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SYSTEMATIC REVIEW

Dietary okra (*Abelmoschus esculentus*) supplementation in poultry: A systematic review of controlled feeding trials on growth performance, intestinal health, metabolic responses, and product quality

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ABSTRACT

Background and Aim: Okra (*Abelmoschus esculentus*) contains bioactive compounds with potential applications as poultry feed additives. However, differences in plant parts, processing methods, inclusion levels, and experimental conditions have produced inconsistent findings. This systematic review evaluated the effects of dietary okra supplementation on poultry growth performance, intestinal health, metabolic responses, and product quality, and assessed the certainty of the available evidence.

Materials and Methods: The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 guidelines and was retrospectively registered on the Open Science Framework. Scopus, Web of Science, PubMed, and AGRIS were searched through October 2, 2026, supplemented by citation tracking and regional-journal searches. Controlled poultry feeding trials were evaluated using an adapted Systematic Review Centre for Laboratory Animal Experimentation risk-of-bias tool. Standardized mean differences were calculated using Hedges' g. Because studies lacked sufficient comparability for meta-analysis, findings were synthesized narratively following the Synthesis Without Meta-analysis guideline. Evidence certainty was assessed using the Grading of Recommendations Assessment, Development and Evaluation framework adapted for animal studies.

Results: Thirteen controlled studies comprising 15 reports were included: ten involving broilers, two involving laying hens, and one involving turkey breeders. Eight studies were judged at high risk of bias. Low-dose seed and fruit powders generally showed favorable growth responses, with positive body weight estimates in eight of 11 treatment arms. Significant standardized effects were observed with 1 g/kg dried fruit powder (g = 1.38) and 1% seed powder (g = 2.44). Feed conversion improved with 1%–2% seed powder, although the evidence was inconsistent across preparations. Okra meals and processing wastes did not consistently improve growth performance, and several reports contained discrepancies in dietary formulations or duplicated performance data. Limited studies reported changes in intestinal bacterial counts, villus morphology, serum biochemical indicators, antioxidant responses, meat oxidation, and pigmentation. Evidence certainty was low for growth, feed conversion, intestinal outcomes, and meat quality, and very low for other outcomes.

Conclusion: Dietary okra effects depend on plant part, processing, and inclusion level. Low-dose seed and fruit powders show potential for improving broiler performance, whereas high-inclusion meals and wastes lack consistent benefits. Current evidence does not support a definitive optimal dose. Standardized, adequately replicated feeding trials are required before routine supplementation can be recommended.

Keywords: *Abelmoschus esculentus*, broiler chickens, feed conversion ratio, growth performance, intestinal health, okra supplementation, phytogenic feed additives, systematic review.

INTRODUCTION

Poultry production systems face increasing pressure to maintain growth performance, feed efficiency, intestinal health, and product quality while reducing reliance on antimicrobial growth promoters. Consequently,

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plant-derived feed ingredients and phytogenic additives have attracted considerable attention as potential nutritional strategies for improving poultry productivity and health [1–5]. These materials contain diverse nutritional and bioactive constituents, including dietary fiber, polysaccharides, phenolic compounds, flavonoids, and natural pigments, which may influence digestive function, intestinal microbial populations, oxidative balance, and physiological responses. However, their effectiveness varies considerably according to botanical origin, chemical composition, processing methods, inclusion levels, and experimental conditions. Previous reviews have highlighted inconsistent biological responses and insufficient standardization as major barriers to the widespread adoption of phytogenic feed additives in commercial poultry production [1, 3, 6].

Okra (*Abelmoschus esculentus* (L.) Moench) is a widely cultivated vegetable crop in tropical and subtropical regions and represents a potential source of functional feed ingredients. Different anatomical parts of the plant, including fruits, seeds, leaves, stems, and processing residues, exhibit substantial variation in their nutritional and phytochemical compositions [7, 8]. Okra contains mucilaginous polysaccharides capable of forming viscous hydrocolloids [9], while its fruits contain phenolic constituents, including quercetin and *N*-*E*-coumaroyl tyramine [10]. In contrast, okra processing residues may contain relatively high concentrations of crude fiber (CF) [11]. These compositional differences suggest that okra-derived materials may serve distinct nutritional purposes depending on the plant part and preparation method. Low-dose preparations may function as sources of bioactive compounds, whereas meals and processing residues incorporated at higher dietary concentrations may contribute substantial fiber and potentially alter dietary nutrient density. Nevertheless, these proposed functional differences require evaluation against controlled feeding-trial evidence.

Previous poultry feeding experiments have investigated several okra-derived preparations across different production systems. An aqueous okra polysaccharide preparation was evaluated for its effects on *Campylobacter jejuni* in broiler chickens [12], while stem-and-leaf meal was investigated as a potential dietary ingredient affecting skin pigmentation [13]. Other studies have examined okra seed powder, dried fruit powder, leaf meal, processing waste meal, and maltodextrin-encapsulated preparations in broilers and laying hens [14–18]. The reported dietary inclusion levels have ranged from 1 g/kg feed to 30% of the total diet, reflecting substantial differences in intervention composition and intended nutritional function. Evaluated outcomes have included body weight, feed utilization, intestinal morphology, selected microbial populations, hematological and biochemical indicators, antioxidant responses, carcass characteristics, meat quality, pigmentation, egg production, and reproductive performance. However, the diversity of interventions, experimental populations, outcome measurements, and study designs complicates direct comparisons and limits the formulation of consistent feeding recommendations.

Despite increasing interest in okra as a poultry feed ingredient, the available experimental evidence has not been comprehensively evaluated using a systematic approach that simultaneously considers intervention characteristics, methodological quality, outcome consistency, and certainty of evidence. A previous narrative mini review suggested that low-to-moderate dietary inclusion levels of okra could improve growth performance and feed efficiency in broilers and enhance egg quality in laying hens [19]. However, that review did not employ a systematic literature search strategy, formally assess risk-of-bias, differentiate the effects of individual plant parts and processing methods, or evaluate the certainty of the reported findings. Consequently, the reliability, reproducibility, and generalizability of these proposed benefits remain uncertain.

An important unresolved issue is whether the reported effects of okra supplementation depend on its use as a low-dose functional preparation or as a higher inclusion dietary ingredient. Seed powders, fruit powders, extracts, encapsulated preparations, leaf meals, and processing wastes differ substantially in their composition and inclusion levels, making it inappropriate to assume equivalent biological effects. Furthermore, differences in poultry species, production stage, environmental conditions, experimental duration, and dietary formulation may contribute to variation in the reported responses. In particular, the effects observed under thermoneutral conditions may not be directly comparable with those reported during heat stress. The extent to which favorable findings have been reproduced across independent experiments also remains unclear.

Methodological limitations represent an additional research gap. Controlled feeding trials may differ in experimental unit selection, replication, dietary formulation, intervention reporting, outcome measurement, and statistical analysis. Such differences can affect the reliability of estimated treatment effects and complicate evidence synthesis. Moreover, inconsistencies between nominal inclusion levels and actual diet formulations, incomplete reporting of variability, and overlapping reports from the same experimental populations may influence the interpretation of individual studies. Without systematic risk-of-bias assessment and outcome-specific evaluation of evidence certainty, apparently favorable results may be overinterpreted. Therefore, a

structured synthesis is needed to distinguish findings supported by repeated, methodologically reliable observations from those based on isolated or uncertain evidence, and to determine whether quantitative pooling is appropriate.

This systematic review aimed to critically evaluate controlled *in vivo* feeding trials investigating dietary okra and okra-derived preparations in domesticated poultry, with particular emphasis on growth performance, feed utilization, intestinal health, physiological and metabolic responses, and product quality. The review characterized the experimental populations, poultry production stages, okra plant parts, processing methods, administration routes, inclusion levels, dietary comparators, and study conditions reported in the literature.

The primary objectives were to synthesize the effects of okra supplementation on final body weight, body weight gain, feed intake, feed conversion ratio (FCR), and mortality. Secondary objectives were to evaluate reported effects on gastrointestinal development, intestinal morphology, selected microbial populations, hematological and biochemical indices, antioxidant and immune-related indicators, carcass characteristics, meat quality, pigmentation, laying performance, egg quality, and reproductive outcomes. The review focused on comparing low-dose functional preparations with higher-inclusion meals and processing wastes, and on whether responses differed between thermoneutral and heat-stress conditions.

