0.22 to 1.06)
Heterogeneity ($I^2 = 0.00\%$)	



(FCR)

Study name	Hedges' g (95% CI)
Mohammadigheisar <i>et al.</i> ²⁷	-0.37 (-1.04 to 0.29)
Bai <i>et al.</i> ²⁹	-0.08 (-1.27 to 1.11)
Shi <i>et al.</i> ³¹	-1.17 (-2.10 to -0.32)
Ahmed <i>et al.</i> ²⁸	-0.13 (-1.46 to 1.17)
Choi <i>et al.</i> ³⁰⁻¹	-0.94 (-3.53 to 1.21)
Choi <i>et al.</i> ³⁰⁻²	-1.51 (-4.41 to 0.68)
Choi <i>et al.</i> ³⁰⁻³	-0.94 (-3.53 to 1.21)
Choi <i>et al.</i> ³⁰⁻⁴	-0.94 (-3.53 to 1.21)
Abudabos <i>et al.</i> ³²	0.01 (-1.11 to 1.12)
Overall ($P = 0.004$)	-0.53 (-0.95 to -0.11)
Heterogeneity ($I^2 = 0.00\%$)	

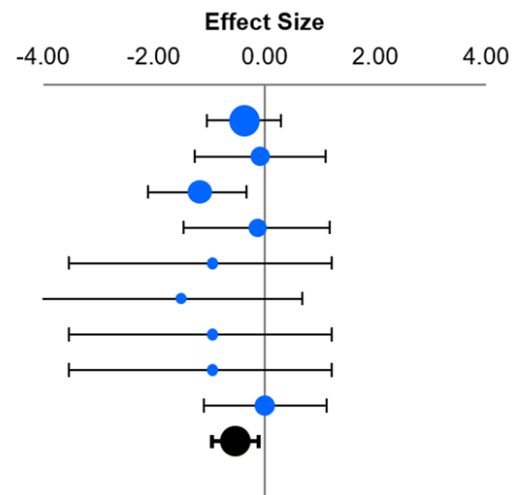


Figure 2. Forest plot showing the effect of dietary seaweed inclusion on growth performance of broiler chicken. FI: feed intake, BWG: body weight gain, FCR: feed conversion ratio, CI: confidence interval.

overall estimated effect size values for BWG and FCR were 0.64 and -0.53, respectively, which were equivalent to the raw mean difference of 77.24 g and -0.07, respectively.

Discussion

In this study, the use of dietary seaweed had a beneficial impact on BWG and FCR of broiler chickens. According to Cohen³⁴, the overall estimated effect size of BWG and FCR in the present study was categorized into the medium (0.5) to large (0.8) standardized effect size. In agreement with this finding, other studies also showed that the use of seaweed could improve production performance in laying hens^{35–37} and geese³⁸. Seaweed contained numerous unique bioactive substances such as alginate, ulvan, laminarin, fucoidan, and fucoxanthin. Those compounds could inhibit the colonization of pathogenic bacteria (*Escherichia coli* and *Salmonella* Enteritidis), promote the growth of beneficial gut microbes (lactic acid bacteria), improve small intestinal architecture, antioxidant status, and immune response^{39–43}. Together, those mechanisms could ultimately improve the growth performance of broiler chickens.

Nevertheless, this finding is accompanied by the limited number of included studies. It is possible that not all relevant studies were captured by the searching strategies. For those reasons, the current results should be elucidated with caution. Moreover, due to the enormous diversity of seaweed in nature (around twenty thousand species)⁴⁴, future studies regarding seaweed intervention in broiler chickens are still open and strongly encouraged to provide a robust body of knowledge.

Conclusions

The current systematic review and meta-analysis highlight that dietary seaweed had no adverse effect on FI. Instead, they

could improve BWG and FCR of broiler chickens. However, more research on this issue is still required to build more comprehensive evidence.

Data availability

Underlying data

All data underlying the results are available as part of the article and no additional source data are required.

Extended data

Figshare: Extended data for ‘The effects of dietary seaweed inclusion on growth performance of broiler chickens: a systematic review and meta-analysis’. <https://doi.org/10.6084/m9.figshare.12721454.v1>³³.

