

RESEARCH ARTICLE

Meta Analysis of Growth Performance of Broilers in Response to Dietary Cassava Leaf Meal Intervention

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Abstract: The use of Cassava Leaf Meal (CLM) in broiler diets has gained attention due to its high crude protein content (24-35%) and other valuable nutrients. Therefore, the objective of this meta-analysis was to assess the impact of diets with and without CLM on broiler growth performance. Search performed on four bibliographic databases produced 584 articles of which 11 were used for meta-analysis. A Random-Effects Model (REM) was employed, with results expressed as Mean Difference (MD). Data was pooled in Open OpenMEE software and results suggested that CLM significantly decreased Feed Intake (FI) ($p < 0.001$) and Average Daily Gain (ADG) in comparison with control treatments (MD = 0.45 g/bird/day (d), $p < 0.001$ and MD = 0.83 g/bird/d, respectively). Results also indicated that CLM increased Feed Conversion Ratio (FCR) compared with the control treatment (MD = 0.27, $p < 0.001$). Subgroup analyses showed that Cobb broilers utilized CLM-based diets better than Anak broilers. Feeding duration also influenced the analysed outcomes: adverse impacts on feed intake and FCR were more pronounced during the standard 1-42-day growth phase than the extended 1- 56-day phase. Dose-response evaluation indicated differences in growth parameters across low, moderate, and high CLM inclusion, revealing that low CLM levels are more effective in improving broiler growth performance. Meta-regression suggested that inclusion level and broiler strain were predictors of growth performance in broilers offered CLM-based diets. In conclusion, inclusion of CLM in broiler nutrition at $\leq 5\%$ enhanced growth performance. It is recommended that the findings of this study serve as a decision-support system for safe and effective use of CLM in broiler nutrition.

Keywords: Leaf Meal, Broiler Nutrition, Feed Intake, Daily Gain, Feed Conversion, Data Synthesis

Received: 16-07-2026 | **Revised:** 24-08-2026 | **Accepted:** 31-08-2026 | **DOI:** 10.3844/ajavsp.2026.21.03.023

Introduction

With the growing demand for sustainable broiler farming, developing countries are increasingly turning to alternative feed sources [1-2]. The incorporation of cassava, one such alternative feedstuff into poultry diets is to reduce reliance on maize and soybean [2-4]. Cassava is widely cultivated in many tropical countries because of its strong tolerance to drought, ability to thrive in low-quality soil and resilience to erratic rainfall [5]. The global annual production is estimated at 315 million metric tons in 2021, 9% higher than the value obtained in 2017 [6]. During harvest, a substantial portion of residues

(peels and leaves) are generated which are largely underutilized despite their availability and rich nutrient profiles [5]. Leaves make up approximately 6% of cassava plants and contain 24-35% dry matter crude protein, in addition to micronutrients and carotenoids [7-8]. Cassava Leaf Meal (CLM) is rich in important amino acids, particularly leucine, glutamic acid, and aspartic acid [8]. Studies indicate that CLM is deficient in cysteine and methionine, but it is a good source of lysine, which is commonly deficient in cereal grains [9-10]. This makes CLM a valuable feed resource for enhancing protein quality in chicken diets.

Despite its rich nutrient profile, the inclusion of CLM in chicken feed is hindered by its high fibre content (15-25% dry matter), presence of cyanogenic glycosides (200 to 400 mg/kg), poor protein digestibility, and deficiencies in methionine and cysteine compared to cereal grains [5,11]. Cassava contains high amounts of cyanogenic glycosides and other Anti-Nutritional Factors (ANFs), including condensed tannins, fibre, and phytate. Therefore, fresh cassava leaf needs to be processed through drying, enzyme supplementation, or a combination of both [5]. These processing methods help to reduce cyanogenic glycoside levels, improve digestibility, and enhance nutrient utilisation in broiler rations [3, 12].

