A META-ANALYSIS OF DIETARY TURMERIC (*CURCUMA LONGA* L.) SUPPLEMENTATION ON THE ENHANCEMENT OF BROILER CHICKEN PRODUCTIVITY

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Abstract. The increased awareness of consumers on the health benefits of organically produced animals has triggered interest on the use of phytogenics to boost broiler chicken productivity. Therefore, this meta-analysis aimed to determine the effect of turmeric (*Curcuma* longa L.) supplementation on feed intake, feed conversion efficiency (FCE) and body weight gain (BWG) in broiler chickens. Data from 31 studies that met the selection criteria for the meta-analysis were pooled using a random-effects model and expressed as a natural log of the response ratio (In*R*) at 95% confidence interval (CI) for each investigation. Results indicated that broiler chickens fed treatment diets had better FCE and BWG than controls. Furthermore, broiler chickens fed diets supplemented with turmeric at 5–10 g/kg consumed less feed and exhibit better FCE (In*R* = -0.06 g/bird, 95% CI: -0.07 to -0.04) and BWG (In*R* = 0.05 g/bird, 95% CI: 0.03 to 0.08) in comparison to the controls. Meta-regression results showed that studied moderators (broiler strain, dosage and supplementation duration) had an impact on the results of the meta-analysis. It was concluded that turmeric supplementation increased broiler chicken performance, and could be used as a performance enhancing agent in the broiler chicken industry.

Keywords: *phytogenics, poultry, feed intake, feed conversion efficiency, body weight gain, data synthesis*

Introduction

Broiler chickens play a vital role in improving food security, especially in developing countries. However, because of the direct competition for grains between animals and humans, the cost of rearing broiler chickens for optimal productivity has escalated. As a result, the contribution of broiler chickens to food security in developing nations is on the decline. This is traced to the exorbitant price of broiler meat, which can be propelled by the high cost of chicken feed, and this has prompted animal nutritionists to use natural growth-promoting agents to mitigate this challenge. A large body of evidence has demonstrated the ability of some tropical medicinal plants to enhance animal productivity (Amad et al., 2011; Ogbuewu et al., 2020). The anti-stress, antioxidant, anti-inflammatory and antimicrobial properties of turmeric (*Curcuma* longa L), one of such medicinal plants have been reported (Gul and Bakht, 2015; Panahi et al., 2015). Turmeric is low in nutrients but high in essential oils (Ikpeama et al., 2014; Youssef et al., 2014) and its addition in broiler diets have been claimed to boost chicken performance and nutrient utilization (Gobiraju et al., 2017; Guil-Guerrero et al., 2017). However, the effect of turmeric on broiler chickens is inconsistent and therefore will not allow for a generalized conclusion on the effect of turmeric in broiler chicken performance. Several attempts made to ascertain the factors that were responsible for

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the inconsistent results among studies that investigated the impact of dietary turmeric supplementation in broiler chicken performance were not successful (Tajodini et al., 2015; Gobiraju et al., 2017; Guil-Guerrero et al., 2017). This may be due to fact that these studies used a qualitative method to pool and synthesize evidence across several published primary studies, which usually is subjective and easily biased. Meta-analysis is one of the methods used to resolve inconsistent results studies addressing the research objective. It uses a quantitative approach to pool and synthesizes evidence across several individual studies with conflicting findings. It also increases the chances of detecting the true effect of an intervention that ordinarily cannot be detected by the individual studies. Therefore, the objective of this study was to determine the meta-analysis effect of turmeric supplementation on the productivity of broiler chickens.

Materials and methods

Search protocols

The search on Scopus, Google Scholar, Google engine and AGORA databases was focused on the effect of diets with or without turmeric supplementation on the growth performance of broiler chickens. The search was done using Boolean operators ("and" / "or") and combinations of search words such as turmeric, growth performance, average daily gain, weight gain, body weight gain, feed conversion ratio, feed conversion efficiency, feed efficiency, feed consumption, feed intake and broiler chickens. The reference lists of retrieved studies were manually searched for other related studies. The search was not restricted by publication year as to our knowledge this is the first meta-analysis that studied the effect of turmeric supplementation in broiler chicken performance. One hundred and forty studies were identified at the end of the systematic search.

Inclusion and exclusion criteria

Thirty-one out of the 140 studies identified were included in the meta-analysis as illustrated in our study selection flow chart (*Fig. 1*). To be included in the meta-analysis, (1) the study randomly assigned animals to treatment and controlled groups; (2) study was published in English; (3) experimental diets must contain turmeric additive with no other added growth promoters; (4) study reported at least one of the response variables (FI, FCE or BWG) with their measures of variance; and (5) study provide sufficient data to determine effect size. On the other hand, studies were excluded if (1) experiment was not in broiler chickens; (2) study lacked sufficient data to compute effect size; (3) trial was not published in English; (4) study published only the abstract; (5) study that mixed turmeric with other feed additives; (6) study appeared in more than one of the selected databases and (7) studies were in heat-stressed broiler chickens.

Data extraction

Information on response variables (FI, FCE, and BWG), covariates (supplementation duration, dosage and broiler strain), surname of the first author, publication year, study country and continents were extracted from each study that met the inclusion criteria as shown in *Table 1*. In addition, information on the mean and the number of broiler chickens included in the treatment and control groups were also extracted.