This project contains the following extended data in DOC format:

- Extended data 1 – extracted data of feed intake
- Extended data 2 – extracted data of body weight gain
- Extended data 3 – extracted data of feed conversion ratio
- Extended data 4 – list of included studies

Reporting guidelines

Figshare: PRISMA checklist for ‘The effect of dietary seaweed inclusion on growth performance of broiler chickens: a systematic review and meta-analysis’. <https://doi.org/10.6084/m9.figshare.12721118.v1>²⁰.

Data are available under the terms of the [Creative Commons Zero “No rights reserved” data waiver](#) (CC0 1.0 Public domain dedication).

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Version 1

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? **Henny Akit** 

Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia, Serdang, Malaysia

Some of the keywords such as alginate, fucoidan, fucoxanthin and laminarin were not mentioned in the abstract and introduction. You may consider excluding these keywords.

The rationale for the systematic review was to provide a more accurate insight than the narrative review. The authors may add on how this insight could benefit researchers or related feed industries for seaweed application.

In discussion, the authors explained the possible mechanisms that led to improved broiler performance. I suggest that the authors include the year of broiler studies used. In addition, I think more points should be included emphasising how the results could benefit other researchers, for example, suggestions on the inclusion rate of seaweed, etc. Since this is a review paper, I feel that the discussion should be more extensive.

Are the rationale for, and objectives of, the Systematic Review clearly stated?

Yes

Are sufficient details of the methods and analysis provided to allow replication by others?

Yes

Is the statistical analysis and its interpretation appropriate?

I cannot comment. A qualified statistician is required.

Are the conclusions drawn adequately supported by the results presented in the review?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: I am an expert in broiler nutrition currently doing research in alternative

protein ingredients in broilers. However, i am not an expert in the statistic part.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 05 November 2020

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Mary Kivali Ambula

Department of Animal Sciences, Egerton University, Njoro, Kenya

- The keywords listed are not mentioned much in the text which might make searching for the article a little difficult.
- Clearly state if seaweed was used as a substitute for another ingredient or not.
- Conclusions may not fully be drawn from the results since information on the type of basic diets is not provided e.g were they typical corn-soybean broiler diets or what?
- The effect of seaweed on broilers may also depend on other feed ingredients used (alfalfa meal, corn gluten meal etc). Authors can clarify this to the reader to inform further research.

Are the rationale for, and objectives of, the Systematic Review clearly stated?

Yes

Are sufficient details of the methods and analysis provided to allow replication by others?

Yes

Is the statistical analysis and its interpretation appropriate?

Yes

Are the conclusions drawn adequately supported by the results presented in the review?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Poultry nutritionist with interest in use of non-conventional feed ingredients in chicken diets

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 28 September 2020

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Samadi Samadi 

Animal Husbandry Department, The Faculty of Agriculture, Syiah Kuala University, Banda Aceh, Indonesia

This manuscript aims to assess the effects of dietary seaweed inclusion on the growth performance of broiler chickens by using a systematic review and meta-analysis approach. The type of work is suitable for publication in the journal. However, the manuscript needs some correction before it can be fully accepted. The comments are as follows.

- Introduction was too short and needs more explanation from the previous study (state of arts) relating to seaweed on broiler production.
- From PRISMA flow diagram, there were a lot of studies excluded for data analysis, out of 47 studies only 6 studies were continued for quantitative analysis. Is the data sufficient to make conclusions for this meta-analysis study?
- There was a wide range of seaweed inclusion in broiler performance from the data (2-30 g/kg). Any explanation?
- Discussion of this study was too short, it is better to extend more explanation regarding to the findings based on this study.
- Based on the literature, are there any different bioactive compound from various seaweed in nature (around twenty thousand species) #44
- Conclusion of this study was too general, are there any recommendations for seaweed inclusion in the broiler diet based on the meta-analysis data, since the seaweed concentration from the literature of this study was too wide-ranging from 2-30 g/kg diet.

I suggest it is better also to add one more table informing about FI, BWG, and FCR from 6 studies to get information for the readers about the broiler performance data.

Are the rationale for, and objectives of, the Systematic Review clearly stated?

Partly

Are sufficient details of the methods and analysis provided to allow replication by others?

Partly

Is the statistical analysis and its interpretation appropriate?

Yes

Are the conclusions drawn adequately supported by the results presented in the review?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Animal Nutrition

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

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