Studies have found positive effects of CLM at low inclusion levels on broiler growth performance [13-14]. In a similar experiment, inclusion of 10% CLM in broilers feed had no deleterious effect on growth performance [15]. In contrast, dietary CLM at 2.5-7.8% in broiler diets reduced growth performance [16]. These differences could be influenced by factors such as cassava variety, plant age, processing method, inclusion levels, diet composition, and the genetic makeup of the chicken [1, 17]. These variations have left nutritionists and farmers unsure about how to use CLM safely and effectively in broiler diets. To harness the nutritional benefits of CLM as a viable alternative feedstuff, and boost broiler productivity, rigorous and systematic methods are needed to evaluate its impact on broiler performance.

The application of meta-analysis in animal science discipline is widely recognized as an effective strategy for pooling multiple studies with inconsistent results, thereby resolving uncertainty, identifying knowledge gaps, and generating new insights [17-18]. In addition, meta-regression quantifies the extent to which moderator variables account for heterogeneity in broiler growth performance [17]. It is hypothesized that including CLM in broiler diets at the right amount will improve growth performance. Thus, this meta-analysis aimed to:

- (i) Quantitatively assess the effect of CLM inclusion on broiler growth performance
- (ii) Conduct a meta-regression analysis to determine the amount of variation that is explained by moderator variables

Materials and Methods

Selection Criteria, Data Sources, and Extraction

Four databases (PubMed, Web of Science, Scopus, and Google Scholar) were systematically searched for articles published on the topic without date and language restrictions. A manual search was also performed on reference sections of the identified studies for other relevant publications. Search terms include CLM*, broiler*, broiler chicken*, growth performance*, FI*, daily gain*, ADG*, weight gain*, and FCR*. The trials included in the present study met the following predefined eligibility criteria:

- (i) Were randomised controlled original trials that used diseased free broilers
- (ii) Findings published in peer-reviewed journals
- (iii) CLM was administered via the feed
- (iv) Reported the means of feed intake, FCR, or ADG along with their Standard Error (SE) or Standard Deviation (SD). Reviews and studies that appear in two or more databases were excluded. Studies that blended CLM with other cassava products and trials not performed in broilers were not used. Titles, abstracts, and full text were assessed and 11 trials that met the inclusion criteria (Figure 1). Data on study characteristics (author's information, publication date and country), moderator variables (broiler strains, inclusion level, and feeding duration of CLM) and measured outcomes (feed intake, ADG, and FCR) were obtained from each trial. For studies that reported SE, SD was computed as $SD = SE \times \sqrt{n}$, with n denoting the number of replications. Results presented in graphs were digitized with Web-Plot-Digitizer (<https://apps.automeris.io/wpd/>)

Statistical Analysis

Statistical analysis utilized OpenMEE software [19]. Results were reported as Mean Differences (MD) at 95% Confidence Interval (CI) based on REM. This model assumes that the true effect may vary across studies, and accounts for both between-study heterogeneity and sampling error [20].

A mixed-effects meta-regression analysis was conducted to explore the sources of variability in the effects of CLM on broiler performance. This analysis explores the association between potential moderators (broiler strains, broiler age, CLM inclusion level, feeding duration) and growth performance outcomes. Pre-defined subgroup analyses were also assessed based on moderators considered to likely influence the effect CLM. These included:

- (i) Broiler strains
- (ii) Inclusion level
- (iii) Feeding duration. CLM inclusion levels were grouped into three categories: $\leq 5\%$ (low), 5.1-10.0% (moderate), and $> 10\%$ (high). Subgroup analysis was performed only when individual strata contained at least three or more studies [21]. Consequently, subgroup analyses for Arbor Acres and Ross broilers were not conducted due to an insufficient number of studies in each strata

Heterogeneity among trials was examined using the Q statistic and quantified with I^2 statistic. The I^2 statistic was classified with 0-25% indicating no heterogeneity, 26-50% low, 51-75% moderate, and above 75% high heterogeneity [22]. Sensitivity analysis was performed to detect individual studies exerting undue effect on the overall pooled results [23]. This involves repeating the analysis severally, each time omitting one study. The Egger regression method was used to assess [24], and the corresponding P-values were reported for each outcome.