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Moderator and subgroup analysis

Several moderators may influence the response of broiler chickens to turmeric supplementation. The moderators used in the present study conformed with some of the variables we presumed to influence the responses of broiler chickens to turmeric supplementation. The moderators tested for were broiler strain (Cobb, Ross, Anak, Arbor acres and Hubbard), Dosage (<5, 5–10 and > 10 g/kg feed) and supplementation duration (1–21, 1–28, 1–35, 1–42 and 1– > 42 d). They were taking from each article that passed the eligibility criteria. The same moderators were also used for subgroup analysis in the present meta-analysis. Heterogeneity was determined using Cochran's Q statistic and I^2 statistics.

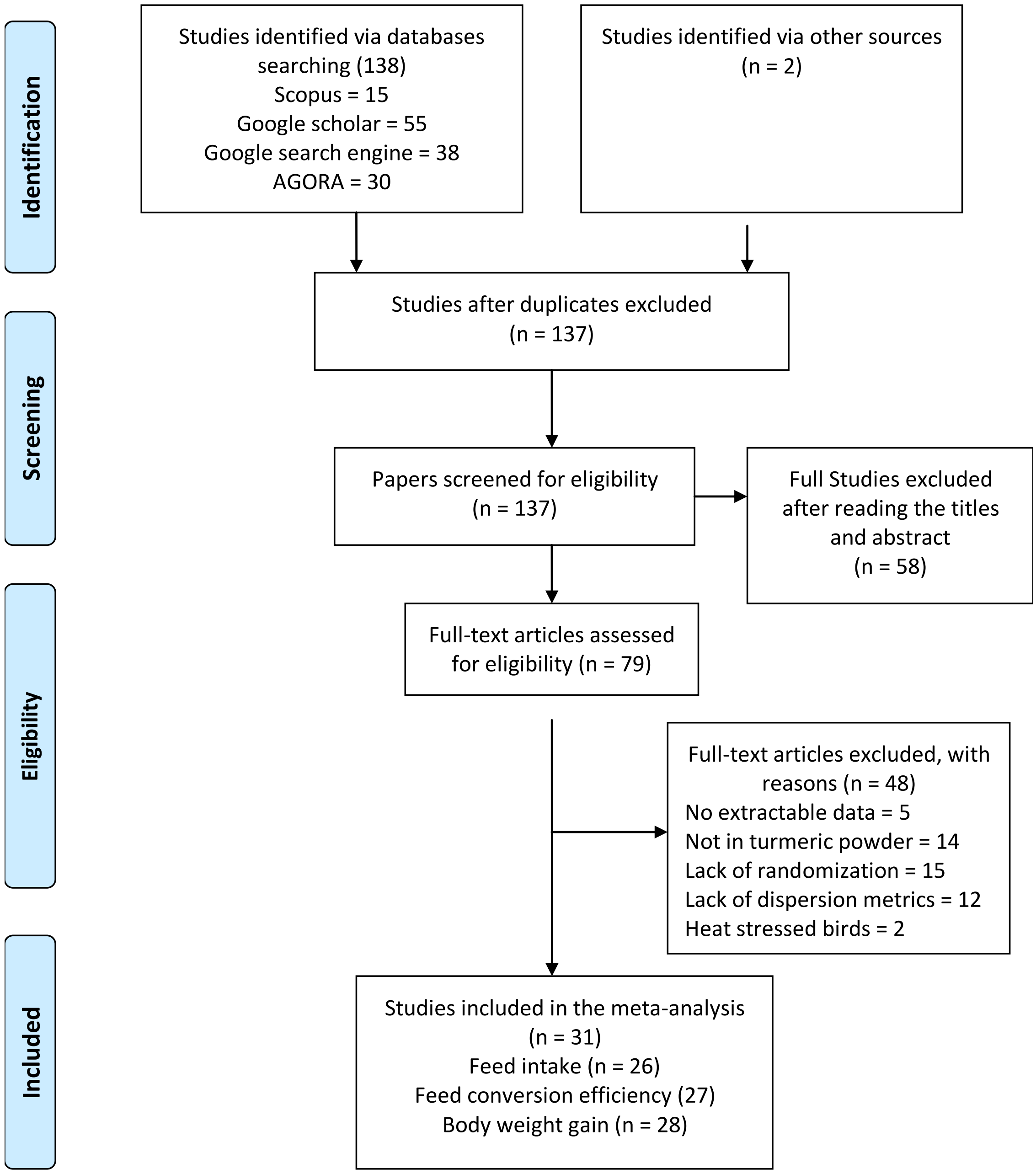

Figure 1. *Preferred reporting items for systematic review and meta-analysis flow diagram of study selection methods used in this meta-analysis*

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Table 1. *Studies used to determine the effect of turmeric supplementation in broiler chicken productivity*

