META-ANALYSIS OF THE HYPOCHOLESTEROLEMIC POTENTIALS OF TURMERIC (*CURCUMA LONGA*) IN BROILER CHICKENS

OGBUEWU, I. P.* – MBAJIORGU, C. A.

Department of Agriculture and Animal Health, University of South Africa, Florida Science Campus, Johannesburg, South Africa

**Corresponding author*
e-mail: dr.ogbuewu@gmail.com

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Abstract. The purpose of this experiment was to use a meta-analysis approach to resolve conflict, identify knowledge gap and develop new insights on the effect of turmeric on plasma total cholesterol (TC), high-density lipoprotein cholesterol (HDL-c) and low-density lipoprotein cholesterol (LDL-c) concentrations in broiler chickens. The authors found 64 studies following a systematic search conducted in 3 electronic databases and the World Wide Web using several search queries. Eighteen out of the 64 publications met the predefined eligibility criteria to assess the impact of turmeric on plasma TC, HDL-c and LDL-c concentrations in broiler chickens. Data collected were analysed in OpenMEE software and pooled estimation revealed that turmeric-based diets significantly reduced the concentrations of TC and LDL-c ($p<0.01$), and improved the concentrations of HDL-c ($p<0.01$) in chicken blood when compared to those on the control diets. Sub-analysis found significant associations between covariates (chicken strain, supplementation level, number of birds per treatment and duration of supplementation) and measured outcomes (TC, HDL-c and LDL-c). Significant heterogeneity (I^2) existed in the meta-analysis, and meta-regression analysis found that chicken strain and duration of supplementation were predictors of HDL-c and LDL-c, and explained 72% of the sources of heterogeneity among the studies used in the meta-analysis. The results of the present meta-analysis showed the potential of turmeric-based diets to modulate the production of blood cholesterol in broiler chickens.
Keywords: *turmeric, meat-typed broilers, cholesterol, data synthesis, meta-regression, funnel plot*

Introduction

Currently, herbs and spices such as ginger, garlic and turmeric are receiving attention in chicken production because of their positive health benefits. Turmeric (*Curcuma longa* L.), a member of Zingiberaceae family is used in preparations of human foods and native medicines. It is low in macro-nutrients, moderate in fibre and rich in essential oils. Turmeric is a potent source of curcuminoids and possesses antioxidative, anti-inflammatory, antihepatotoxic and anticarcinogenic properties and may be used as a phytoadditive in animal feed. The beneficial effects of turmeric in chickens include improvement of immune response, reduction of negative effects of heat stress via several mechanisms, enhancement of antioxidant activity, reduction in the number of harmful microbes in the gut, and improvement of blood indices which are linked to its rich phytochemicals (Jurenka, 2009; Rahimi and Kazemi-Oskuee, 2014). Addition of turmeric in animal diet has been found to enhance growth performance in broiler chickens (Emadi and Kermanshahi, 2006; Adegoke et al., 2018) and improve reproductive efficiency in rabbits (Ogbuewu et al., 2017). Emadi et al. (2007) have reported low plasma LDL-c value and improved plasma HDL-c value in broiler chickens fed turmeric at 7.5 g/kg feed. Furthermore, the incorporation of turmeric at 2 g/kg feed lowers plasma triglyceride, TC and LDL-c concentrations in laying hens (Kermanshahi and Riasi, 2006). Others have

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reported the influence of turmeric on blood cholesterol values of broiler chickens (Akbarian et al., 2012; Alagawany, 2015; Arslan et al., 2017; Choudhury et al., 2018). However, these results were at variance with one another and the variability may depend on factors such as dietary components, inclusion rate, feeding duration, age and stocking density among others. The use meta-analysis approach to resolve conflicting results among authors have been reported (Ressing et al., 2009). Meta-analysis is an inferential statistical method that enables the results of individual studies to be pooled and quantitatively analysed to reach conclusion that ordinarily could not be drawn from individual primary studies or narrative reviews. To our knowledge, no meta-analysis has investigated the effect of turmeric on health indices of broiler chickens. Therefore, this meta-analysis aimed to determine the effect of turmeric on plasma cholesterol characteristics in broiler chickens as to aid evidence-based decision-making.

Materials and Methods

The meta-analysis was conducted in the Department of Agriculture and Animal Health, University of South Africa, Florida Science Campus, South Africa. To realize the objectives of the current research, the authors searched Scopus, Google scholar and AGORA databases and the World Wide Web for studies that investigated the effect of turmeric on plasma TC, HDL-c and LDL-c concentrations in broiler chickens using combinations of different search queries. The search terms were turmeric, broiler chickens, plasma cholesterol, serum cholesterol and blood cholesterol. The search was conducted using Boolean logic operators (AND, NOT and OR), wildcat (* or $), alternate spellings (?) and proximity searching ("…" or "…."). Our search yielded 64 publications of which 18 met the apriori selection criteria. For an article to be included in the analysis, the experiment must have control treatment (without turmeric) and experimental treatments (with turmeric). The diet must be free of growth-promoting substances. The study is written in English and reported at least one of these outcomes (TC, LDL-c or HDL-c) in healthy chickens with their corresponding measures of dispersion such as standard deviation (SD) or standard error (SE). In a condition, where SE of the mean was reported instead of SD, the SD value was calculated from SE using standard method (Higgins and Deeks, 2011). Information on the surname of first author/year of publication, outcomes of interest (TC, HDL-c and LDL-c) with their corresponding SD as well as our chosen covariates (strain, supplementation level, duration of supplementation and the number of birds included in each treatment group) were extracted from each paper that fulfilled the eligibility criteria. This meta-analysis was conducted following standard protocols as described by Koricheva et al. (2013). Standardized effect sizes were estimated using standardized mean difference (SMD), and SMD was said to significant at $p < 0.01$ (Koricheva et al., 2013). We employed 2 random effect model in the study with Model I being a full model:

$$Y_i = \mu + T_i + e_i \tag{Eq.1}$$

where,
Y_i: Response variable (TC, LDL-c and HDL-c) for the ith study (i = I, 2, ….., N), N is the number of study included in the analysis,
μ: Overall mean,
T_i: Treatment effect (dietary turmeric),

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e_i: Random error associated with observation *i*.