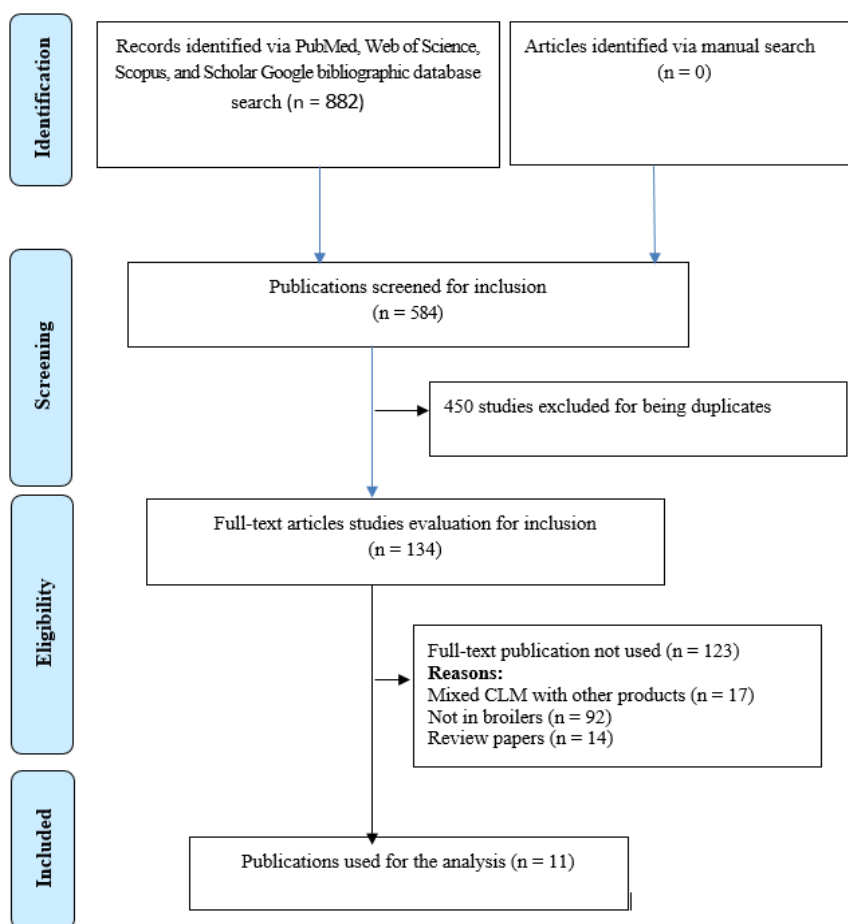


Fig. 1: Paper selection process for the meta-analysis

Results

Characteristics of Studies Used for the Meta Analysis

After thorough screening of the identified studies based on the predefined inclusion criteria, 11 studies [15-16, 25-33] were used for the meta-analysis (Supplementary Table S1). As shown in Table 1, most of the research were done in Nigeria (36.36%) and Fiji (18.18%). The majority of the articles were published in 2020 (18.18%) and 2024 (27.27%). Cobb broilers were the most frequently used strain (50.00%), followed by Anak (25.00%). Moderate CLM level (42.86%) was most common, followed by low (33.33%) and high (23.81%) levels.

Table 1: Study identity and moderators, and their percentage distribution

Study identification	Moderators	Levels	Frequency (%)
Publications year		1986	1 (9.09)
		2005	1 (9.09)
		2007	1 (9.09)
		2008	1 (9.09)
		2018	1 (9.09)
		2020	2 (18.18)
		2024	3 (27.27)
		2025	1 (9.09)
Study location		Bangladesh	1 (9.09)
		Fiji	2 (18.18)
		Samoa	1 (9.09)
		Nigeria	4 (36.36)
		Ethiopia	1 (9.09)
		Philippines	1 (9.09)
		USA	1 (9.09)
Moderators	Broiler strain	Arbor Acres	1 (12.50)
		Cobb	4 (50.00)
		Anak	2 (25.00)
		Ross	1 (12.50)
	Inclusion level (%)	≤5 (Low)	7 (33.33)
		5.1-10 (Moderate)	9 (42.86)
		> 10 (High)	5 (23.81)
	Feeding duration (day)	1.0-42	9 (18.18)

Feed Intake (FI)