The review also aimed to assess the methodological quality and risk-of-bias of eligible studies, identify findings reproduced across independent experiments, examine the feasibility of quantitative meta-analysis for comparable intervention–outcome combinations, and synthesize heterogeneous findings without meta-analysis when statistical pooling was inappropriate. Finally, the certainty of evidence was evaluated for each outcome domain to identify the strength of existing findings, clarify uncertainties concerning effective inclusion levels and potential benefits, and establish priorities for future controlled poultry feeding trials.

MATERIALS AND METHODS

Ethical approval

This systematic review was based exclusively on data obtained from previously published poultry feeding studies. No new experiments involving animals or humans were conducted, and no additional biological samples were collected. Therefore, institutional ethical approval was not required for the present review. The ethical approval and animal welfare procedures reported in the included primary studies were considered as part of the methodological information available for assessment. The use of artificial intelligence (AI) tools during study selection, data extraction, and risk-of-bias assessment is described in the corresponding subsection.

Study period and location

The literature searches were conducted between July 28 and October 2, 2026. The initial Scopus search was performed on July 28, 2026, followed by supplementary database and citation searches on August 13, 2026. Updated searches of the principal bibliographic databases and AGRIS were completed on October 2, 2026, which was designated as the evidence cutoff date. The review was conducted using electronic bibliographic databases, publisher records, and publicly accessible research resources. No physical experimental study site was involved.

Study design

This investigation was designed as a systematic review of controlled *in vivo* feeding experiments evaluating dietary okra and okra-derived preparations in domesticated poultry. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement and its literature search extension, PRISMA-S [20, 21]. Where quantitative meta-analysis was not feasible, findings were synthesized following the Synthesis Without Meta-analysis (SWiM) reporting guideline [22]. The review included predefined eligibility criteria, systematic literature searching, study selection, structured data extraction, risk-of-bias assessment, calculation of study-level effect estimates, evaluation of quantitative pooling feasibility, and outcome-specific assessment of evidence certainty. The PRISMA and PRISMA-S checklists are provided in Supplementary Table S6.

Protocol registration and amendments

The review question, eligibility criteria, outcome domains, and data extraction variables were established before screening commenced. However, the protocol was not registered prospectively. To document the review methods and subsequent modifications transparently, the protocol was registered retrospectively with the Open Science Framework (OSF) in October 2026 under the Generalized Systematic Review Registration framework (DOI: 10.17605/OSF.IO/UD8YQ).

The registration documents the methods specified when screening began and records nine dated amendments. The original Scopus search conducted on July 28, 2026, was supplemented by a PubMed search, citation searching, and targeted regional-journal searches on August 13, 2026 (Amendments A1–A2). On October 2, 2026, the search strategies were updated using poultry-specific terms, Web of Science Core Collection was added, and restrictions on language and document type were removed (Amendments A3–A4).

Subsequent methodological amendments introduced a second assessment of screening decisions, eligibility, risk-of-bias, and principal outcome data (Amendment A5); replaced the original risk-of-bias instrument with an adapted Systematic Review Centre for Laboratory Animal Experimentation (SYRCLE) tool incorporating an explicit overall-judgment rule (Amendment A6); and specified primary and secondary outcomes, intervention classes, individual study effect sizes, a quantitative pooling feasibility matrix, and Grading of Recommendations Assessment, Development and Evaluation (GRADE) certainty ratings (Amendment A7). An abstract-only report was subsequently excluded from the synthesis (Amendment A8). Finally, responsibility for verifying the second assessment was reassigned to another co-author (NL) before that verification had been conducted (Amendment A9).

These amendments were documented to distinguish the original review procedures from modifications introduced during the review process.

Eligibility criteria

Eligibility criteria were established using the population, intervention, comparator, outcome, and study design framework (Table 1).

Table 1: Eligibility criteria for selecting controlled poultry feeding studies evaluating okra (*Abelmoschus esculentus*) and okra-derived preparations.

Component	Inclusion criterion
Population	Domesticated poultry, including broilers, laying hens, breeders, turkeys, quail, ducks, geese, and other domesticated poultry species
Intervention	Okra (*Abelmoschus esculentus*; synonym: *Hibiscus esculentus*) or identifiable okra-derived preparations, including seed powder, fruit or pod powder, whole meal, leaf or stem meal, mucilage, aqueous extracts, encapsulated preparations, and processing wastes, administered through feed or drinking water
Comparator	Unsupplemented basal diet or drinking water control; alternative okra inclusion levels; conventional feed additives; other phytogenic ingredients; or synthetic pigment, antioxidant, or antimicrobial comparators
Primary outcomes	Final body weight, body weight gain, feed intake, FCR, and mortality
Secondary outcomes	Gastrointestinal development, intestinal morphology, microbial counts, hematological and blood biochemical indices, antioxidant and immune-related indicators, carcass traits, meat quality, pigmentation, laying performance, egg quality, and reproductive outcomes
Study design	Controlled *in vivo* poultry feeding experiment reported as a peer-reviewed primary research article or full-length proceedings paper
Language	No language restrictions following Amendment A4

Okra refers to *Abelmoschus esculentus* (L.) Moench, historically also classified as *Hibiscus esculentus* L. FCR = Feed conversion ratio. Eligibility required sufficient information to identify the poultry population, intervention, inclusion level, comparator, sample size, and at least one relevant outcome. Comparisons with unsupplemented controls were used to evaluate the independent effects of okra. Amendment A4 removed the original language restrictions.

Eligible studies were controlled *in vivo* feeding experiments involving domesticated poultry in which okra or an identifiable okra-derived preparation was administered through feed or drinking water. The contribution of okra had to be distinguishable from that of other dietary ingredients. Conclusions concerning the effects of okra itself were based exclusively on comparisons with unsupplemented controls.

Peer-reviewed primary research articles and full-length conference proceedings papers were eligible when they reported the poultry population, intervention and inclusion level, comparator, number of animals, and at least one relevant outcome. Theses, preprints, and conference abstracts were excluded because their methodological details and peer-review status could not be verified consistently. Studies involving other species of the genus *Abelmoschus* were excluded.

Following Amendment A4, no language restrictions were applied. Studies combining okra with another active ingredient contributed only treatment arms in which okra was administered independently. Feed-based and drinking water interventions were classified separately. When a preparation was described only as “okra powder,” the plant part specified in the study methods was used for classification; in both relevant reports, this was the pod.

Peer-review status was verified using the publisher's stated editorial and review policies. The same eligibility criteria were applied to studies involving broilers, laying hens, and breeding poultry.

Information sources and search strategy

The initial literature search was conducted in Scopus on July 28, 2026, using a livestock-wide search strategy restricted to English-language articles and reviews. This search identified 420 records, of which 355 were screened. On August 13, 2026, an additional PubMed search identified 45 records. Supplementary identification procedures included backward citation searching of eligible reports and relevant reviews, verification of DOIs and publisher records, and targeted searches of regional journals and conference proceedings.

To improve the comprehensiveness of the search, all principal database searches were updated on October 2, 2026, using a poultry-focused strategy. The updated queries incorporated the botanical synonym *Hibiscus esculentus*. In Scopus and Web of Science, additional common names, including lady's finger, bhindi, and gombo, were included, whereas PubMed searches incorporated relevant Medical Subject Headings (MeSH). No language, publication-date, or document-type restrictions were applied.

The updated searches identified 353 records in Scopus, 250 in Web of Science Core Collection, and 56 in PubMed. AGRIS, maintained by the Food and Agriculture Organization of the United Nations (FAO), was also searched on October 2, 2026, using four combinations: “okra poultry,” “okra broiler,” “okra chicken,” and “okra hens.” These searches identified 156 records, which were screened directly through the AGRIS interface.

CAB Abstracts was examined through the CABI Digital Library; however, access to abstracts and record export was unavailable without an institutional subscription. AGRICOLA was not accessible to the review team. ScienceDirect was not searched independently because its journal content was considered to be represented within Scopus.