Model II = Model I + effects for potential of between-study variance across studies:

$$Y_{ijklm} = \mu + T_i + S_j + D_k + C_l + B_m + e_{ijklm} \quad \text{(Eq.2)}$$

where,
Y_{ijklm}: Measure for the ith study (i = I, 2, ….., N),
μ: Overall mean,
S_j: Effect of jth strain (j = 5; Hubbard, Ross, Cobb, Arbor acre and Anak),
D_k: Effect of kth duration of supplementation (k = 1 to 56 days),
C_l: Effect of lth supplementation level (l = 0.2 g/kg feed ≥ n ≤ 15 g/kg feed),
B_m: Effect of mth number of broiler chickens included in each treatment group (m = 10 ≥ n ≤ 108),
e_{ijklm}: Random error.

Pooled effects estimate with 95% confidence interval (CI) for the TC, HDL-c and LDL-c were presented in forest plots using OpenMEE software (Wallace et al., 2016). Funnel plot method and Rosenberg's fail-safe number (Nfs) were used to identify the presence of publication bias. Jennions et al. (2013) have reported the robustness of meta-analysis results despite the presence of publication bias if Nfs is greater than (5n + 10), where, n = number of comparisons. We used Q statistics (Hedges and Olkin, 1985) and I^2 statistics (Higgins et al., 2003) to identify the presence of heterogeneity across studies, whereas sources of heterogeneity were quantified using meta-regression analysis.

Results

Overview of studies included in the analysis

Our search yielded 64 articles of which 18 papers with 2200 broiler chickens and 54 comparisons met the predefined inclusion criteria for the meta-analysis (*Table 1*). The articles used for the analysis span 12 years with the first study published in 2007 and the most recent published in 2018.

Meta-analysis and analysis of covariates

Pooled estimation revealed significantly (p<0.01) lower TC (SMD = − 0.332, I^2 = 90.74%; *Fig. 1*) in broiler chickens fed turmeric diets compared to those fed control diets. In addition, statistically increased (p<0.01) HDL-c (SMD = 0.581, I^2 = 90.29%; *Fig. 2*) were recorded for broiler chickens on treatment diets when compared with broiler chickens on control diets. LDL-c (SMD = − 0.331 mg/dl; *Fig. 3*) was lower in broiler chickens fed turmeric-based diets as compared to those fed control diets, however, the difference was not significant (p>0.01). There was presence large heterogeneity among the studies used in the analysis as presented in *Figs. 1*, *2* and *3* (results from Model I). In an effort to determine the actual turmeric dose that optimizes blood cholesterol concentrations in broiler chickens, the authors chose 2 levels of supplementation (i.e. < 6 g/kg feed and > 6 g/kg feed) based on the mean inclusion levels reported in the studies included in the meta-analysis. The results of the effect of turmeric on plasma TC in broiler chickens are presented in *Table 2*. Chickens fed turmeric diet at > 6 g/kg feed and < 6 g/kg feed had significantly reduced TC. Similarly, there was no significant association between the plasma TC and the studied covariates.

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There was a significant relationship between TC and duration of supplementation with chickens from studies that fed turmeric for 42 days recording lower value than studies that fed turmeric for 21, 35 and 56 days.

Table 1. *Studies used to evaluate the effect of turmeric on TC, HDL-c and LDL-c in broiler chickens*

References	Moderators				Outcomes
	Strain	SL (g/kg)	DOS (day)	No. of birds per treatment	
Adegoke et al 2018	Arbor acres	<6	42	<46	TC, HDL-c
Adegoke et al 2018	Arbor acres	<6	42	<46	TC
Hussein 2013	Ross	<6	42	>46	TC
Hussein 2013	Ross	>6	42	>46	TC
Hussein 2013	Ross	>6	42	>46	TC
Abou-Elkhair et al 2014	Cobb	<6	35	<46	TC
Fallah & Mirzaei 2016	Ross	<6	42	>46	TC, HDL-c, LDL-c
Nouzarian et al 2011	Ross	<6	42	>46	TC, HDL-c, LDL-c
Nouzarian et al 2011	Ross	>6	42	>46	TC, HDL-c, LDL-c
Nouzarian et al 2011	Ross	>6	42	>46	TC, HDL-c
Choudhury et al 2018	Arbor acres	<6	42	<46	TC, HDL-c
Choudhury et al 2018	Arbor acres	<6	42	<46	TC, HDL-c
Choudhury et al 2018	Arbor acres	>6	42	<46	TC
Ukoha and Onunkwo 2016	Anak	>6	56	<46	TC
Ukoha and Onunkwo 2016	Anak	>6	56	<46	TC
Ukoha and Onunkwo 2016	Anak	>6	56	<46	TC
Alagawany et al 2015	Hubbard	<6	35	<46	TC, LDL
Alagawany et al 2015	Hubbard	<6	35	<46	TC, HDL-c, LDL-c
Arslan et al 2017	Hubbard	<6	35	<46	TC, HDL-c, LDL-c
Arslan et al 2017	Hubbard	>6	35	<46	TC, HDL-c, LDL-c
Arslan et al 2017	Hubbard	>6	35	<46	TC, HDL-c, LDL-c
Emadi et al 2007	Ross	<6	21	>46	TC, HDL-c, LDL-c
Emadi et al 2007	Ross	<6	21	>46	TC, HDL-c, LDL-c
Emadi et al 2007	Ross	>6	21	>46	TC, HDL-c, LDL-c
Emadi et al 2007	Ross	<6	35	>46	TC, HDL-c, LDL-c
Emadi et al 2007	Ross	<6	35	>46	TC, HDL-c
Emadi et al 2007	Ross	>6	35	>46	TC, HDL-c
Emadi et al 2007	Ross	<6	42	>46	TC, HDL-c
Emadi et al 2007	Ross	<6	42	>46	HDL-c
Emadi et al 2007	Ross	>6	42	>46	HDL-c
Kamdev et al. 2016	Cobb	<6	21	<46	TC
Kamdev et al. 2016	Cobb	>6	42	<46	TC
Mehala & Moorthy 2008	Cobb	<6	42	<46	TC, HDL-c
Mehala & Moorthy 2008	Cobb	<6	42	<46	TC, HDL-c
Mehala & Moorthy 2008	Cobb	<6	42	<46	HDL-c
Mehala & Moorthy 2008	Cobb	<6	42	<46	HDL-c
Tirupati Reddy et.al. 2012	Cobb	<6	42	<46	TC
Tirupati Reddy et.al. 2012	Cobb	<6	42	<46	TC
Ratika et al. 2018	Ross	<6	21	<46	TC
Daneshyar et al. 2011	Ross	<6	21	>46	TC, HDL-c, LDL-c
Daneshyar et al. 2011	Ross	<6	21	>46	TC, HDL-c, LDL-c
Daneshyar et al. 2011	Ross	>6	21	>46	TC, HDL-c, LDL-c
Daneshyar et al. 2011	Ross	<6	42	>46	TC, HDL-c, LDL-c
Daneshyar et al. 2011	Ross	<6	42	>46	TC, LDL-c
Akbarian et al. 2012	Ross	<6	21	<46	TC, HDL-c, LDL-c
Al-Noori et al. 2011	Ross	<6	42	<46	TC
Al-Noori et al. 2011	Ross	>6	42	<46	TC
Saima et al. 2014	Cobb	<6	42	<46	TC