The pooled estimate showed that CLM inclusion significantly decreased FI compared to the control group (MD = -0.45 g/bird/d; -5.98; -2.91; $p < 0.001$; Table 2). High heterogeneity was noticed across the 11 studies included in the meta-analysis (Q-statistic: $P < 0.001$; I^2 -test = 92%; Table 2). Subgroup analysis revealed that FI was reduced in experiments using Anak (MD = -7.75 g/bird/d; -13.84, -1.66; $p = 0.013$) and Cobb (MD = -1.53 g/bird/d; -2.79, -0.28; $p = 0.017$). FI was significantly lower in studies where CLM was for 1-42 d (MD = -4.72 g/bird/d; -6.26, -3.18; $p < 0.001$). Results revealed that FI dropped significantly in experiments that fed moderate (5.1-10.0%) (MD = -6.59 g/bird/d; -10.38, -2.80; $p < 0.001$) and high (>10%) inclusion levels (MD = -8.60 g/bird/d; 13.24, -3.95; $p < 0.001$).

In contrast, feed intake was not affected in experiments that fed ≤5% CLM (MD = -1.49 g/d; 95% CI -3.62, 0.65; $p < 0.172$). No significant publication bias was detected for feed intake based on Egger test. Table 3 indicates that inclusion level was significantly associated with feed intake ($p = 0.007$). However, inclusion level as a moderator accounted only 17% of the

sources of heterogeneity. There was no association between moderators (Strain and FD) and FI feed ($p = 0.179$ and $p = 0.302$, respectively; Table 3).

Table 2: Pooled and subgroup effects of dietary CLM on feed intake of broilers

Outcomes/ moderators	MD	95% CI		SE	p-Value	Heterogeneity				ET
						τ^2	Q	p-Value	I^2	
Pooled result	-0.45	-5.98,	-2.91	0.78	<0.001	18.35	495.93	<0.001	92	0.064
Subgroup										
Broiler strain										
Anak	-7.75	-13.84	-1.66	0.01	0.013					
Cobb	-1.53	-2.79	-0.28	0.64	0.017					
FD (d)										
1-42	-4.72	-6.26	-3.18	0.79	<0.001					
IL (%)										
≤5%	-1.49	-3.62	0.65	1.09	0.172					
5.1-10	-6.59	-10.38	-2.80	1.93	<0.001					
>10	-8.60	-13.24	-3.95	2.37	<0.001					

CLM = Cassava Leaf Meal; FD = Feeding Duration; IL = Inclusion Level; MD = Mean Difference; d = day; ET = Egger Test; CI = Confidence Interval; Q - statistic; I² = Inconsistency index; SE = Standard Error; p = probability

Table 3: Effects of CLM and moderators on growth parameters of broilers

Outcomes	Moderators	β	Q_M	df	p-value	R^2
FI (g/bird/d)	Broiler strain	0.67	4.90	3	0.179	10
	Inclusion level	-1.30	9.82	1	0.007	17
	Feeding duration	-5.03	1.07	1	0.302	0
FCR	Broiler strain	0.00	36.72	3	<0.001	58
	Inclusion level	0.05	9.52	2	0.009	17
	Feeding duration	0.31	1.65	1	0.199	2
ADG (g/bird/d)	Broiler strain	0.27	6.56	3	0.087	14
	Inclusion level	-1.942	12.32	2	0.002	22
	Feeding duration	-6.19	0.23	1	0.632	0

CLM = Cassava Leaf Meal; FI = Feed Intake; FCR = Feed Conversion Ratio; ADG = Average Daily Gain; Q_M = Coefficient of Moderators; df = degree of freedom; β = meta-regression coefficient; p = probability; R^2 = amount of I² explained by the moderator

Feed Conversion Ratio (FCR)

Pooled effect size showed that broilers from experiments that fed CLM had poor FCR compared to the control group (MD = 0.27; 0.18, 0.36; $p < 0.001$; Table 4). There is significant heterogeneity across the studies used for the computation of FCR (Q-statistic: $p < 0.001$; I²-test = 97%; Table 4). Compared with the control groups, FCR was significantly higher in experiments that used Anak broiler strain (MD = 0.83; 95% CI 0.49, 1.17; $p < 0.001$). In contrast, FCR was not significantly affected in experiments that used Cobb broiler strain (MD = -0.06; -0.03, 0.15; $p = 0.189$). Experiments that fed CLM-based diets for 1-42 d had significantly higher FCR than the control (MD = 0.30; 0.20, 0.40; $p < 0.001$). Results suggest that FCR were significantly higher in experiments that fed CLM-based diets at 5.1-10.0% (MD = 0.49; 0.28, 0.70; $p < 0.001$) and >10% (MD = 0.42; 0.21, 0.62; $p < 0.001$). On the other hand, FCR was not significantly affected in experiments that fed ≤5% CLM (MD = 0.05; -0.02, 0.12; $p = 0.181$). No significant publication bias was detected for FCR based on Egger test. Table 3 revealed that strains ($p < 0.001$) and inclusion level ($p = 0.009$) were significantly associated with FCR and accounted for 58% and 17% of the sources of variations, respectively. In contrast, FD was not significantly related with FCR ($p = 0.199$).