Previous reviews addressing okra supplementation in poultry were identified through the same unrestricted searches, and their reference lists were examined for potentially eligible studies. Google Scholar was used exclusively to verify individual records rather than as a primary search source because reproducible bulk searching and exporting were not feasible.

Backward citation searching included the reference lists of all included reports and relevant reviews. Forward citation checking of included reports was conducted using Scite. Known-item searches were also performed to verify specific article titles and DOIs.

The initial supplementary searches were conducted on August 13, 2026, and the final database updates were completed on October 2, 2026. The latter date was designated as the evidence cutoff. Complete search strategies, search dates, restrictions, and record yields for each information source are provided in Supplementary Table S1.

Study selection and verification

Bibliographic records and abstracts were exported and consolidated in a spreadsheet. Duplicate records were identified using normalized DOIs, normalized article titles, and PubMed identifiers. Title normalization involved conversion to lowercase and removal of punctuation and redundant spacing. Records with uncertain duplication status were manually compared using author names, publication year, and publication source.

Records already screened during the initial search were identified and were not screened again. Multiple reports describing the same experimental population were linked using a common study-family identifier and counted as one independent study (Supplementary Table S5).

One reviewer (WN) screened all titles and abstracts, evaluated full-text eligibility, extracted study data, and assessed risk-of-bias. A second assessment of records, full-text reports, risk-of-bias judgments, and principal outcome values was generated using an AI-assisted tool, OpenAI Codex, based on the same records and full texts.

A second reviewer (NL), who was blinded to WN's decisions, independently checked the AI-generated decisions against the original sources and corrected discrepancies where necessary. However, four reports excluded following full-text assessment were not included in this verification procedure; for these reports, AI-generated decisions were compared directly with WN's assessments. One additional report could not be retrieved.

Disagreements between WN and the human-verified second assessment were resolved through discussion. Agreement was quantified using Cohen's kappa coefficient and interpreted according to Landis and Koch [23].

Accordingly, the review process was characterized as AI-assisted and human-verified rather than as a fully independent dual-review procedure.

Data extraction

A piloted data extraction form (Supplementary Table S7) was used to collect bibliographic characteristics, study country, poultry species and strain, sex, age, sample size, experimental unit, replication, study duration, environmental conditions, okra plant part, processing method, administration route, nominal and formulated inclusion levels, comparator characteristics, and reported outcomes.

For each eligible outcome, group means, measures of variability, sample sizes, and reported p-values were extracted when available. Numerical values were not estimated or digitized from graphical presentations.

For growth performance, final body weight and cumulative FCR over the complete feeding period were prioritized. Period-specific measurements were retained for descriptive purposes but were not substituted for cumulative estimates.

Nonsignificant findings were recorded together with their reported numerical values and were not interpreted as evidence of equivalence or absence of an effect.

When discrepancies occurred among abstracts, methods, and results tables, numerical values presented in tables and information reported in the methods were prioritized. The discrepancies were documented and considered during methodological appraisal.

The authors of primary studies were not contacted because many reports were several years old or published in regional outlets without readily verifiable current contact information. Consequently, unresolved inconsistencies were retained in the extraction records and considered during risk-of-bias and evidence certainty assessments.

Risk-of-bias assessment

Risk-of-bias was assessed using the SYRCLE risk-of-bias tool for animal intervention studies [24], adapted to address methodological characteristics of poultry feeding experiments.

The original 10 SYRCLE domains were retained. Three poultry-specific considerations were incorporated within the other-bias domain: appropriateness of the experimental unit and replication, completeness of dietary formulation and intervention reporting, and numerical completeness and internal consistency of the reported results.

Assessment of dietary formulation included agreement between nominal inclusion levels and the corresponding formulated dietary concentrations.

Each domain was categorized as low risk, some concerns, or high risk, with supporting information extracted from the primary report.

An overall high risk judgment was assigned when any item concerning incomplete outcome data, experimental unit selection, dietary formulation, or numerical consistency was rated as high risk, or when three or more other domains were rated as high risk.

A study was classified as low risk only when all assessed domains were rated as low risk. All remaining studies were categorized as having some concerns.

Funding sources and conflict-of-interest disclosures were recorded but were not incorporated into the overall risk-of-bias judgment.

Effect-size calculation

For each eligible okra treatment arm, outcomes were compared with the corresponding unsupplemented control group from the same experiment.

Continuous outcomes were expressed as standardized mean differences using Hedges' g and corresponding 95% confidence intervals (CIs) [25]. The replicate pen or cage was treated as the experimental unit when calculating effect sizes.

When a pooled standard error of the mean (SEM) was reported, the corresponding standard deviation (SD) was calculated as:

$$\mathrm{SD} = \mathrm{SEM} \times \sqrt{\mathrm{n}}$$

where n represents the number of independent experimental units contributing to the reported estimate.

When the meaning of a reported ± statistic was not specified, it was treated as an SEM. This assumption produced a larger estimated SD than interpreting the same value as an SD and consequently reduced the absolute magnitude of the calculated standardized effect.

For FCR, negative effect sizes indicated improved feed conversion relative to the unsupplemented control.

Treatment arms sharing a common control were recognized as statistically dependent. Consequently, no effect estimates were pooled across treatment arms or studies.

Feasibility of meta-analysis

Quantitative meta-analysis was considered only for intervention–outcome combinations represented by at least three independent studies with comparable plant parts, administration routes, inclusion units, poultry types, production stages, and sufficient variance information.

A pooling feasibility matrix was developed to document whether each intervention–outcome combination satisfied these requirements.

Where quantitative pooling was not appropriate, studies were organized according to poultry population and intervention class.

Interventions were grouped into two broad categories. The first comprised low-dose functional preparations, including seed and fruit powders, extracts, and encapsulated okra preparations, administered at inclusion levels ranging from 1 g/kg to 4% of the diet or through drinking water. The second comprised okra meals and processing wastes used as bulk dietary ingredients at inclusion levels ranging from 2% to 30% of the diet.

These categories were used to organize the evidence and were not assumed to represent biologically equivalent preparations within each group.

Narrative synthesis and sensitivity analyses

When meta-analysis was not feasible, findings were synthesized narratively according to poultry population, intervention type, inclusion level, and outcome domain, following the SWiM reporting guideline [22].

The direction of each reported effect was standardized relative to the corresponding unsupplemented control. Individual study effect sizes were presented in forest plots without calculating pooled summary estimates.

Outcomes for which effect sizes could not be calculated were summarized descriptively using an evidence map.

Narrative sensitivity analyses examined the robustness of the findings by considering whether the overall interpretation changed when less weight was assigned to studies at high risk of bias, reports identified exclusively through supplementary searching, and study families containing companion reports.

Certainty of evidence

The certainty of evidence for each outcome domain was assessed using the GRADE approach adapted for animal intervention studies [26].

Evidence derived from controlled feeding experiments was initially assigned a high-certainty rating. Certainty was subsequently downgraded, where appropriate, according to five domains: risk-of-bias, inconsistency, indirectness, imprecision, and publication bias.

The certainty assessment considered methodological limitations, consistency of treatment effects across studies, relevance of experimental populations and interventions, precision of reported estimates, and the possibility of selective publication.

Findings were summarized in a Summary of Findings table reporting the number of independent studies and birds contributing to each outcome domain, together with the corresponding certainty ratings.

RESULTS

Study selection

During the initial search, 387 unique database records were screened, and 19 reports underwent full-text assessment. Fifteen reports representing 13 independent studies met the eligibility criteria. One additional report was available only as an abstract and was classified as awaiting further assessment [27] (Supplementary Figure S1 and Supplementary Table S2).

The updated database searches conducted on October 2, 2026, identified 659 records. Of these, 239 duplicates were removed, and 136 records had already been screened during the initial search. The remaining 284 records underwent title and abstract screening (Figure 1). Among these, 279 were excluded, primarily because they addressed okra cultivation or crop protection (n = 153) or did not investigate okra administration through poultry feed or drinking water (n = 70). The five remaining records corresponded to reports already identified through supplementary searching. Consequently, no additional eligible studies were identified, and the final synthesis comprised 15 reports representing 13 independent studies.