SL = supplementation level, DOS = duration of supplementation; TC = total cholesterol; HDL-c = high density lipoprotein cholesterol; LDL-c = low density lipoprotein cholesterol

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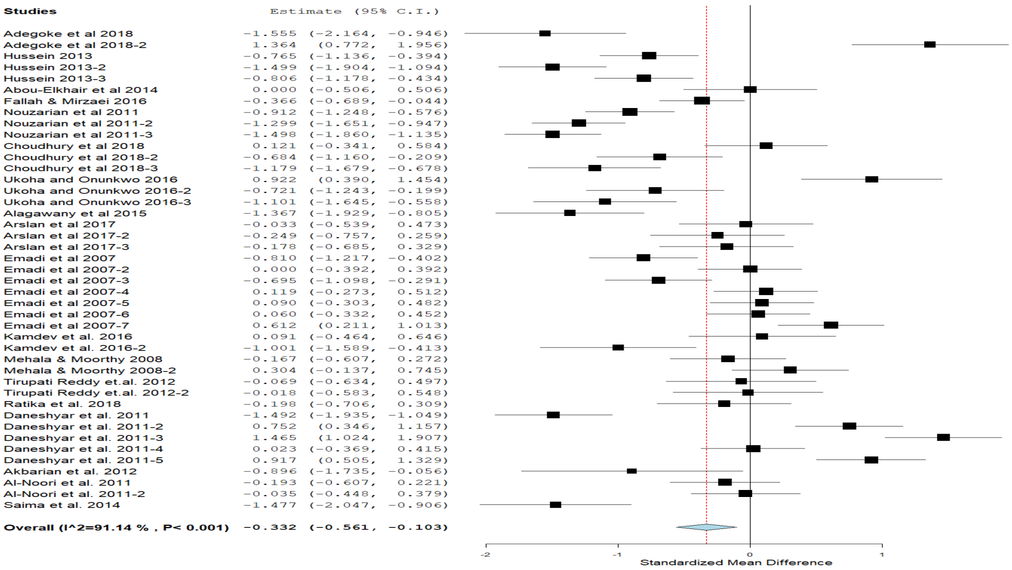

Figure 1. *Forest plots of the effect of dietary turmeric supplementation on TC (mg/dl) in broiler chickens. The solid vertical line represents the line of no effect. Points to the left of the vertical line depict a reduction in the parameter of interest and point to the right depicts an increase. Each square in the plot represents the mean effect size for the study, while the line that joined the individual square depict the lower and upper confidence interval of the effect size. The dotted line with the diamond at the base showing the 95% CI depicts the pooled estimation.* I^2 *is a measure of variance above chance among studies included in the analysis. Pooled estimation is considered significant when the diamond did not touch the solid vertical line*