References	Continent	Country	Dosage (g/kg)	Explanatory variables		Outcomes
				Duration (d)	Strain	
AL-Sultan (2003)	Asia	Saudi Arabia	0, 2.5, 5, 10	1–35	Ross	FI, FCR, BWG
Samarasinghe et al. (2003)	Asia	Sri Lanka	0, 1, 2, 3	1–28	Anak	FI, FCR, BWG
Durrani et al. (2006)	Asia	Pakistan	0, 2.5, 5, 10	1–35	Ross	FI, FCR, BWG
Emadi and Kermanshahi (2006)	Asia	Iran	0, 2.5, 5. 7.5	1–49	Ross	FI, FCR, BWG
Mehala and Moorthy (2008)	Asia	India	0, 1, 2	1–42	Cobb	FI, FCR, BWG
Nouzarian et al. (2011)	Asia	Iran	0, 3.3, 6.6, 10	1–42	Ross	FI, FCR, BWG
Sadeghi et al. (2012)	Asia	Iran	0, 5	1–42	Ross	BWG
Tirupati et. al. (2012)	Asia	India	0, 2.5	1–42	Cobb	FI, FCR, BWG
Raghdad (2012)	Asia	Iraq	0, 2.5, 10, 15	1–42	Ross	FI, FCR, BWG
Hussein (2013)	Asia	Iraq	0, 5, 7, 9	1–42	Ross	FI, FCR, BWG
Nayaka et al. (2013)	Asia	India	0, 2	1–42	Raja II	FCR
Abou-Elkhair et al. (2014)	Africa	Egypt	0, 5	1–35	Cobb	FI, FCR, BWG
Naderi et al. (2014)	Asia	Iran	0, 2.5, 7.5	1–21	Ross	FI, FCR, BWG
Anjali (2015)	Asia	India	0, 5	1–42	Cobb	FI, FCR, BWG
Mondal et al. (2015)	Asia	Bangladesh	0, 5, 10, 15	1–28	Ross	FI, BWG
Alagawany et al. (2015)	Africa	Egypt	0, 5, 10	1–35	Hubbard	FI, FCR, BWG
Fallah and Mirzaei (2016)	Asia	Iran	0, 5	1–42	Ross	FI
Kassu et al. (2016)	Africa	Ethiopia	1, 2	1–49	Cobb	FCR, BWG
Maha et al. (2016)	Africa	Egypt	0, 2.5	1–35	Ross	FI, FCR, BWG
Ukoha and Onunkwo (2016)	Africa	Nigeria	0, 10, 20, 30	1–56	Anak	FI, FCR, BWG
Arslan et al. (2016)	Asia	Pakistan	0, 5, 10, 15	1–35	Hubbard	FI, FCR, BWG
Kamdev et al. (2016)	Asia	India	0, 5, 10	1–42	Cobb	BWG
Łukasiewicz et al. (2017)	Europe	Poland	0, 7.5	1–42	Ross	FCR
Urusan and Bolukbasi (2017)	Europe	Turkey	0, 2, 4, 6, 8, 10	1–42	Ross	FI, FCR, BWG
Kafi et al. (2017)	Asia	Bangladesh	0, 5, 7.5	1–35	Cobb	FI, FCR, BWG
Esonu et al. (2017)	Africa	Nigeria	0, 10, 15, 20	1–21	Cobb	FI, FCR, BWG
Attia et al. (2017)	Africa	Egypt	0, 5, 10, 20	1–35	Hubbard	FI, FCR, BWG
Adegoke et al. (2018)	Africa	Nigeria	0, 2, 4	1–35	AA	FI, FCR, BWG
Ratika et al. (2018)	Asia	India	0, 5	1–21	Ross	FI, FCR, BWG
Choudhury et al. (2018)	Asia	India	0, 2.5, 5, 7.5	1–21	AA	FI, FCR, BWG
Shohe et al. (2019)	Asia	India	0, 2.5, 5, 7.5	1–21/1–42	Cobb	FI, FCR, BWG

d – day, AA – Arbor acres

Statistical analysis

We considered the random-effects model (REM) more appropriate in this analysis than the fixed-effects model (FEM) since the studies included in the meta-analysis were performed under different experimental conditions. Furthermore, researchers consider the REM approach more natural choice than FEM in the decision-making process (Ades and Higgins, 2005). The point estimate was expressed as In*R* with 95% confidence intervals. Forest and funnel plots were created in OpenMEE software (Wallace et al., 2016). Rosenberg's fail-safe number (Nfs) was used to determine the presence of publication bias which was assessed through a funnel graph. Symmetrically funnel graphs denote an absence of publication bias. Meta-analysis results were deemed robust despite publication bias when Nfs > 5(n) + 10, where n is the number of studies (Ogbuewu et al., 2020; Jennions et al., 2013). The diamond at the bottom of the plot represents the overall mean estimation (In*R*) and is said to be significant when CI did not include zero (Koricheva et al., 2013). The points to the left of the line of no effect (i.e. when In*R* = 0) connotes a

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reduction in the response variable; whereas the points to the right of the line of no effect indicate an increase. The relationships between the In*R* and the studied moderators were evaluated using the mixed-effects meta-regression analysis.

Results

The features of the 31 papers included in the meta-analysis are presented in *Table 1*. The articles used for the meta-analysis spanned 16 years, with the earliest study published in 2003 and the most recent being published in 2019. The studies used for the meta-analysis were conducted in 12 countries drawn from three regions around the world: Europe (n = 2), Asia (n = 21) and Africa (n = 8). Six studies were published in 2016 followed by seven studies published in 2017, whereas one study each was published in 2008, 2011 and 2019. The effect of turmeric supplementation on growth performance traits in broiler chickens is presented in *Figures 2–4*. The meta-analysis of 26 peer-reviewed journal papers, 79 comparisons, with 4392 broiler chickens (1128 and 3264 for the control and treatment groups respectively) indicated that turmeric supplementation significantly reduced feed intake when compared with the controls (In*R* = -0.02 g/bird, 95% CI: -0.03 to -0.01; I^2 = 69%; *Fig. 2*). The meta-analysis of 28 studies, 86 comparisons, with 4755 broiler chickens (1184 and 3572 each for control and treatment groups respectively) showed better FCE (computed as the quotient of average daily feed intake and the average in chickens) in treatment group when compared with the controls (In*R* = -0.06, 95% CI: -0.07 to -0.05, I^2 = 89%; *Fig. 3*). The meta-analysis of 28 peer-reviewed journal articles, 87 comparisons, with 4779 broiler chickens (1231 and 3548 each for control and treatment groups respectively) suggested that broiler chickens on turmeric supplementation had significantly higher BWG (calculated as final live weights - initial live weights divided by the duration of study) in comparison to the controls (In*R* = 0.05 g/bird, 95% CI: 0.03 to 0.07, *Fig. 4*), taking cognizance of significant heterogeneity ($p < 0.001$; I^2 = 92%).