The AGRIS searches identified 156 records, predominantly concerning okra cultivation using poultry manure or okra-based food products. Three records corresponded to two previously included reports [14, 15], and none represented an additional eligible study. Twelve non-English records retrieved after the removal of language restrictions were excluded because they did not address the review question.

The updated database searches identified eight of the 15 included reports, compared with four during the initial search. The remaining seven reports were published in regional journals not indexed in Scopus, Web of Science, or PubMed and were identified exclusively through supplementary searching.

Agreement between the lead reviewer and the AI-assisted, human-verified second assessment was substantial to almost perfect, with Cohen's κ = 0.85 for title and abstract screening and κ = 0.77 for full-text eligibility assessment. The latter calculation included 18 of the 19 reports assessed in full because the AI-assisted assessment did not have access to one excluded report. Four disagreements, comprising three screening decisions and one full-text eligibility decision, were resolved through discussion.

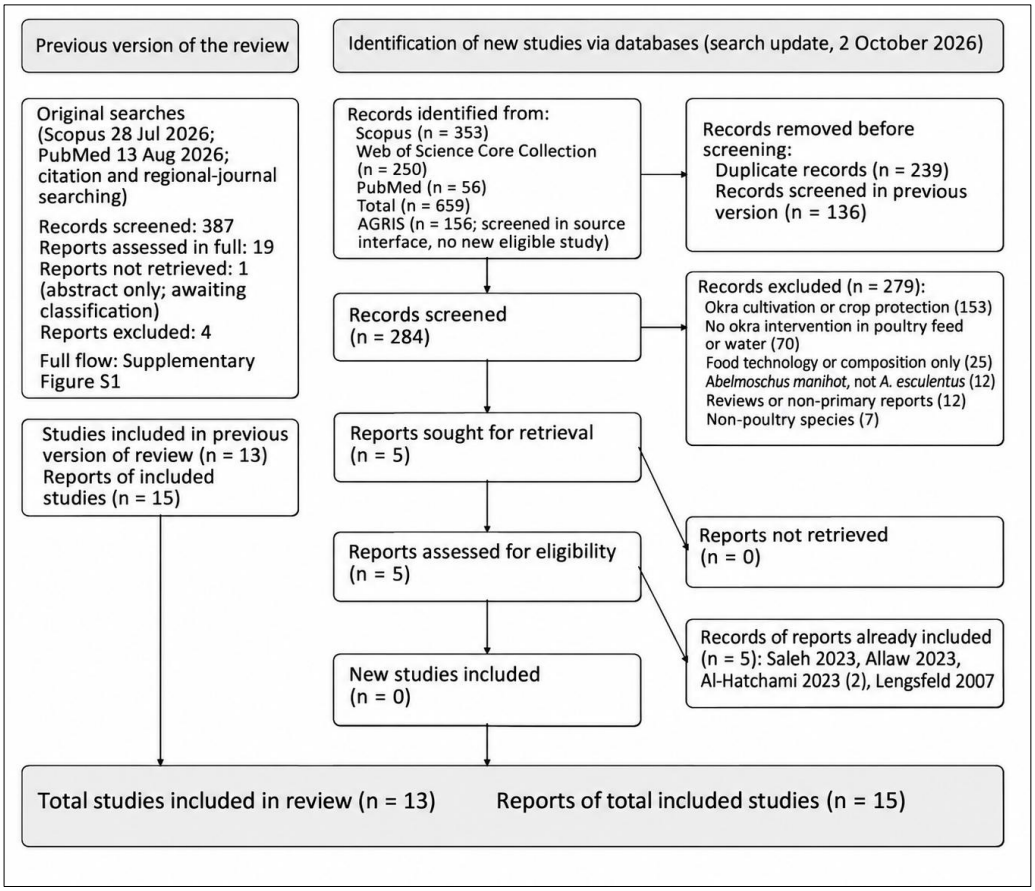


Figure 1: PRISMA 2020 flow diagram illustrating study selection for the updated systematic review. The left column summarizes the original searches, with the complete selection process presented in Supplementary Figure S1. The right column shows records identified through the updated database searches conducted on October 2, 2026. PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Characteristics of the included studies

The 13 independent studies were published between 2007 and 2026, with ten published from 2020 onward. Five studies were conducted in Nigeria, three in Iraq, and one each in Egypt, China, Bangladesh, Indonesia, and the Netherlands. The included investigations comprised ten broiler experiments, two laying-hen experiments, and one turkey-breeder experiment. Study populations ranged from 20 to 360 birds, and intervention periods ranged from 28 days to 12 weeks (Table 2).

Six broiler studies evaluated low-dose functional preparations, including seed powder [14], dried fruit powder [15], seed and fruit powders administered under cyclic heat stress [28, 29], maltodextrin-encapsulated okra [16], and aqueous extracts supplied through drinking water [12, 30]. Four broiler studies investigated okra as a bulk dietary ingredient, including stem-and-leaf meal, immature or mature okra meal, and processing waste meal [13, 18, 31, 32].

In three studies evaluating meals or processing wastes, the nominal inclusion levels of 5%–30% were

approximately two to three times higher than the corresponding concentrations presented in the dietary formulation tables, which ranged from 2% to 15%.

The two laying-hen studies evaluated leaf meal at inclusion levels up to 10% [17] and pod powder at 2 and 4 g/kg feed [33, 34]. The turkey-breeder study investigated an aqueous seed extract administered through drinking water [35]. Two study families were each represented by two companion reports.

Five studies reported the proximate composition of the okra preparations [14, 17, 18, 31, 32], and one reported total phenolic content [15]. The remaining seven studies provided no compositional analysis. None measured the carotenoid concentration of the administered okra material.

Only the stem-and-leaf meal study conducted by Liu *et al.* [13] used isoenergetic and isonitrogenous diets. In other meal and processing waste studies, increasing okra inclusion was accompanied by increased dietary fiber concentrations or reduced dietary energy density [17, 18, 32].

The principal characteristics of the included studies are summarized in Table 2, and the directions of reported treatment effects across outcome domains are illustrated in Figure 2.

Table 2: Characteristics of the included controlled poultry feeding studies.

Country, poultry population, and setting	Experimental design	Okra preparation and administration route	Inclusion levels	Duration	Outcome domains	Risk-of-bias	Reference
Iraq; day-old Ross 308 broilers	216 birds; 4 groups × 3 replicates × 18 birds	Seed powder; feed	0%, 1%, 2%, 4%	28 days	Growth, carcass, blood, gastrointestinal outcomes, microbiota	Some concerns	[14]
Egypt; Ross broilers, 1 week old	240 birds; 4 × 6 × 10	Dried fruit powder; feed	0, 1, 2, 3 g/kg	5 weeks	Growth, carcass, blood, immunity, meat quality	High	[15]
Iraq; Ross 308 broilers under cyclic heat stress (27–35°C)	360 birds; 6 × 4 × 15	Seed and/or fruit powder; feed	Seed: 5, 10 g/kg; fruit: 5, 10 g/kg; seed 5 + fruit 5 g/kg	35 days	Growth, blood, antioxidant and stress indicators	High	[28, 29]
Indonesia; MB-202 male broilers	200 birds; 4 × 5 × 10	Maltodextrin-encapsulated okra; feed	0%, 0.5%, 1.0%, 1.5%	Days 8–35	Intestinal morphology, microbiota, carcass, meat quality	High	[16]
Netherlands; female Ross 308 broilers challenged with *Campylobacter jejuni*	144 birds; 3 groups × 8 cages × 6 birds	Aqueous fresh-fruit extract; drinking water	0, 50, 100 g/kg water	42 days	Growth, *C. jejuni* excretion	Some concerns	[12]
Bangladesh; Cobb 500 broilers	4 groups × 4 replicates; number of birds per replicate not stated	Aqueous pod extract; drinking water	5 mL/L (okra-only arm)	35 days	Weight gain, mortality	Some concerns	[30]
China; Da-Ma-Hua broilers, 50 days old	288 birds; 6 × 3 × 16	Stem-and-leaf meal; feed	0%, 2%, 3%, 4%, 5%; synthetic pigment comparator	6 weeks	Growth, pigmentation	Some concerns	[13]
Nigeria; Arbor Acres finishing broilers	84 birds; 4 × 3 × 7	Okra waste meal; feed	Nominal: 0%, 5%, 10%, 15%; formulated: 0%, 2.0%, 4.0%, 5.3%	28 days	Growth, carcass, economic outcomes	High	[18]
Nigeria; Arbor Acres finishing broilers	70 birds; 5 × 2 × 7	Immature or mature okra meal; feed	Nominal: 5%, 10% of each; formulated: approximately 2%, 4%	28 days	Growth, carcass, economic outcomes	High	[31]
Nigeria; Ross 308 finishing broilers	144 birds; 4 × 3 × 12	Okra waste meal; feed	Nominal: 0%, 10%, 20%, 30%; formulated: 0%, 4.9%, 9.8%, 14.7%	28 days	Growth, carcass, economic outcomes	High	[32]
Nigeria; Black Harco laying hens, 18 weeks old	75 hens; 5 × 3 × 5	Leaf meal; feed	0%, 2.5%, 5%, 7.5%, 10%	12 weeks	Laying performance, egg quality, egg lipids	Some concerns	[17]
Iraq; Lohmann Brown-Lite laying hens, approximately 34 weeks old	300 hens; 5 × 3 × 20	Pod powder; feed	2, 4 g/kg; vitamin C or E comparator arms	12 weeks	Laying performance, blood, egg quality, oxidation	High	[33, 34]