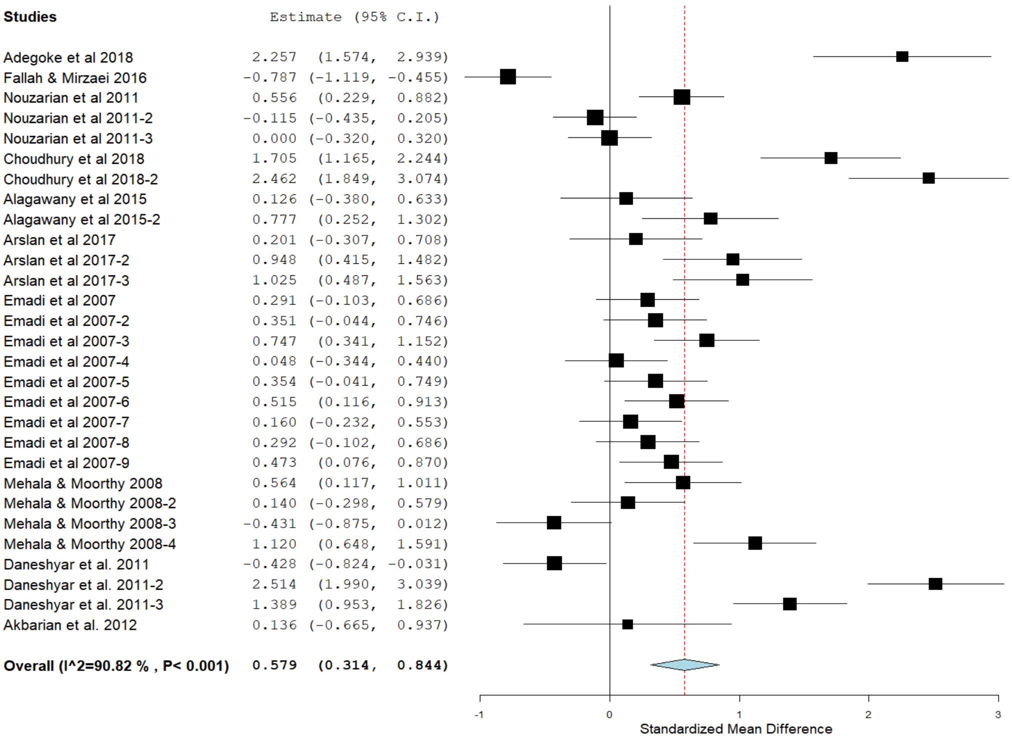

Figure 2. *Forest plots of the effect of dietary turmeric supplementation on HDL-c (mg/dl) in broiler chickens*

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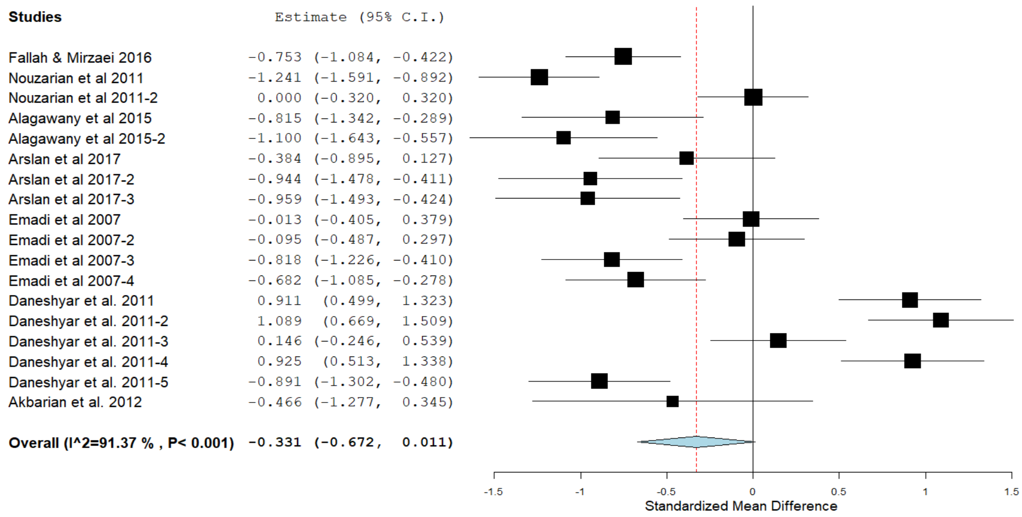

Figure 3. *Forest plots of the effect of dietary turmeric supplementation on LDL-c (mg/dl) in broiler chickens*

Table 2. *Subgroup analysis and meta-regression of effects of the moderators on TC in broiler chickens*

Covariates	Sub group analysis			Meta-regression		
	SMD	95% CI	I^2 (%)	Q_M	df	R^2 (%)
Supplementation level				0.600	1	0.00
< 6 g/kg	-0.259	-0.514 to -0.004	88.27*			
> 6 g/kg	-0.452	-0.890 to -0.013	93.73*			
Mean	-0.332*	-0.561 to -0.103	91.14*			
Duration of supplementation				1.030	3	0.00
21 d	-0.188	-0.800 to 0.423	93.70*			
35 d	-0.168	-0.464 to 0.128	69.39*			
42 d	-0.444*	-0.758 to -0.129	91.85*			
56 d	-0.300	-1.512 to 0.913	93.57*			
Mean	-0.332*	-0.561 to -0.103	91.14*			
Strain of broiler used				0.149	4	0.00
Ross	-0.321*	-0.644 to -0.002	93.32*			
Arbor acres	-0.388	-1.317 to 0.541	93.70*			
Hubbard	-0.447	-1.018 to 0.124	79.25*			
Cobb	-0.279	-0.684 to 0.126	79.15*			
Anak	-0.300	-1.512 to 0.913	93.57*			
Mean	-0.332*	-0.561 to -0.103	91.14*			
Number of bird / treatment				0.004	1	0.00
< 46 birds	-0.337*	-0.605 to -0.068	84.52*			
> 46 birds	-0.324	-0.700 to 0.052	94.45*			
Mean	-0.332*	-0.561 to -0.103	91.14*			

*Significant at $p<0.01$; SMD = standardized mean difference; CI = confidence interval; I^2 = heterogeneity; Q_M = moderator coefficient; df = degree of freedom; R^2 = amount of heterogeneity accounted for

The sub-analysis of the impact of turmeric on HDL-c as illustrated in *Table 3* revealed that the effect of turmeric on HDL-c was more pronounced in chickens from studies that fed turmeric at < 6 g/kg feed than studies that fed > 6 g turmeric/kg feed. Birds from studies that fed turmeric for 35 and 42 days had statistically increased plasma HDL-c relative to those that fed the same diet for 21 days. However, we noticed

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that effect estimation was higher in chickens from studies that fed turmeric for 42 days. Strain influenced (p<0.01) HDL-c with chickens from studies that used Hubbard and Arbor acres recording higher HDL-c as compared to those studies that used Ross and Cobb. Higher (p<0.01) HDL-c value was obtained in chickens from trials that included < 46 birds per treatment group than trials that included > 46 birds. The sub-analysis of the influence of covariates on plasma LDL-c as presented in *Table 4* revealed that birds from studies that fed turmeric at > 6 g/kg feed for 35 days (p<0.01) had statistically reduced LDL-c. Additionally, broiler chickens from trials that used Hubbard and included less than 46 birds per treatment group had significantly reduced LDL-c.