Table 4: Pooled and subgroup effects of dietary CLM on FCR of broilers

Outcomes/ moderators	MD	95% CI		SE	p-Value	Heterogeneity				ET
						tau ²	Q	p-Value	I ²	
Pooled result	0.27	0.18	0.36	0.05	<0.001	0.07	1270.49	<0.001	97	0.091
Subgroup										
Broiler strain										
Anak	0.83	0.49	1.17	0.17	<0.001					
Cobb	0.06	-0.03	0.15	0.05	0.189					
FD (d)										
1-42	0.30	0.20	0.40	0.05	<0.001					
IL (%)										
≤5%	0.05	-0.02	0.12	0.04	0.181					
5.1-10	0.49	0.28	0.70	0.11	<0.001					
>10	0.42	0.21	0.62	0.10	<0.001					

CLM = Cassava Leaf Meal; FD = Feeding Duration; IL inclusion level; MD = Mean Difference; d = day; ET = Egger Test; CI = Confidence Interval; Q = Q - statistic; I² = Inconsistency index; SE = Standard Error; p = probability

Average Daily Gain (ADG)

Pooled results revealed that CLM decreased ADG compared to control (MD = -0.83 g/bird/d; 95% CI -7.01, -4.64; p<0.001; Table 5). Significant heterogeneity was discovered across the trials used for the meta-analysis (Q-statistic: p<0.001; I²-test = 99%). Experiments that used Anak (MD = -0.86 g/bird/day; -12.76 -4.96; p<0.001) and Cobb (MD = -0.83 g/bird/d; -2.74 -0.98; p<0.001) had lower ADG than the controls. The study also revealed that broilers fed CLM for 1-42 d (MD = -0.06 g/bird/d; -7.32, -4.81; p<0.001) had decreased ADG. ADG was not negatively affected in experiments that included ≤5% CLM (MD = 0.97 g/d; -3.58, 0.36; p = 0.056). However, broilers that received CLM at ≤5% had significantly better ADG than those that received CLM at 5.1-10% (MD = -0.58 g/bird/d; -12.51, -6.66; p<0.001), and >10% (MD = -0.16 g/bird/d; -9.28 -5.05; p<0.001). There was no significant publication bias for ADG, suggesting an absence of significant publication bias. Inclusion level was significantly associated with ADG (p = 0.002) and, as a moderator, explained 22% of the observed heterogeneity (Table 3). Conversely, there was no significant relationship between moderators (broiler strains and FD) and ADG (p = 0.087 and p = 0.632, respectively).

Table 5: Pooled and subgroup effects of dietary CLM on ADG of broilers

Outcomes/ moderators	MD	95% CI		SE	p-Value	Heterogeneity				ET
						tau ²	Q	p-Value	I ²	
Pooled result	-0.83	-7.01	-4.64	0.60	<0.001	12.79	2708.16	<0.001	99	0.082
Subgroup										
Broiler strain										
Anak	-0.86	-12.76	-4.96	1.99	<0.001					
Cobb	-0.83	-2.74	-0.98	0.45	<0.001					
FD (d)										
1-42	-0.06	-7.32	-4.81	0.64	<0.001					
IL (%)										
≤5%	0.97	-3.58	0.36	0.82	0.056					
5.1-10	-0.58	-12.51	-6.66	1.49	<0.001					
>10	-0.16	-9.28	-5.05	1.08	<0.001					