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Country, poultry population, and setting	Experimental design	Okra preparation and administration route	Inclusion levels	Duration	Outcome domains	Risk-of-bias	Reference
Nigeria; turkey-breeder hens, 32 weeks old	20 hens; 4 groups × 5 hens	Aqueous seed extract; drinking water	50 mL/L; guava and pumpkin seed extract comparator arms excluded	8 weeks	Egg number, fertility, hatchability	High	[35]

Experimental design is presented as treatment groups × replicates × birds per replicate unless otherwise specified. The replicate pen or cage was the experimental unit, except in the turkey study, in which individual hens were replicates. For dietary inclusion, 1% corresponds to 10 g/kg. Drinking water concentrations are presented as reported because the dry matter content of the extracts was unavailable. Nominal inclusion levels are distinguished from the corresponding formulated concentrations where discrepancies occurred. For Islam *et al.* [30], the number of birds per replicate was not specified for the herbal-extract experiment. Reported composition on a dry matter basis was as follows: seed powder, crude protein (CP) 22.0%, CF 17.6%, and ether extract (EE) 15.0% [14]; fruit powder, total phenolics 65 mg gallic acid equivalents (GAE)/g extract [15]; leaf meal, CP 13.2% and CF 15.1% [17]; waste meal, CP 15.9% and CF 33.7% [18], or CF 16.9% [32]; and immature and mature okra meals, CP 18.8% and 13.0% and CF 16.6% and 17.1%, respectively [31]. Composition was not reported in the remaining studies. Risk-of-bias classifications were based on the adapted SYRCLE tool (Supplementary Table S3).

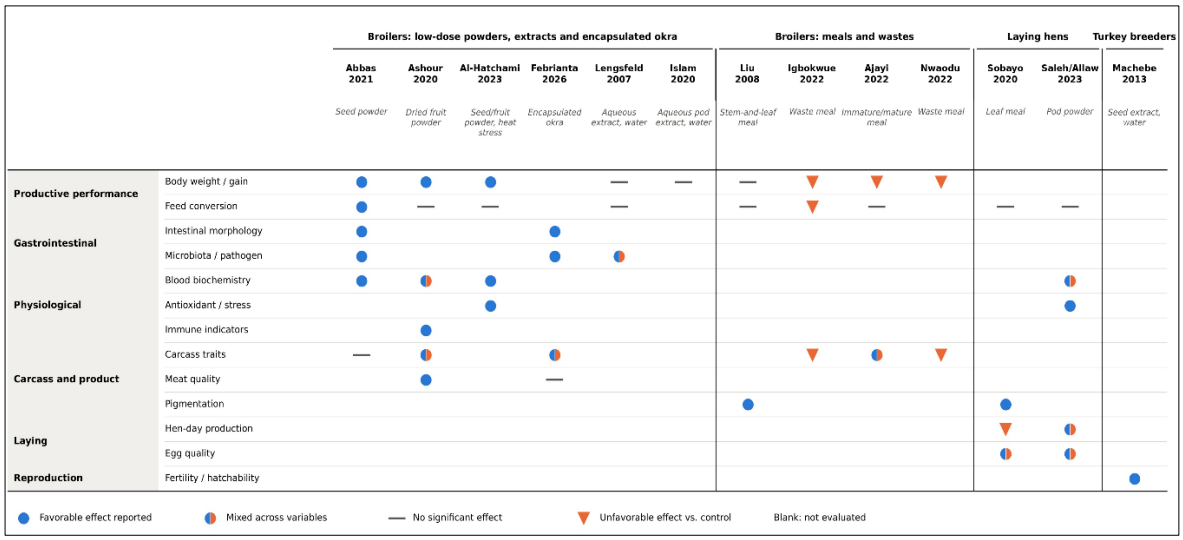


Figure 2: Evidence map showing the direction of statistically significant treatment effects relative to unsupplemented controls, grouped by poultry population and intervention class. Each column represents an independent study, with companion reports combined. Favorable or unfavorable indicates a statistically significant difference from the control for at least one variable within the corresponding outcome domain, without a significant change in the opposite direction. Mixed indicates statistically significant changes in opposing directions across variables. A dash indicates no statistically significant difference. The evidence map provides a qualitative summary of effect direction and does not represent effect magnitude, certainty of evidence, or risk-of-bias, which are presented separately in the forest plots and the Summary of Findings table.

Risk-of-bias

Study-level risk-of-bias assessments are presented in Supplementary Table S3, with domain-level judgments summarized in Supplementary Figure S2.

Although most studies reported random allocation of birds to experimental groups, none described the method used to generate the allocation sequence. No study reported allocation concealment or blinding of animal caretakers or outcome assessors. Only Lengsfeld *et al.* [12] described random housing allocation. Consequently, sequence generation, allocation concealment, housing, and blinding were generally categorized as having some concerns.

Insufficient reporting was not automatically interpreted as evidence that an appropriate methodological procedure had not been performed. However, poultry-specific methodological criteria identified several substantial concerns.

Discrepancies between nominal and formulated dietary inclusion levels were identified in three studies [18, 31, 32]. Conflicting treatment labels between the methods and table footnotes were observed in another report [28], while inconsistencies involving sample size or bird age were identified between abstracts and methods sections [16, 31]. These issues contributed to high risk judgments for dietary formulation or numerical consistency.

Three reports originating from the same institution contained duplicated numerical tables. Ajayi *et al.* [31] and Nwaodu *et al.* [32] reported identical growth performance, carcass, and dietary analysis values for the control and three okra treatment columns, despite describing different diets and replicate numbers. In addition, the carcass table reported by Igbokwue *et al.* [18] reproduced the values presented by Ajayi *et al.* [31] in a different column order.

Additional numerical inconsistencies included FCR values below 1.0 that were incompatible with the reported feed intake and body weight gain [18], discrepancies between growth values reported in the text and tables, and an unsupported claim of improved sensory quality without a corresponding sensory evaluation method [15].

In the turkey-breeder study, reported embryo mortality and hatchability percentages were incompatible with the stated proportion of infertile eggs [35]. Other concerns included inconsistent replicate sizes and an implausible period-specific value for hen-day egg production [33]. These discrepancies contributed to high risk judgments for numerical consistency.

In the leaf meal study, the abstract reported a direction of change in hen-day production that differed from the results section and tables. Because the latter two sources were consistent, the corresponding item was categorized as having some concerns [17].

Applying the prespecified overall-judgment criteria, eight studies were classified as having a high risk of bias, while five were classified as having some concerns. None received an overall low risk classification.

Agreement between the lead reviewer and the verified second assessment was observed for nine of the 13 studies (κ = 0.43). The four disagreements involved the numerical consistency domain and were resolved through discussion and verification against the original reports.