Sub-analysis of the effects of moderators on the productivity of broiler chickens fed turmeric-supplemented diets is presented in *Table 2*. Broiler chickens fed turmeric supplemented diets at 5–10 and > 10 g/kg feed had significantly reduced FI in comparison with the controls. In contrast, broiler chickens fed turmeric supplemented diets at < 5 g/kg feed had similar FI with the controls. Broiler chickens offered turmeric supplemented diets at < 5, 5–10 and > 10 g/kg feed had significantly better FCE and BWG when compared with the controls, except for the birds fed turmeric supplemented diets at > 10 g/kg feed that had similar BWG with the controls. On the other hand, chickens from studies that fed turmeric supplemented diets for 1–42 d had significantly better FCE and gained weight at a reduced FI. Cobb, Ross, Hubbard, Arbor acres and Anak strains fed turmeric supplemented diets had significantly better FCE than the controls. Ross and Cobb broiler chickens gained weight at reduced FI in comparison with the controls. Conversely, Arbor acres and Hubbard broiler chickens gained weight at a similar FI with the controls.

Heterogeneity analysis is crucial in meta-analysis because it helps to determine the sources of variation between studies. A significant I^2-statistic indicates that the difference between study outcomes is more than anticipated naturally by chance. Significant heterogeneity was found among the studies included in the analysis as indicated by I^2-statistic and ranged from 69–92% as shown in *Figures 2–4*. The observed significant heterogeneity in treatment response as found in the present meta-

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analysis could perhaps be attributed to our chosen moderators. Meta-regression analysis as shown in *Table 3* showed that dosage is a significant predictor of the effect of turmeric on FI and accounted for about 26% of the source of heterogeneity. In contrast, duration and broiler strain had no significant influence on FI in broiler chickens. Furthermore, meta-regression analysis found significant relationships between dosage and FCE, which explained about 7% of the sources of heterogeneity. Similarly, we found significant associations between duration and strain and BWG in broiler chickens. However, the studied moderators and their interactions explained only 23% of the heterogeneity among the studies that evaluated the effect of turmeric on BWG.