Table 3. *Subgroup analysis and meta-regression of effects of the moderators on HDL-c in broiler chickens*

Covariates	Subgroup analysis			Meta-regression		
	SMD	95% CI	I^2 (%)	Q_M	df	R^2 (%)
Supplementation level				0.037	1	0.00
< 6 g/kg	0.602*	0.245 to 0.959	92.72*			
> 6 g/kg	0.511*	0.206 to 0.816	76.97*			
Mean	0.579*	0.335 to 0.827	90.82*			
Duration of supplementation				0.129	2	0.00
21 d	0.601	-0.146 to 1.347	93.87*			
35 d	0.476*	0.225 to 0.726	56.48			
42 d	0.622*	0.214 to 1.030	93.20*			
Mean	0.579*	0.314 to 0.844	90.82*			
Strain of broiler used				17.8*	3	37.35
Ross	0.372	0.063 to 0.680	90.44*			
Arbor acres	2.116*	1.644 to 2.587	44.50			
Hubbard	0.608*	0.235 to 0.981	60.81			
Cobb	0.345	-0.290 to 0.980	87.44*			
Mean	0.579*	0.314 to 0.844	90.82*			
No. bird / treatment				2.33	1	5.05
< 46 birds	0.837*	0.391 to 1.282	89.33*			
> 46 birds	0.383	0.065 to 0.702	91.03*			
Mean	0.579*	0.314 to 0.844	90.82*			

Table 4. *Subgroup analysis and meta-regression of effects of the moderators on LDL-c in broiler chickens*

Covariates	Subgroup analysis			Meta-regression		
	SMD	95%CI	I^2 (%)	Q_M	df	R^2 (%)
Supplementation level				5.70	1	23.53
< 6 g/kg	-0.071	-0.484 to 0.342	91.04*			
> 6 g/kg	-0.842*	-1.286 to -0.399	84.29*			
Mean	-0.331	-0.672 to 0.011	91.37*			
Duration of supplementation				9.65*	2	34.62
21 d	0.322	-0.240 to 0.883	87.10*			
35 d	-0.827*	-1.032 to -0.623	0.00			
42 d	-0.359	-0.892 to 0.174	91.16*			
Mean	-0.331	-0.672 to 0.011	91.37*			
Broiler strain used				3.63	1	14.20
Ross	-0.144	-0.558 to 0.270	92.88*			
Hubbard	-0.831*	-1.076 to -0.586	6.53			
Mean	-0.331	-0.672 to -0.011	91.37*			
No. bird / treatment				3.61	1	14.15
< 46 birds	-0.802*	-1.029 to -0.574	0.00			
> 46 birds	-0.122	-0.555 to 0.311	93.46*			
Mean	-0.331*	-0.672 to -0.011	91.37*			

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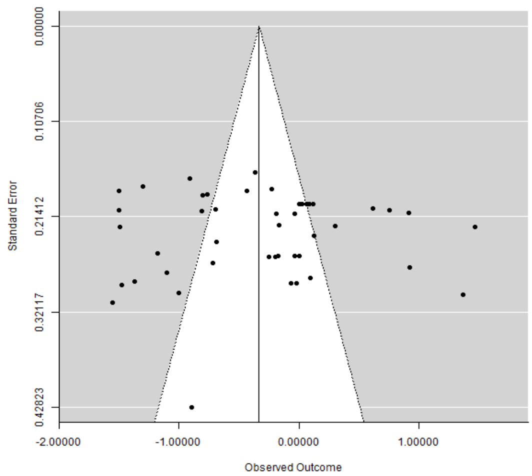
Analysis of heterogeneity and publication bias

Results of the potential causes of heterogeneity as shown in the results of Model II showed no significant association between covariates and plasma TC (*Table 2*). However, broiler strain (Q_M = 17.80, p<0.01) influenced HDL-c and accounted for 37.35% of the between-study variance (*Table 3*), while duration of supplementation (Q_M = 9.65, p < 0.01) influenced plasma LDL-c and accounted for 34.62% of between-study variance (*Table 4*). The funnel plots of differences in means of plasma TC, HDL-c and LDC-c between broiler chickens fed diet with or without turmeric as displayed in *Figure 4a*, *b* and *c*, respectively suggest the existence of publication bias. The Rosenberg's Nfs for the database was 565, which is more than 2 folds of the threshold of 280 (5 × n = 54 + 10) needed to find the mean effect size robust. Therefore, the existence of publication bias was not a serious problem in the current meta-analysis as a large number of unpublished studies would be required to alter the significant difference between the experimental and control groups.

a



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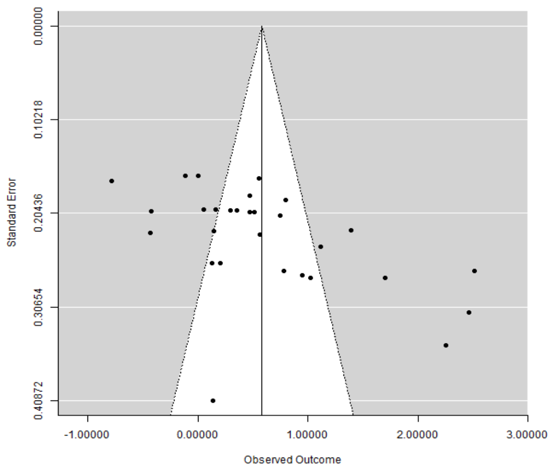