Growth performance and feed utilization

Effects of low-dose functional preparations: Growth responses differed between okra preparation classes (Table 3; Figure 3).

Table 3: Growth performance and feed utilization in broiler studies evaluating okra supplementation.

Study and preparation	Final body weight	FCR	Hedges' g for body weight (range across treatment arms)
Abbas [14]; seed powder, 1%–4%	Control: 1473 g; treatments: 1540, 1524, 1468 g	Control: 1.64; treatments: 1.57, 1.55, 1.61	−0.18 to 2.44
Ashour *et al.* [15]; fruit powder, 1–3 g/kg	Control: 1827 g; treatments: 1913, 1792, 1793 g	Control: 1.72; treatments: 1.71, 1.76, 1.85 (NS)	−0.58 to 1.38
Al-Hatchami and Alshukri [28]; seed/ fruit powder, 5–10 g/kg, heat stress	Control: 1946 g; treatments: 1967–2040 g	Control: 1.67; treatments: 1.61–1.63 (NS)	0.14–0.60
Lengsfeld *et al.* [12]; aqueous extract in drinking water	No difference in body weight gain; numerical values not tabulated	No difference	Not calculable
Islam *et al.* [30]; pod extract in drinking water	Similar to control; values presented graphically	Not reported	Not calculable
Liu *et al.* [13]; stem-and-leaf meal, 2%–5%	Control: 1842 g; treatments: 1837–1845 g	3.2 in all groups	−0.45 to 0.31
Igbokwue *et al.* [18]; waste meal, 5%–15%	Control: 2.44 kg; treatments: 2.43, 2.29, 2.14 kg	Values incompatible with reported intake and gain	−0.69 to −0.03
Ajayi *et al.* [31]; immature/mature meal, 5%–10%	Control: 2.60 kg; treatments: 1.56–2.09 kg	Control: 3.15; treatments: 3.14–3.56 (NS)	−3.35 to −1.30[a]
Nwaodu *et al.* [32]; waste meal, 10%–30%	Control: 2.60 kg; treatments: 2.09, 1.77, 1.56 kg	Control: 3.15; treatments: 3.14–3.44 (NS)	−3.83 to −1.49[a]

Values are presented in ascending order of dietary inclusion level unless otherwise indicated. NS = Not significant; FCR = Feed conversion ratio; Hedges' g = Standardized mean difference corrected for small sample bias. Negative Hedges' g values for body weight indicate lower values than the corresponding control, whereas negative values for FCR indicate improved feed conversion. [a]Identical growth performance values were reported in both studies despite differences in the stated experimental designs; estimates are presented for transparency and should be interpreted cautiously.

Among low-dose preparations, dried fruit powder at 1 g/kg was associated with a positive standardized estimate for final body weight (Hedges' g = 1.38; 95% CI: 0.12–2.64), although the original study did not report a statistically significant treatment effect. At 2 and 3 g/kg, the corresponding estimates were negative [15].

Seed powder at 1% produced a positive estimate for final body weight (g = 2.44; 95% CI: 0.33–4.56). The estimated effect was smaller at 2%, while no favorable effect was observed at 4% [14].

Under cyclic heat stress, all five treatment arms receiving seed powder, fruit powder, or their combination produced positive body weight estimates (g = 0.14–0.60). However, the 95% CIs for all five estimates included zero [28]. Because the treatment labels in the table footnotes reversed the inclusion levels within individual powder types, comparisons with the control remained interpretable, whereas dose-specific comparisons within each powder type were uncertain.

Only two broiler studies reported period-specific growth responses. In the fruit powder study, the reported improvement in body weight gain was confined to weeks 1–3 [15]. Under cyclic heat stress, the control group had the highest body weight during week 1, whereas the okra-supplemented groups showed higher values from week 3 onward [28].

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Aqueous okra extracts administered through drinking water did not alter body weight gain or feed intake in experimentally challenged broilers [12]. Similarly, the okra-only treatment arm evaluated by Islam *et al.* [30] showed body-weight gain comparable to that of the control, although the corresponding values were presented graphically rather than in numerical tables.

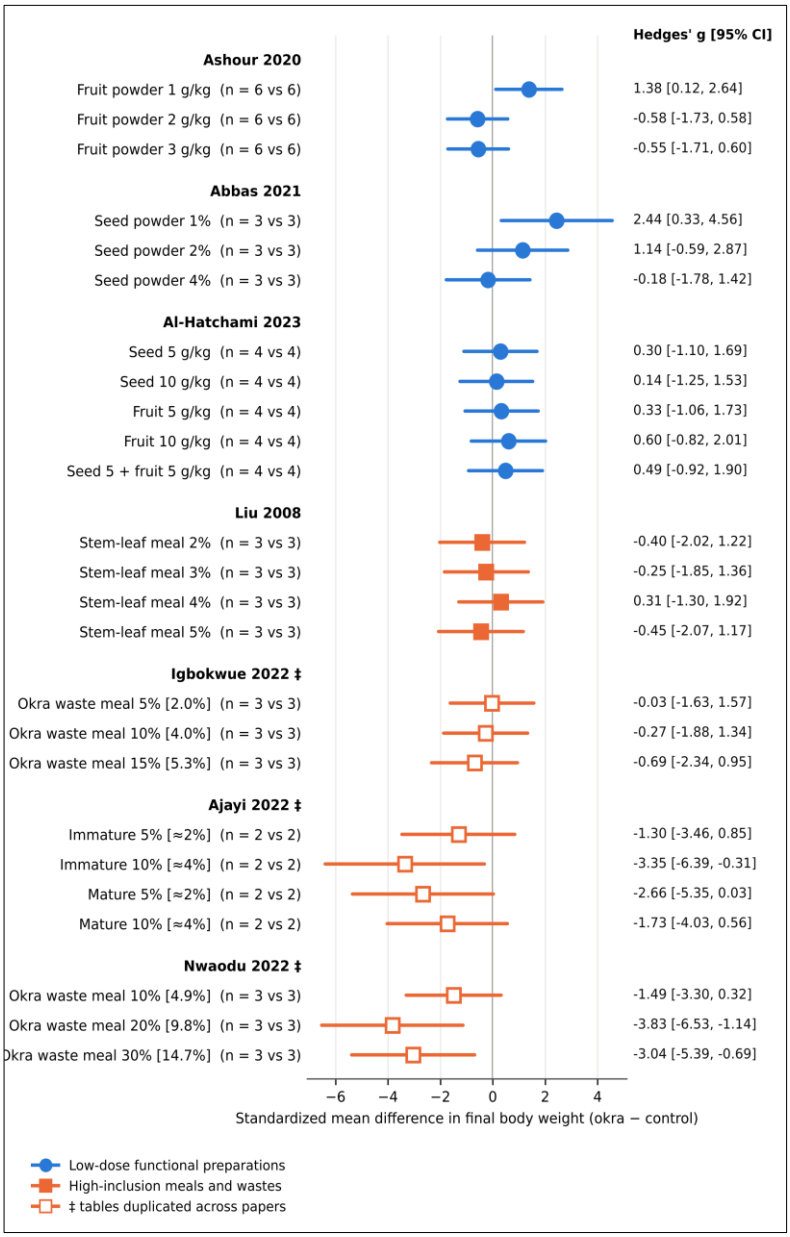


Figure 3: Standardized mean differences (Hedges' g) and 95% confidence intervals for final body weight in individual okra treatment arms compared with the corresponding unsupplemented controls. Circles represent low-dose functional preparations, filled squares represent meals and processing wastes, and open squares identify reports containing duplicated numerical tables. Nominal inclusion levels are presented, with formulated concentrations shown in brackets where applicable. Treatment arms sharing a common control are statistically dependent; therefore, no pooled estimate is presented.

Feed conversion responses: Seed powder improved FCR at 2% inclusion (g = −3.65; 95% CI: −6.26 to −1.04). At 1%, the estimated effect was also negative (g = −1.94; 95% CI: −3.88 to 0.00), although the CI reached zero.

Under heat stress, the standardized estimates for FCR were consistently negative (g = −0.61 to −0.84), suggesting favorable directions of effect, but the estimates were imprecise. In contrast, fruit powder supplementation produced estimates close to zero (Figure 4).