CLM = Cassava Leaf Meal; FD = Feeding Duration; IL Inclusion Level; MD = Mean Difference; d = day; ET = EGGER TEst; CI = Confidence Interval; Q= Q -statistic; I² = Inconsistency index; SE = Standard Error; p = probability

Discussion

Growth performance in broilers is important in assessing profitability, health and operational efficiency. Understanding how broilers respond to CLM is essential for optimizing its inclusion and effective use in broiler feeding programs. The pooled results suggested that CLM-based diets significantly decreased feed intake and ADG while increasing FCR. Feed intake regulation in broilers is highly complex. In this meta-analysis, pooled results demonstrated that CLM-based diets significantly reduced feed intake in broilers. Although the exact mechanism underlying this reduction is not well understood, several plausible explanations have been proposed. One key factor is the presence of residual cyanogenic glycosides in CLM, which hydrolyse to release hydrogen cyanide (HCN), a highly toxic compound [4, 34]. The resulting HCN imparts a bitter taste that broilers find unpalatable, acting as a potent feeding deterrent and leading to both immediate and sustained decreases in voluntary feed intake. Another likely explanation is CLM's high crude fibre (15-25% on a dry matter) and insoluble carbohydrates, which increase digesta bulkiness, delay gastric emptying and increase gut viscosity [4]. These physical effects induce a sensation of gut fullness, suppresses appetite, and further reduces feed intake [34]. This reduction in feed intake aligns with earlier studies that reported decreased feed intake when 15% CLM was incorporated into broiler rations from 1 to 21 days of age [25, 31, 35]. However, the current finding contrasts with that of [16], who reported a significant increase in feed intake when 10% SBM was replaced with CLM broiler diets. These differences may be attributed to variations in broiler genetics and the amount of CLM added to the diets, both which have been demonstrated to affect feed intake [4].

This meta-analysis revealed that dietary CLM inclusion increased FCR in broilers. This finding agrees with [36], who reported higher FCR in broilers fed cassava by-product-based diets compared with those fed control diets without cassava by-products, indicating a negative effect of CLM on feed utilization efficiency. The high heterogeneity (97%) suggests that the impact of CLM on FCR is not uniform and may be influenced by factors such as fibre content, amino deficiencies, plant age, processing methods, broiler age and strain. These results indicate that diets having CLM should be supplemented with exogenous multi-enzymes to assist in fibre digestion and with synthetic amino acids such as methionine to correct nutritional imbalances.

Broilers fed CLM-based diets had significantly lower ADG compared with those on control diets. This reduction could be ascribed primarily to ANFs in CLM, especially HCN, which may surpass the level the broilers can tolerate [37]. CLM is also high in fibre and insoluble carbohydrates, including cellulose, hemicellulose, and lignin [38]. High fibre levels are known to reduce nutrient digestibility in poultry [38]. When fibre inclusion exceeds optimal level, it leads to increased digesta viscosity and prolonged retention time in the gastrointestinal tract, thus impairing growth performance [39-40]. These mechanisms collectively explain the observed reduction in ADG of broilers fed CLM-based diets.

These findings contrast with those of [37] and [41], who reported enhanced growth performance in broilers offered enzyme supplemented cassava by-product meals. Although this meta-analysis did not evaluate the effect of multi-enzyme supplementation in CLM-based diets due to limited published studies. However, the observed differences may result from exogenous enzymes breaking down insoluble carbohydrates and ANFs in cassava by-products, thereby enhancing nutrient digestibility and utilization [37, 42].

Analyses of Moderators

Broiler Strains

This study revealed that strain as a moderator is a significant predictor of the effect of CLM-based diets on FCR and no more than 58% of the effect was explained by broiler strain. Subgroup analyses demonstrated that CLM had adverse impacts on growth performance parameters in Anak broilers. This supports the views of [30], who discovered impaired growth performance parameters in Anak broilers given diets that contained CLM at 10 and 15%. This trend indicates that the Anak strain has a limited ability to handle CLM-based diets, leading to reduced growth performance. However, due to the small number of studies used for its computation, this result should be interpreted with caution. On the other hand, Cobb strain showed a better ability to utilize CLM-based diets consistent with the previous results of [15]. This corroborates the results of [43], who demonstrated that CLM can substitute 50% SBM in Cobb broiler diets without deleterious influence on growth performance metrics. Also, results showed moderate effect for broiler strain as a moderator and 58% of the effect is explained by broiler strain. This supports the subgroup analysis results that revealed that Cobb strain fed CLM-based diets had better FCR than the Anak strain. Although the Cobb strain consumed less feed, the efficiency with which they converted feed into weight gain (FCR) was similar to broiler fed a control diet (without CLM). This suggests the Cobb strain may have higher ability to tolerate CLM-based diets than Anak strain.