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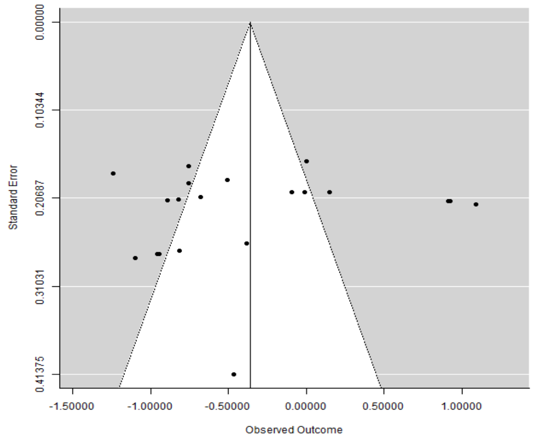

Figure 4. *Funnel plots of the effect of dietary turmeric supplementation on concentrations of TC (a), HDL-c (b) and LDC-c (c) in broiler chickens*

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Discussion

To our knowledge this study is the first meta-analysis that evaluated the effect of turmeric on plasma TC, LDL-c and HDL-c concentrations in broiler chickens. The main thrust of this meta-analysis was to provide evidence that turmeric improves health indices in broiler chickens. Blood biochemical components are indicators of the state of the cells, tissue and organs in farm animals (Akinfola et al., 2007). The association between blood cholesterol and nutrition in animal model has been documented (Okeudo, 2000; Iwuji et al., 2018). The finding from this meta-analysis showed that turmeric influenced plasma cholesterol characteristics in broiler chickens. This is in harmony with Kermanshahi and Riasi (2006) and Hosseini-Vashan et al. (2012) who reported significantly reduced TC and LDL-c value in broiler chickens fed turmeric supplemented diets for 42 days. More so, turmeric supplementation increased plasma HDL-c and reduced plasma TC levels which further confirm the earlier report that turmeric improve plasma HDL-c and reduce the plasma LDL-c in broiler chickens (Emadi et al., 2007). However, the result of present meta-analysis differed from Mehala and Moorthy (2008), who reported lack of significant changes in plasma TC levels of broiler chickens fed turmeric at 2 g/kg feed. The reason for this disparity is not known, however it could be attributed to supplementation dose. The superior effect of dietary turmeric in lowering plasma TC and LDL-c concentrations in broiler chickens as seen in the present meta-analysis may be due to increased bioavailability of turmeric bioactive compounds thus inhibiting the production of hepatic 3-hydroxyl-3-methyglutaryl-CoA reductase and cholesterol 7α-hydroxylase by up-regulation of ATP-binding cassette transporter A1 in foam cells in broiler chickens fed turmeric.

Birds fed turmeric > 6 g/kg feed had reduced TC and LDL-c than birds fed the same diet at < 6 g/kg feed, but birds fed turmeric at < 6 g/kg feed had better HDL-c. This systematic review has shown the effectiveness of turmeric diet at a level more than 6 g/kg feed in lowering plasma TC and LDL-c concentrations in broiler chickens. Importantly, birds from studies that fed less or more than 6 g turmeric/kg feed had better HDL-c value. However, the effect was more pronounced in studies that fed turmeric at > 6 g/kg feed. The reason for the disparity is not known, however, it is likely that blood cholesterol parameters require different dietary levels and nutrient components for its production in the liver. This observation is in line with the earlier results of others (Ogbuewu and Mbajiorgu, 2019; Modisaojang-Mojanaja et al., 2019) who reported that dietary nutrient requirements for optimizing different blood components in animal model are dynamic. However, it is advised that more research be conducted to determine the exact amount of turmeric required to optimize the different blood cholesterol components in broiler chickens using a quadratic optimization model. Birds from studies that fed turmeric for 35 days had significantly reduced LDL-c, whereas birds from studies that fed turmeric for 21 and 42 days had comparable LDL-c concentrations. Conversely, birds from trials that fed turmeric for 35 and 42 days had significantly better HDL-c compared to birds from the experiment that fed the same ration for 21 days. The plasma TC levels were significantly reduced in birds fed turmeric for 35 days relative to those on the other 3 supplementation durations. The superior plasma cholesterol values of broiler chickens on turmeric intervention for 35 and 42 days as compared to those on turmeric intervention for 21 and 56 days is an indication that impact of turmeric in blood cholesterol levels of broiler chickens may be dependent on duration feeding. Thus for improved blood cholesterol production in broiler chickens, turmeric-based diets should be fed between 35 and 42 days. The

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present meta-analysis showed that broilers from Hubbard strains had significantly reduced plasma LDL-c, while those from Hubbard and Arbor acres strains had significantly better plasma HDL-c compared to broiler chickens from the other three strains (Ross, Cobb and Anak). The physiological explanation for this discrepancy is not fully known. However, it may be partially attributed to genetic variations among the different broiler strains included in the meta-analysis (Acar et al., 1991). Results also showed that number of broilers included in each treatment affected plasma cholesterol concentration with those from studies that included less than 46 birds per treatment having significantly better LDL-c and HDL-c than broilers from studies that included more than 46 broiler chickens. The observed poor blood cholesterol levels recorded in broiler chickens from trials that included more than 46 chickens per treatment could be explained in part to overcrowding stress which has been established to negatively affect the biochemical and physiological parameters in broiler chickens (Thaxton et al., 2005; Guardia et al., 2011).

Heterogeneity and publication bias exist in the current meta-analysis. This was envisaged as studies used for the analysis were drawn from different part of the globe. Meta-regression of the moderators that may act as effect modifiers (i.e. chicken strain, supplementation level, duration of supplementation and number of broilers included in each treatment) accounted for most of the heterogeneity. Furthermore, we observed that duration of supplementation and chicken strain are significant predictors of plasma LDL-c and serum HDL-c, respectively in broiler chickens, and explained 72% of the heterogeneity among studies included the analysis. Funnel plots suggest the existence of publication bias and the Rosenberg's Nfs for the database is 565, which is more than 2 folds of the threshold of 280 ($5 \times n = 54 + 10$) needed to find the mean effect size robust. However, Jennions et al. (2013) have reported that meta-analysis results can still be robust in the presence of publication bias provided Nfs is greater than ($5n + 10$). Thus, the existence of publication bias was not an issue in the current meta-analysis as large number of unpublished studies would be required to alter the significant difference found between the mean effect size of birds in experimental and control groups.