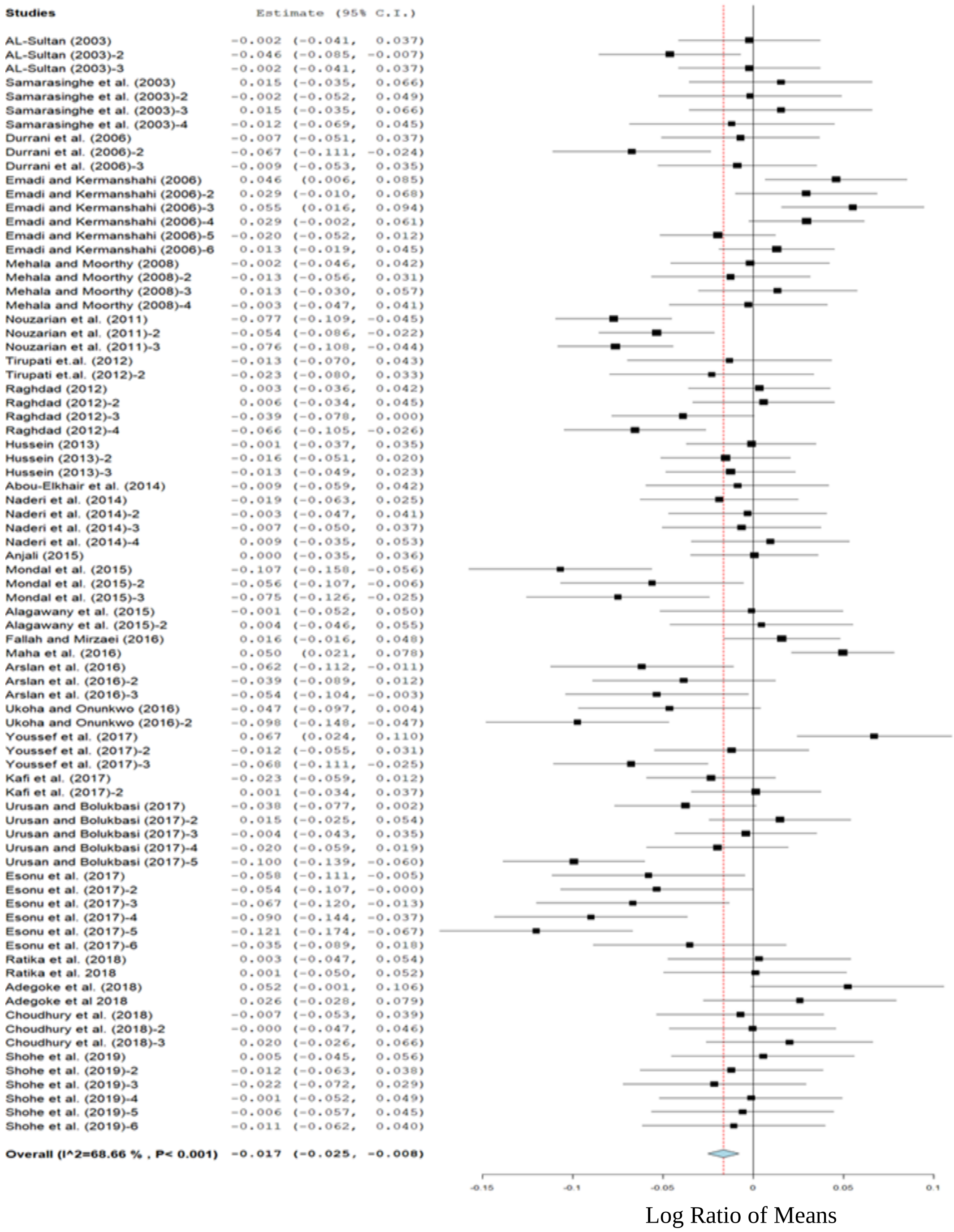

Figure 2. *Effect of turmeric supplementation on FI in broiler chickens*

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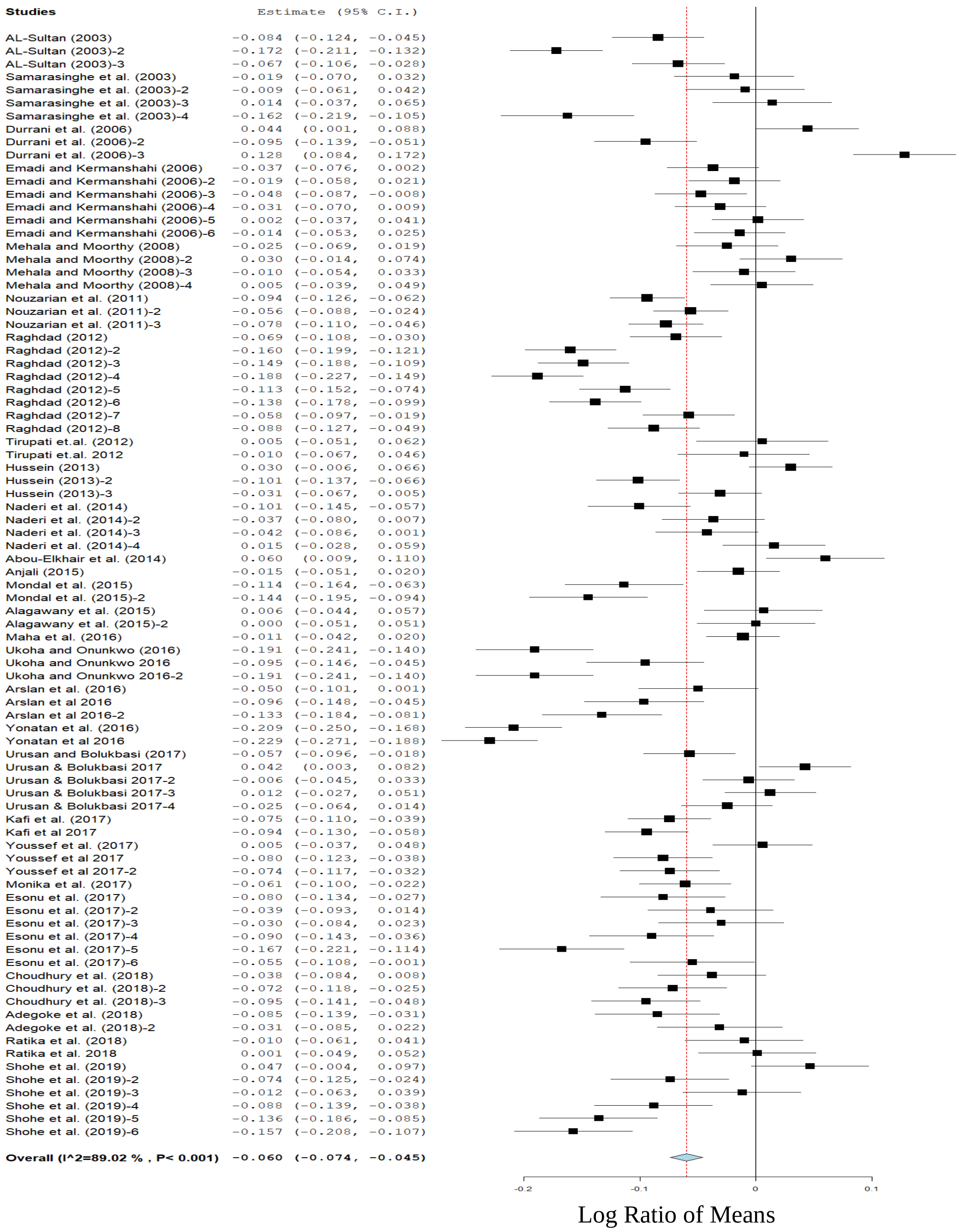

***Figure 3.** Impact of turmeric supplementation on FCE in broiler chickens*

The funnel plots for all the production indices as shown in *Figure 5a–c* were asymmetrical. The Nfs of the dataset for FI, FCE and BWG were 709, 13662 and 7618, respectively, which is about 2, 32 and 17 times higher than the threshold of 405 (5 × 79 + 10), 430 (5 × 86 + 10) and 445 (5 × 87 + 10) needed to declare the mean effect sizes robust.

Discussion

India is the location with the highest number of studies in the present analysis followed by Iran, and this is expected since turmeric is native to Asia (Anantkawlas,

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2014). However, Europe (Turkey and Poland) contributed the least to turmeric research in broiler chickens in the current study, which could be attributed to the fact that turmeric is not widely available in this region. The observed yearly increase in turmeric research apart from the year 2019 may be due to the global campaign on the use of natural products in animal feed to curtail the rising incidence of antibiotic resistance and the appearance of antibiotic residues in animal products and the environment (FAO, 2003; Forgetta et al., 2012). However, the lower research figure put for the year 2019 may not reflect the true picture on the ground, as most of the works done in 2019 may be undergoing peer-review processes as at the time the literature search used for the analysis was conducted.