FCR effect sizes could not be calculated reliably for four studies. Liu *et al.* [13] reported feed-to-gain ratios rounded to one decimal place with standard deviations of 0.0–0.1. Igbokwue *et al.* [18] reported values below 1.0 that were incompatible with their corresponding feed intake and weight-gain data. Ajayi *et al.* [31] and Nwaodu *et al.* [32] reported standard deviations of zero.

None of the included studies specified whether FCR had been adjusted for mortality. Individual study data and the corresponding conversions are provided in Supplementary Table S4.

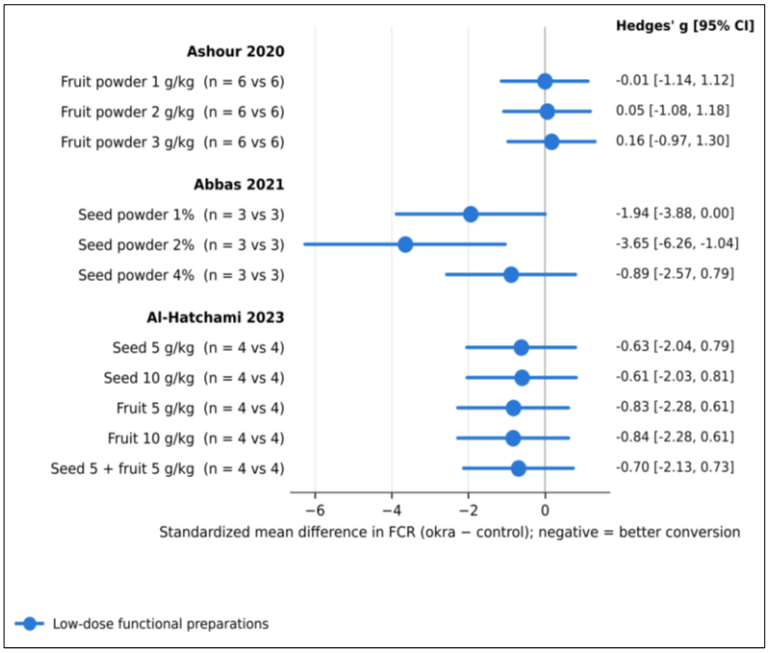


Figure 4: Standardized mean differences (Hedges' g) and 95% confidence intervals for feed conversion ratio (FCR) in individual okra treatment arms compared with unsupplemented controls. Negative standardized differences indicate improved feed conversion. Studies reporting FCR variances rounded to zero or internally inconsistent FCR values were excluded from the effect-size calculations.

Effects of meals and processing wastes: Okra meals and processing wastes did not consistently improve growth performance.

Stem-and-leaf meal incorporated at 2%–5% into isoenergetic and isonitrogenous diets produced standardized body weight estimates ranging from −0.45 to 0.31, indicating no consistent treatment effect [13].

Okra waste meal produced estimates at or below zero, with increasingly negative values at higher inclusion levels. The estimate reached g = −0.69 at a nominal inclusion level of 15%, corresponding to a formulated concentration of 5.3% [18].

Two reports containing identical growth performance tables produced large negative estimates for immature and mature okra meals and processing waste meal at nominal inclusion levels of 10%–30% [31, 32]. Because the duplicated values could not reliably represent two distinct experimental datasets, these estimates were not used to quantify the magnitude of growth reduction.

In laying hens, hen-day egg production was highest in the unsupplemented control group in the leaf meal study [17]. Pod powder supplementation produced improvements during selected periods but did not change overall hen-day production [33].

Gastrointestinal outcomes

Three studies evaluated gastrointestinal outcomes (Table 4). All microbial measurements were based on culture-dependent enumeration of selected bacterial groups using selective media. Results were generally expressed as logarithmic colony-forming units per gram ($\log_{10}$ CFU/g), without confirmation of pathogenic strains. In the seed powder study, the table was labeled using logarithmic CFU/g units, although the reported values included numerical multipliers, making the actual measurement scale uncertain.

Dietary seed powder reduced jejunal *Escherichia coli* and total bacterial counts while increasing lactic acid bacterial counts [14]. The greatest gastrointestinal tract length was reported at 2% inclusion. Microbial measurements were obtained from jejunal digesta collected from six birds per treatment.

Maltodextrin-encapsulated okra at 0.5%–1.5% increased villus height and the villus height-to-crypt depth ratio in the duodenum, jejunum, and ileum [16]. Supplementation was also associated with increased lactic acid bacterial counts, reduced coliform counts, and lower intestinal pH, with the largest reported changes at 1.5% inclusion.

Intestinal morphology was evaluated using hematoxylin- and eosin-stained tissue sections. However, the

number of birds and villi examined per replicate was not specified. Furthermore, increased crypt depth was reported alongside increased villus height, preventing an unqualified interpretation of the morphological changes as evidence of improved intestinal health.

In contrast, aqueous okra polysaccharides that inhibited *C. jejuni* adhesion to chicken colonic tissue under *in vitro* conditions did not reduce *C. jejuni* counts in excreta when administered through drinking water to experimentally challenged broilers [12]. No reduction was observed between days 12 and 40 following challenge on day 7.

Table 4: Gastrointestinal, hematological, biochemical, and physiological responses to okra supplementation in poultry.

Study and preparation	Gastrointestinal outcomes	Hematological, biochemical, and physiological outcomes
Abbas [14]; seed powder, 1%–4%	Lower *Escherichia coli* and total bacterial counts; higher lactic acid bacterial counts; greatest gastrointestinal tract length at 2%	Lower cholesterol and ALT at all inclusion levels; glucose, triglycerides, and total protein unchanged
Ashour *et al.* [15]; fruit powder, 1–3 g/kg	Not assessed	Lower urea; higher IgM and lysozyme activity; higher creatinine at 2–3 g/kg
Al-Hatchami and Alshukri [29]; seed/fruit powder under heat stress	Not assessed	Higher SOD activity; lower MDA, glucose, uric acid, and H/L ratio in selected groups
Febrianta *et al.* [16]; encapsulated okra, 0.5%–1.5%	Increased villus height and VH ratio; higher lactic acid bacterial counts; lower coliform counts and intestinal pH	Not assessed
Lengsfeld *et al.* [12]; aqueous extract in drinking water	No reduction in *Campylobacter jejuni* excretion; anti-adhesion activity observed *in vitro* was not reproduced *in vivo*	Not assessed
Saleh *et al.* [33]; pod powder, 2–4 g/kg, laying hens	Not assessed	Lower triglycerides at 2 g/kg; lower MDA at both inclusion levels; cholesterol unchanged

ALT = Alanine aminotransferase; H/L = Heterophil-to-lymphocyte ratio; IgM = Immunoglobulin M; MDA = Malondialdehyde; SOD = Superoxide dismutase; VH = Villus height-to-crypt depth ratio; pH = Measure of acidity or alkalinity. Bacterial findings were based on culture-dependent measurements of selected microbial groups. *Escherichia coli* and *Campylobacter jejuni* are written in full at their first occurrence within this table. The terms *in vitro* and *in vivo* refer to experiments conducted outside and within living organisms, respectively.

Hematological, biochemical, and physiological responses

Four studies reported hematological, biochemical, or physiological outcomes (Table 4). Dietary seed powder reduced serum cholesterol concentrations from 120.1 mg/dL in the control group to 87.8–105.9 mg/dL in supplemented groups [14]. Alanine aminotransferase activity was also lower, decreasing from 254 U/L in the control group to 243–247 U/L following supplementation. Serum glucose, triglycerides, and total protein were unchanged.

Dried fruit powder reduced serum urea concentrations and increased immunoglobulin M concentrations and lysozyme activity [15]. However, serum creatinine concentrations were higher at 2 and 3 g/kg than in the control group, indicating that the reported biochemical responses were not uniformly favorable.

Under cyclic heat stress, malondialdehyde concentrations were lower across okra-supplemented groups [29]. Superoxide dismutase activity increased, and the heterophil-to-lymphocyte ratio decreased in selected treatment groups. Serum cholesterol was reduced in two of the five okra treatment arms. Because all experimental groups were exposed to the same daily heat stress cycle, the study did not provide a thermoneutral comparator.