Conclusion

The findings of this meta-analysis revealed that dietary turmeric supplementation improved plasma cholesterol values in broiler chickens. However, sub-analysis results indicated that dietary turmeric supplementation at a rate less than 6 g/kg feed or more than 6 g/kg feed reduced plasma TC concentration. Broiler chickens fed diet supplemented with turmeric at a rate more than 6 g/kg feed, on the other hand, reduced the concentrations of LDL-c in broiler chickens. Dietary turmeric supplementation improved plasma HDL-c; however, the effect was higher in the group that received turmeric at a rate more than 6 g/kg feed. Meta-regression analysis revealed significant associations between covariates (duration of supplementation and chicken strain) and outcomes of interest (LDL-c and HDL-c) and explained 72% of the sources of heterogeneity among the studies included in the meta-analysis. It is concluded that turmeric supplementation to the rations of broiler chickens is desirable, mainly due to its beneficial influences on blood TC, LDL-c and HDL-c. However, more studies are needed to ascertain the exact turmeric supplementation dose that optimize blood TC, LDL-c and HDL-c in broiler chickens.

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REFERENCES

[1] Abou-Elkhair, R., Ahmed, H. A., Selim, S. (2014): Effects of black pepper (*Piper nigrum*), turmeric powder (*Curcuma longa*) and coriander seeds (*Coriandrum sativum*) and their combinations as feed additives on growth performance, carcass traits, some blood parameters and humoral immune response of broiler chickens. – Asian-Australasian Journal of Animal Science 27: 847-854.

[2] Acar, N., Moran, E. T. Jr., Bligili, S. F. (1991): Live performance and carcass yield of male broilers from two commercial strain crosses receiving rations containing lysine below and above the established requirement between six and eight weeks of age. – Poultry Science 70: 2315-2321.

[3] Adegoke, A. V., Abimbola, M. A., Sanwo, K. A., Egbeyale, L. T., Abiona, J. A., Oso, A. O., Iposu, S. O. (2018): Performance and blood biochemistry profile of broiler chickens fed dietary turmeric (*Curcuma longa*) powder and cayenne pepper (*Capsicum frutescens*) powders as antioxidants. – Veterinary and Animal Science 6: 95-102.

[4] Akbarian, A., Golian, A., Kermanshahi, H., Gilani, A., Moradi, S. (2012): Influence of turmeric rhizome and black pepper on blood constituents and performance of broiler chickens. – African Journal of Biotechnology 11: 8606-8611.

[5] Akinfola, E. O., Matanmi, O., Fatufe, A. A. (2007): Effect of residual cyanogenic glycosides in cassava based diets on serum metabolites of cockerel chicks. – Proceedings of Annual Conference Nigerian Society for Animal Production, pp: 105-107.

[6] Alagawany, M. M. (2015): Nutritional and biological effects of turmeric (*Curcuma longa*) supplementation on performance, serum biochemical parameters and oxidative status of broiler chicks exposed to endosulfan in the diets. – Asian Journal of Animal and Veterinary Advances 10: 86-96.

[7] Al-Noori, M. A., Hossain, A. B., AI-Maahidy, A. H. A., Th, S., AI-Rawi, J. (2011): The effect of dietary *Curcuma longa* powder supplementation on some blood parameters and carcass traits of broiler chickens. – Al-Anbar Journal of Veterinary Sciences 4: 69-74.

[8] Arslan, M., Haq, A., Ashraf, M., Iqbal, J., Mund, M. D. (2017): Effect of turmeric (*Curcuma longa*) supplementation on growth performance, immune response, carcass characteristics and cholesterol profile in broilers. – Veterinaria 66: 16-20.

[9] Choudhury, D., Mahanta, J., Sapcota, D., Saikia, B., Islam, R. (2018): Effect of dietary supplementation of turmeric (*Curcuma longa*) powder on the performance of commercial broiler chicken. – International Jounal of Livestock Research 8: 182-191.

[10] Daneshyar, M., Alizadeh, G. M., Sabzi, B. F., Farhangpajhoh, F., Aghaei, M. (2011): Effects of dietary turmeric supplementation on plasma lipoproteins, meat quality and fatty acid composition in broilers. – South African Journal of Animal Sciences 41: 420-428.

[11] Emadi, M., Kermanshahi, H. (2006): Effect of turmeric rhizome powder on performance and carcass characteristics of broiler chickens. – International Journal of Poultry Sciences 5: 1069-1072.

[12] Emadi, M., Kermanshahi, H., Maroufyan, E. (2007): Effect of varying levels of turmeric rhizome powder on some blood parameters of broiler chickens fed corn-soybean meal based diets. – International Journal of Poultry Sciences 6: 345-348.

[13] Fallah, R., Mirzaei, E. (2016): Effect of dietary inclusion of turmeric and thyme powders on performance, blood parameters and immune system of broiler chickens. – Journal of Livestock Sciences 7: 180-186.

[14] Guardia, S., Konsak, B., Combes, S., Levenez, F., Cauquil, L., Guillot, J. F., Moreau-Vauzelle, C., Lessire, M., Juin, H., Gabriel, I. (2011): Effects of stocking density on the growth performance and digestive microbiota of broiler chickens. – Poultry Science 90: 1878-1889.