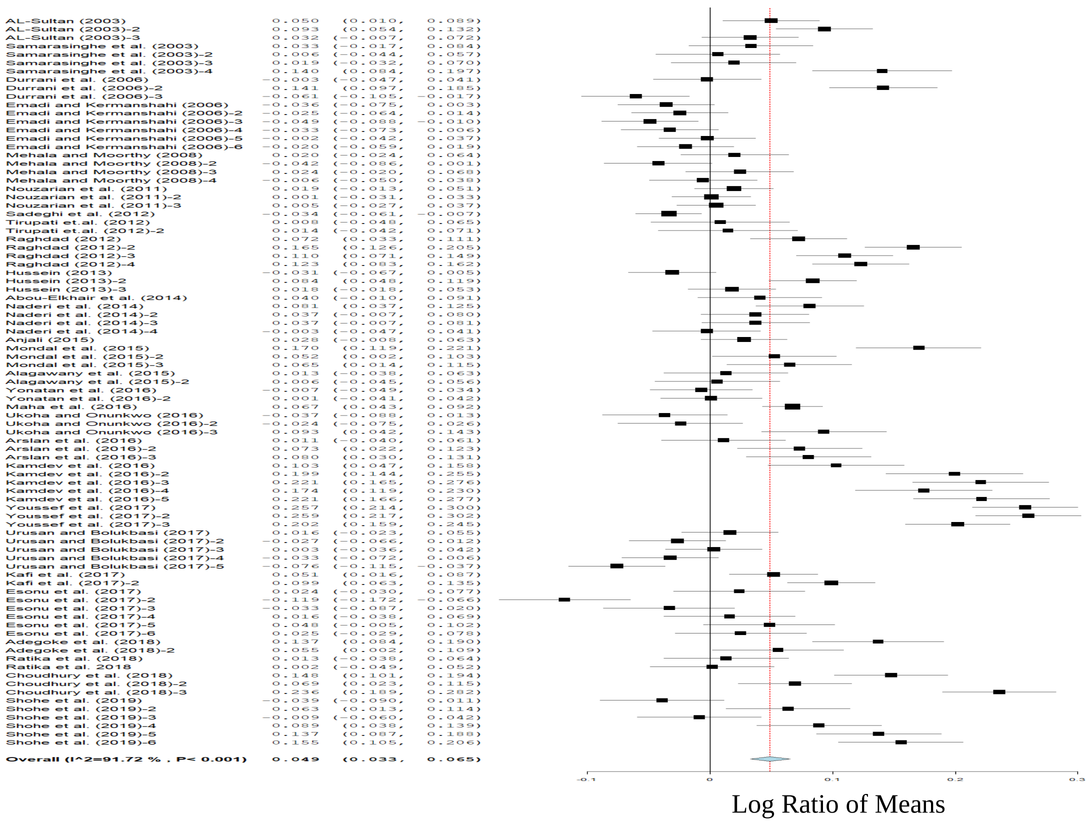

Figure 4. *Effect of turmeric supplementation on BWG in broiler chickens*

Findings of this meta-analysis revealed that chickens fed turmeric supplemented diets had improved FCE and BWG at reduced feed intake when compared with the controls and this is a welcome development. These findings agree with others (Halle et al., 2004; Windisch et al., 2008; Amad et al., 2011; Ogbuewu et al., 2020) who recorded improved FCE and BWG at lower feed consumption in broiler chickens fed diets supplemented with plant-based feed additives. For the digestive system to function optimally there must be equilibrium between the diet, the mucosa and the microbes. The significantly better FCE and BWG observed in broiler chickens fed turmeric supplemented diets over those fed control diets might be attributed to the inert ability of turmeric essential oils to favor the growth and multiplication of beneficial microbes in the digestive tract of chickens (Mohammad et al., 2010; Gul and Bakht, 2015). Furthermore, Trachoo and Boudreaux (2006) indicated that factors such as stress and

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diets may compromise the gut microbial ecosystem of chickens. Although the mechanisms of turmeric in increasing broiler chicken productivity is not clear, there is a hypothesis that bioactive compounds contained in turmeric may improve chicken productivity by alteration of gut metabolic processes in favor of production and secretion of endogenous digestive enzymes as well as the activation of gut defense systems (Ogbuewu et al., 2019).