Feeding Durations

Despite the increasing body of knowledge on CLM in broiler nutrition, no meta-analysis has evaluated its effect on growth performance across the starter phase (1 to 42-day) and finisher phase (22-42-day). This gap is critical, as the effect of CLM on broiler performance may be influenced by bird's production phase. The present meta-analysis did not evaluate the differential effect of production phases (starter versus finisher) on growth performance due to low sample size. In most developing countries, broiler production phase is usually extended to 56 days due to the use of lower-quality feed ingredients, which warrant longer production phase to attain market weight [44-45]. The subgroup analysis demonstrated that growth performance parameters were adversely affected in broilers fed CLM-based diets during the 1- 42 d. This depressed performance indicates that the ANFs in CLM (primarily residual cyanides, high fibre content, and condensed tannins) exceeded the threshold the experimental birds can handle. Given that only few studies were used for the computation, the result need be interpreted with caution. This duration-dependent response suggests the need for effective detoxification and processing of cassava leaves before their inclusion in broilers nutrition.

Inclusion Level

This meta-analysis demonstrates that low inclusion levels of CLM ($\leq 5\%$) exert no adverse impacts on broiler growth performance parameters, consistent with the previous report [46]. This lack of adverse effect indicates that the concentrations of HCN, the key ANFs in CLM, may remain below the tolerance threshold of broilers at low inclusion levels [46-47]. In contrast, moderate (5.1-10%) and high ($>10\%$) inclusion levels compromised growth performance parameters in broilers. This confirms the negative regression coefficient, suggesting that as the levels of CLM in the diet increase, FI and ADG decrease. The observed depressed performance can be attributed to the inherent characteristics of CLM at high inclusions, including bulkiness, low energy density and methionine deficiency, which collectively results in poor nutrient utilisation and growth [5, 47]. The results also showed that inclusion level is a significant predictor of feed intake and explained 17% of variations observed across studies included in this study. However, due to the small sample size, these results should be interpreted with caution.

Conclusion and Future Research Directions

The pooled results demonstrated that dietary inclusion of CLM in broiler feed reduced FI by 0.45 g/bird/d and ADG by 0.83 g/bird/d, while increasing the FCR by 0.27. Subgroup analysis revealed that broilers fed CLM at $\leq 5\%$ exhibited improved growth performance, whereas inclusion levels of 5.1-10% and $>10\%$ CLM reduced growth performance. Meta-regression analysis identified inclusion level and broiler strain as significant predictors of CLM's effects on growth performance. Notably, Cobb broilers utilized CLM-based diets more efficiently than Anak broilers. The negative effects of CLM on FI and FCR were more pronounced during the 1 to 42-day production phase. However, the mechanisms through which moderate to high inclusion levels of CLM impair broiler growth performance remain unclear and warrant further studies. Overall, these findings suggest that farmers and feed producers should exercise caution when incorporating CLM into broiler diets. Inclusion level and broiler strain must be carefully considered to minimize adverse effects on growth performance. Further research is needed to determine the optimal inclusion levels of CLM for different broiler strains and growth phases.

Acknowledgment

The authors acknowledge UNISA for their assistance.

Funding Information

There is no funding to declare.

Author's contributions

Mbajorgu Christain Anayo: Participated in conception and design the study, data collection, extraction, and visualization, data interpretation, reviewed the draft, read and approved the final manuscript.

Ogbuewu Ifeanyichukwu Princewill: Participated in conception and design the study, data collection, extraction and analysis, wrote the draft, read and approved the final manuscript.

Ethics

This study was performed in adherence with institutional guidelines for performing systematic review and meta-analysis.

Conflict of Interest

The authors have no conflict of interest to state.

Data Availability

Data will be made available upon reasonable request.

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