[15] Hedges, L. V., Olkin, I. (1985): Statistical Methods for Meta-Analysis. – Academic Press, San Diego, CA, USA.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1806_80098021

[16] Higgins, J., Thompson, S. G., Deeks, J. J., Altman, D. G. (2003): Measuring inconsistency in meta-analyses. – British Medical Journal 327: 557-560.
[17] Higgins, J. P. T., Deeks, J. J. (2011): Chapter 7: Selecting studies and collecting data. – In: Higgins, J. P., Green, S. (eds.) Cochrane Handbook for Systematic Reviews of nterventions Version 5.1.0 (updated March 2011). The Cochrane Collaboration, 2011. Available from http://handbook.cochrane.org/ (Accessed: 28th April, 2020).
[18] Hosseini-Vashan, S. J., Golian, A., Yaghobfar, A., Zarban, A., Afzali, N., Esmaeilinasab, P. (2012): Antioxidant status, immune system, blood metabolites and carcass characteristic of broiler chickens fed turmeric rhizome powder under heat stress. – African Journal of Biotechnology 11: 16118-16125.
[19] Hussein, S. N. (2013): Effect of turmeric (*Curcuma longa*) powder on growth performance, carcass traits, meat quality, and serum biochemical parameters in broilers. – Journal of Advanced Biomedicine and Pathobiology Research 3: 25-32.
[20] Iwuji, T. C., Ogbuewu, I. P., Herbert, U. (2018): Haematology and serum biochemistry of growing New Zealand white (NZW) rabbits administered Panax ginseng extracts. – Comparative Clinical Pathology 27: 1691-1697.
[21] Jennions, M. D., Lortie, C. J., Rosenberg, M. S., Rothstein, H. R. (2013): Chapter 14: Publication and related bias. – In: Koricheva, J., Gurevitch, J., Mengersen, K. (eds.) Handbook of meta-analysis in Ecology and Evolution. – Princeton University Press, Princeton and London, pp. 207-236.
[22] Jurenka, J. S. (2009): Anti-inflammatory properties of curcumin, a major constituent of *Curcuma longa*: a review of preclinical and clinical research. – Altern Medicine Rev 14: 141-153.
[23] Kamdev, S., Swain, P., Behera, K., Nayak, S. M., Barik, S. R., Patro, P., Meher, P. (2016): Effect of turmeric (*Curcuma Longa*) supplementation on growth and blood chemistry of broilers. – Explor Animal Medical Research 6: 75-79.
[24] Kermanshahi, H., Riasi, A. (2006): Effect of turmeric rhizome powder (*Curcuma longa*) and soluble NSP degrading enzyme on some blood parameters of laying hens. – International Journal of Poultry Science 5: 494-498.
[25] Koricheva, J., Gurevitch, J., Mengersen, K. (2013): Handbook of meta-analysis in ecology and evolution. – Princeton University Press, Princeton and Oxford.
[26] Mehala, C., Moorthy, M. (2008): Production performance of broilers fed with *Aloe vera* and *Curcuma longa* (Turmeric). – International Journal of Poultry Science 7: 852-856.
[27] Modisaojang-Mojanaja, M. M. C., Ogbuewu, I. P., Oguttu, J. W., Mbajiorgu, C. A. (2019): Moderate levels of dietary *Moringa oleifera* leaf meal supplementation improve blood values in broiler chickens. – Journal of Agriculture Food and Environment 17: 39-44.
[28] Nouzarian, R., Tabeidianlo, S. A., Toghyani, M., Ghalamkari, G., Toghyani, M. (2011): Effect of turmeric powder on performance, carcass traits, humoral immune responses, and serum metabolites in broiler chickens. – Journal of Animal and Feed Sciences 20: 389-400.
[29] Ogbuewu, I. P., Okehi, M. C., Jiwuba, P. C. (2017): Effect of phytobiotic (turmeric) supplementation on semen and blood characteristics of rabbits. – Comparative Clinical Pathology 26: 817-822.
[30] Ogbuewu, I. P., Mbajiorgu, C. A. (2019): Supplementation and optimization of ginger (*Zingiber officinale*) rhizome powder in growing rabbit diets. – Indian Journal of Animal Research, doi: 10.18805/ijar.B-101.
[31] Okeudo, N. J. (2000): Introductory biochemistry, 1st edition. – T'Afrique International Associate Publication, Owerri.
[32] Rahimi, H. R., Kazemi-Oskuee, R. (2014): Curcumin from traditional Iranian medicine to molecular medicine. – Razavi Int Journal of Medicine 2: 3-4.
[33] Ratika, K., Singh, R. K. J., Singh, R. K., Singh, M. (2018): Weekly assessment of growth performance of broilers fed diet supplemented with garlic and turmeric powder and their

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1806_80098021

combination. – International Journal of Current Microbiology and Applied Science 7: 1373-1381.
[34] Ressing, M., Blettner, M., Klug, S. J. (2009): Systematic literature reviews and meta-analyses: Part 6 of a series on evaluation of scientific publications. – Dtsch Arztebl Int 106: 456-463.
[35] Saima, A., Mukhtar, M., Manzoor, S., Hssain, Z., Ali, A., Tabassum, R., Imran, M., Amer, M. Y., Bhatti, N. (2014): Effect of garlic, black seed and turmeric on the growth of broiler chicken. – Pakistan Journal Nutrition 13: 204-210.
[36] Thaxton, J. P., Olanrewaju, H. A., Branton, S. L., Roush, W. B. (2005): Stocking density effects on male broilers grown to 1.8 kilograms of body weight. – Poultry Science 708: 344-351.
[37] Tirupati, E. R., Sudhakara, P. R., Satyanarayana, R. P. V. V., Shakila, S. (2012): Effect of herbal preparations (*Phyllanthus emblica*, *Curcuma longa* and *Ocimum sanctum*) on the performance of broilers. – Tamil-Nadu Journal of Veternary and Animal Sciences 8: 209-214.
[38] Ukoha, O. A., Onunkwo, D. N. (2016): The effect of turmeric (*Curcuma longa*) on growth performance of broiler chickens. – International Research Journal of Agriculture and Aquatic Science 3: 131-135.
[39] Wallace, B. C., Lajeunesse, M. J., Dietz, G., Dahabreh, I. J., Trikalinos, T. A., Schmid, C. H., Gurevitch, J. (2016): OpenMEE: intuitive, open-source software for meta-analysis in ecology and evolutionary biology. – Methods Ecology and Evolution 8: 941-947.