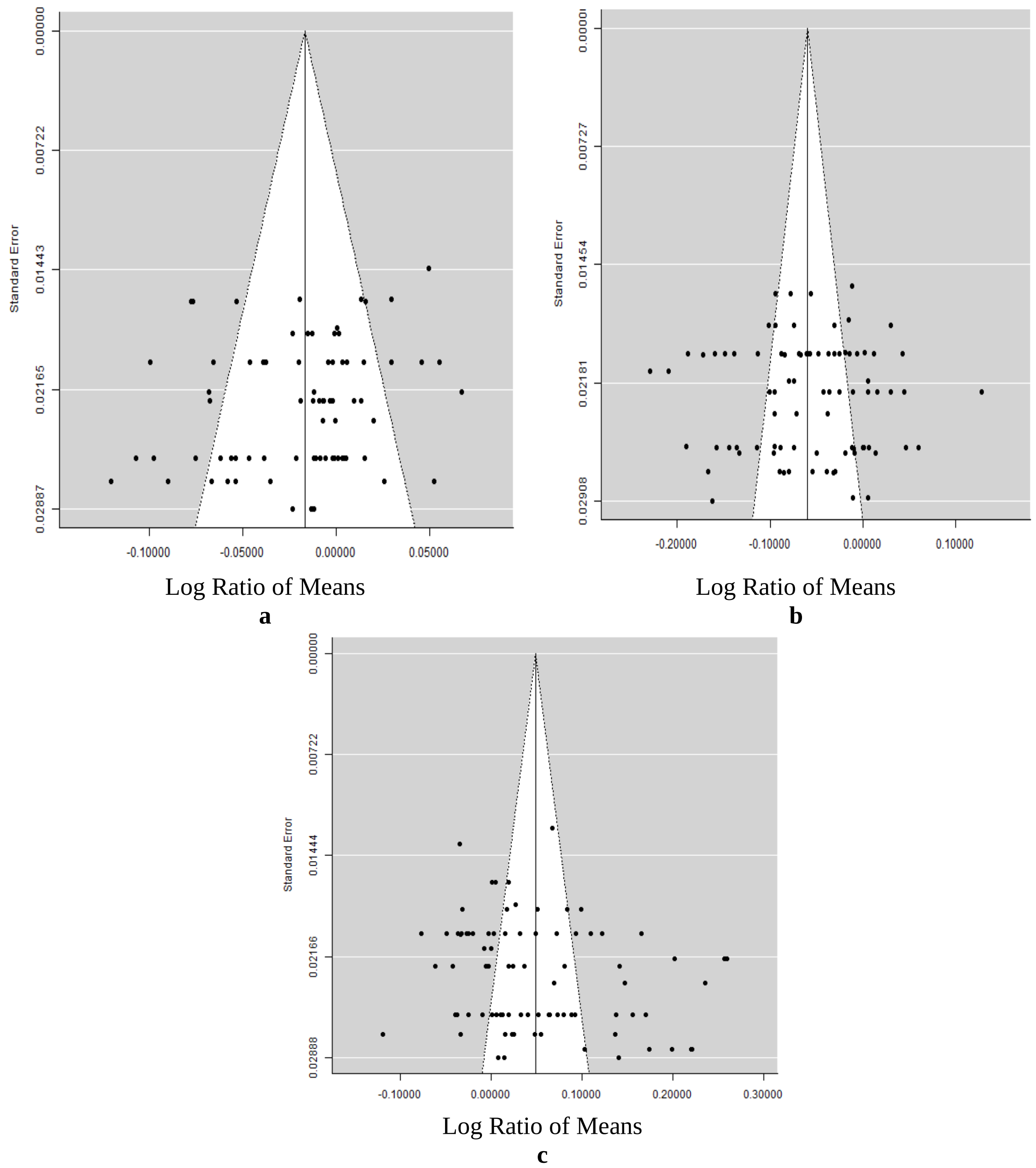

Figure 5. *Funnel graphs of the log ratios of means (InR) for dataset which compared production outcomes: FI (a), FCE (b) and BWG (c) between broiler chickens on diets with and without turmeric. X-axis is the InR, and Y-axis is the standard error*

In this meta-analysis, the supplementation dose was a significant predictor of feed intake and FCE, but not BWG. Results revealed that broiler chickens from studies that fed turmeric at < 5 g/kg feed had similar feed intake with the controls, nonetheless, chickens from studies that fed turmeric at the levels of 5–10 and > 10 g/kg feed consumed less feed than the controls. Knowledge of the process that controls feed intake in broiler chickens fed turmeric supplemented diets is still not clear. However, it is presumed that feed intake is regulated in neuroanatomical sites by well-organized neural and endocrine signaling networks (Richards and Proszkowiec-Weglarz, 2007). The observed difference in feed intake in broiler chickens fed diets supplemented with turmeric at < 5 g/kg feed and those fed diets supplemented with turmeric at 5–10 and > 10 g/kg feed indicate that < 5 g/kg feed may be below the threshold needed for the bioactive ingredients in turmeric to activate specific circuit in the neuroanatomical sites and its signaling molecules to modulate appetite in broiler chickens. The results of this restricted subgroup analysis showed that broiler chickens from studies that supplemented turmeric at the levels of < 5, 5–10 and > 10 g/kg feed had better FCE than the controls, suggesting the ability of turmeric to enhance feed digestion and nutrient uptake. The results of this meta-analysis show significantly heavier BWG due to turmeric supplementation in studies that included turmeric at levels of < 5 and 5–10 g/kg feed. In contrast, broiler chickens from studies that fed turmeric at > 10 g/kg feed had comparable BWG with the controls. This could mean that the optimal supplementation dose of turmeric expected to maximize body weight gain in broiler chickens falls between 5 and 10 g/kg feed. However, more studies are needed to determine the optimal turmeric supplementation dose that maximizes body weight gain in broiler chickens.

Our results indicate that supplementation duration was a significant predictor of BWG. Supplementation duration had a reduction effect on feed intake only in experiments that fed turmeric to broiler chickens from 1–42 d experiments. FCE was enhanced in 1–21, 1–28, 1–35, 1–42 and 1– > 42 d recorded better FCE. Broilers from studies that fed turmeric-supplemented diets from 1–28 d, 1–35 d and 1–43 d had significantly heavier BWG than the controls, suggesting that turmeric supplementation should not exceed 1–42 d for optimal BWG in broiler chickens. Probiotics have been reported to exert a higher beneficial impact on chicken gut during the early stage of life when a stable gut microflora has not been established, and therefore broiler chicks are more vulnerable to pathogens (Gaggia et al., 2010). However, we did not observe this pattern in the current study, as broiler chickens fed diets supplemented with turmeric from 1–21 d had similar BWG with the controls, suggesting that turmeric and probiotics may differ in their mechanism of action. Nevertheless, the poor weight gain seen in broilers fed turmeric-supplemented diets for 1–21 d suggests the low ability of broiler chicks to utilize turmeric-supplemented diets since their digestive tracts may have not been fully developed to handle the bioactive compounds contained in turmeric. The significantly lower weight gain obtained in chickens fed turmeric for more than 1–>42 d, indicates that 1–42 d may be the optimal supplementation duration for turmeric in the broiler chicken diet. This study, therefore, reaffirms the need for further research in this regard.

Strain is a significant predictor of BWG in the current meta-analysis. Ross and Cobb had better FCE and BWG at a reduced feed intake compared with the controls. In contrast, Hubbard Arbor acres gained weight at comparable feed intake with controls. This suggests that Cobb and Ross broilers may have a better ability to regulate turmeric intake than Anak, Hubbard and Arbor acres. Similarly, Korver et al. (2004) and Gonzales et al. (1998) reported the effect of strains on broiler chicken performance.

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These findings demonstrated that different broiler strains may exhibit different growth potentials. This finding may assist farmers in making informed decisions on which broiler strain (s) to rear especially when using turmeric supplements.

Table 2. *Sub-analysis of the effect of moderators on FI, FCE and BWG in broiler chickens fed turmeric*

Moderators	FI	FCE	BWG
	In*R* (95% CI)	In*R* (95% CI)	In*R* (95% CI)
Dosage (g/kg)			
< 5	0.02 (-0.01 to 0.02)	-0.05 (-0.07 to -0.03)	0.05 (0.02 to 0.08)
5–10	-0.02 (-0.03 to -0.01)	-0.06 (-0.07 to -0.04)	0.05 (0.03 to 0.08)
> 10	-0.08 (-0.11 to -0.05)	-0.11 (-0.15 to -0.08)	0.03 (-0.02 to 0.08)
Duration (d)			
1–21	-0.02 (-0.04 to 0.03)	-0.06 (-0.08 to -0.03)	0.01 (-0.02 to 0.02)
1–28	-0.03 (-0.07 to 0.004)	-0.07 (-0.13 to -0.01)	0.07 (0.02 to 0.12)
1–35	-0.01 (-0.03 to 0.01)	-0.05 (-0.08 to -0.02)	0.08 (0.05 to 0.12)
1–42	-0.02 (-0.03 to -0.01)	-0.05 (-0.08 to -0.03)	0.06 (0.03 to 0.08)
1– > 42	-0.02 (-0.06 to 0.02)	-0.12 (-0.19 to -0.05)	0.04 (-0.02 to 0.09)
Broiler strains			
Ross	-0.02 (-0.03 to -0.01)	-0.05 (-0.07 to -0.04)	0.03 (0.01 to 0.05)
Cobb	-0.02 (-0.04 to -0.01)	-0.06 (-0.09 to -0.03)	0.05 (0.02 to 0.08)
Hubbard	-0.02 (-0.05 to 0.01)	-0.05 (-0.09 to -0.02)	0.11 (0.04 to 0.19)
Anak	-0.02 (-0.06 to 0.01)	-0.09 (-0.16 to -0.03)	0.03 (-0.01 to 0.08)
Arbor acres	-0.02 (-0.01 to 0.04)	-0.07 (-0.09 to -0.04)	0.13 (0.07 to 0.19)

Table 3. *Meta-regression of the effect of moderators on performance of broiler chickens fed turmeric*

Outcome	Moderators	Q_M	df	P-value	R^2 (%)
FI	Duration	1.63	4	0.803	0
	Dosage	20.50	2	< 0.001	26
	Strain	4.22	4	0.377	0
FCE	Duration	7.78	4	0.099	4
	Dosage	7.65	2	0.022	7
	Strain	1.98	4	0.739	0
BWG	Duration	11.90	4	0.018	9
	Dosage	0.66	2	0.719	0
	Strain	15.70	4	0.003	14

R^2 = Percentage of heterogeneity explained by moderators

In the current meta-analysis, we included a large number of studies that could permit us to conclude that turmeric supplementation improves growth performance in broiler chickens. Our results were robust despite the presence of publication bias as suggested by Rosenberg Nfs and funnel graphs (Ogbuewu et al., 2020; Jennions et al., 2013; Higgins et al., 2003). Rosenberg Nfs indicated that a large number of unpublished

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studies would be needed to change the significant effects of turmeric supplements on FI, FCE and BWG as observed in the current meta-analysis. There is moderate to substantial heterogeneity in the present meta-analysis as supported by the I^2-statistic. Studied moderators were significant predictors of the study effect and explained most of the sources of heterogeneity. Other factors such as air velocity, ambient temperature, housing type, age, dietary composition and nutrient consistency may have accounted for the remaining heterogeneity. This meta-analysis, therefore, reinforces the need for another study in this area.

Conclusion

The results of the present meta-analysis indicate that turmeric supplementation improves growth performance indices in broiler chickens and may be used to increase the productivity of broiler chickens. Restricted subgroup results showed that dietary turmeric supplementation at the range of 5–10 g/kg feed significantly improved broiler chicken performance at a reduced feed intake, suggesting that turmeric can be included at this range in broiler chicken feed to enhance performance indices. However, more studies are needed to ascertain the exact amount of turmeric that optimizes growth performance indices in broiler chickens using a regression model. Meta-regression found significant relationships between the studied moderators and the variables of interest and explained most of the sources of heterogeneity. Nevertheless, the impact of other factors (ambient temperature, relative humidity, air velocity, housing type, dietary compositions/nutrient consistency and stocking density) that affect chicken performance that were not examined in this meta-analysis needs to be considered since such factors may explain the difference not accounted for by the studied moderators. More research is needed to determine the economics of production of broiler chickens fed diets supplemented with different levels of turmeric as such information is lacking in the literature.

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