In laying hens, pod powder at 2 g/kg reduced serum triglyceride concentrations, while both evaluated inclusion levels reduced malondialdehyde concentrations [33]. Serum cholesterol remained unchanged.

None of the studies interpreted the reported biochemical measurements against age- and species-specific reference intervals or combined biomarker measurements with corresponding tissue histology or functional assessments. Therefore, these findings were considered surrogate physiological indicators rather than direct evidence of improved organ function.

Igbokwue *et al.* [18] reported a claim concerning differences in lipid profiles without presenting corresponding lipid measurements. This unsupported outcome was not included in the synthesis.

Carcass traits, meat quality, and pigmentation

Carcass responses to dietary okra supplementation were generally modest and inconsistent (Table 5). Seed powder supplementation did not alter carcass or individual cut yields, expressed as percentages of live body weight, despite favorable growth responses [14]. Carcass measurements were obtained from two birds per replicate.

Dried fruit powder produced changes in breast, thigh, and dressing yields, although the directions of these changes differed among outcomes [15].

Maltodextrin-encapsulated okra reduced abdominal fat at inclusion levels of 1.0%–1.5% [16]. However, dressing percentage, meat pH, water-holding capacity, tenderness, and instrumental meat color remained unchanged.

At the highest nominal inclusion levels, okra processing waste meal reduced absolute dressed, eviscerated, and individual cut weights [18, 32]. These differences were associated with lower final body weights and did not necessarily indicate reductions in proportional carcass yields. Furthermore, some of the corresponding carcass data appeared in duplicated tables across reports.

Among product quality outcomes, dried fruit powder reduced thiobarbituric acid values in minced breast and thigh meat stored at −20°C for up to three months [15].

Stem-and-leaf meal at 4%–5% increased the intensity of yellow pigmentation in the shanks, skin, and abdominal fat without altering growth performance [13]. Pigmentation was assessed visually using a color fan rather than through instrumental color measurement.

The synthetic pigment comparator produced lower pigmentation scores than 3%–5% okra meal and scores comparable to those obtained with 2% okra meal [13]. However, none of the included studies quantified the carotenoid content of the administered okra preparations. The commercial relevance of increased pigmentation may also vary according to market preferences.

Laying performance and egg quality

Both laying-hen studies reported changes in egg quality characteristics without consistent improvements in overall egg production (Table 5).

Table 5: Effects of okra supplementation on carcass characteristics, meat quality, pigmentation, laying performance, egg quality, and reproductive outcomes.

Study and preparation	Outcome domain	Principal findings
Abbas [14]; seed powder, 1%–4%	Carcass characteristics	No significant differences in carcass or individual cut yields
Ashour *et al.* [15]; fruit powder, 1–3 g/kg	Carcass and meat quality	Carcass yields changed in different directions; lower TBA values during frozen meat storage
Febrianta *et al.* [16]; encapsulated okra, 0.5%–1.5%	Carcass and meat quality	Lower abdominal fat at 1.0%–1.5%; meat pH, WHC, tenderness, and color unchanged
Liu *et al.* [13]; stem-and-leaf meal, 2%–5%	Pigmentation	Increased yellow pigmentation of shanks, skin, and abdominal fat at 4%–5%
Igbokwue *et al.* [18]; waste meal	Carcass characteristics	Lower dressed, eviscerated, breast, and thigh weights at nominal 15% inclusion
Ajayi *et al.* [31]; okra meal	Carcass characteristics	Selected carcass weights were lower with 5% mature okra meal
Nwaodu *et al.* [32]; waste meal	Carcass characteristics	Lower dressed, eviscerated, and individual cut weights at nominal 30% inclusion
Sobayo *et al.* [17]; leaf meal, 2.5%–10%	Laying performance and egg quality	Hen-day production highest in control; increased yolk color and egg weight; lower egg cholesterol, LDL, and HDL
Saleh *et al.* [33] and Allaw *et al.* [34]; pod powder, 2–4 g/kg	Laying performance and egg quality	No overall change in hen-day production or FCR; increased shell thickness; lower yolk FFA and peroxide values
Machebe *et al.* [35]; seed extract, 50 mL/L drinking water	Turkey reproductive performance	Higher egg number, fertility, and hatchability

FCR = Feed conversion ratio; FFA = Free fatty acids; HDL = High-density lipoprotein; LDL = Low-density lipoprotein; TBA = Thiobarbituric acid; WHC = Water-holding capacity; pH = Measure of acidity or alkalinity. The direction of change is relative to the corresponding unsupplemented control. Results represent the outcomes reported by individual studies and should not be interpreted as pooled treatment effects. Carcass weights and proportional yields are distinct measurements.

In the leaf meal study, hen-day egg production was highest in the unsupplemented control group (55.8%) [17]. Among supplemented groups, the highest production was observed at 5% inclusion (50.3%). Dietary leaf meal increased yolk color intensity and egg weight, while egg cholesterol, triglycerides, and low-density lipoprotein concentrations declined with increasing inclusion levels. However, high-density lipoprotein concentrations also decreased.

These lipid measurements were performed on egg yolk rather than serum. Body weight gain was reduced at the higher inclusion levels of 7.5%–10%.

In the pod powder study, supplementation increased eggshell thickness and reduced yolk free fatty acid concentrations at 2 g/kg [33, 34]. Yolk peroxide values were lower at both evaluated inclusion levels, whereas total egg weight and component weights remained unchanged.

An improvement in hen-day production was reported during the second four-week period, but no overall difference was observed across the complete experimental period. Unlike the leaf meal study, lipid measurements in this investigation were performed primarily on serum rather than egg yolk.

Reproductive performance in turkey breeders

Only one included study evaluated reproductive outcomes in a poultry species other than chickens [35].

In 20 turkey-breeder hens, administration of an aqueous okra seed extract at 50 mL/L drinking water was associated with greater egg production (61 vs. 36 eggs), fertility (87% vs. 50%), and hatchability (51% vs. 22%) compared with the untreated control.

The hens were artificially inseminated using pooled semen, and fertility and hatchability were expressed relative to the total number of eggs set.

However, the reported percentages for embryo mortality and hatchability summed to 100% in every experimental group, which was incompatible with the simultaneously reported proportions of infertile eggs.

The study involved only five hens per treatment group, evaluated a single okra inclusion level, and used individual hens as experimental replicates. Accordingly, its findings were considered preliminary and were evaluated separately from the chicken studies.

Feasibility of quantitative synthesis

No intervention–outcome combination satisfied the prespecified criteria for quantitative meta-analysis (Table 6).

Table 6: Feasibility of quantitative meta-analysis for individual okra intervention–outcome combinations.

Intervention–outcome combination	Independent studies	Conditions preventing quantitative pooling	Decision
Seed or fruit powder and body weight or FCR in broilers	3	Different plant parts; inclusion levels of 1–40 g/kg; one study under cyclic heat stress	Not pooled; two studies per preparation
Meals and processing wastes and body weight in broilers	4	Different plant materials and growth stages; discrepancies between nominal and formulated inclusion levels; duplicated tables across three reports	Not pooled
Meals and processing wastes and FCR in broilers	4	Variances rounded to zero or internally inconsistent FCR values	Not pooled
Aqueous extracts administered through drinking water	3	Different plant parts, poultry species, outcomes, and dosage units; insufficient variance information for growth	Not pooled
Intestinal microbiota and morphology	3	Different intestinal segments, enumeration methods, and target organisms	Not pooled
Serum lipids, liver enzymes, and oxidative status	4	No individual biomarker reported by three sufficiently comparable studies	Not pooled
Carcass traits, meat quality, and pigmentation	3	Different outcome constructs, including TBA, pigmentation scores, and abdominal fat	Not pooled
Laying performance and egg quality	2	Fewer than three independent studies; different preparations (leaf meal and pod powder)	Not pooled
Fertility and hatchability	1	Only one eligible study	Not pooled

FCR = Feed conversion ratio; TBA = Thiobarbituric acid. Meta-analysis required at least three independent studies with comparable plant parts, administration routes, inclusion units, poultry species or production types, production stages, and adequate variance data. The complete pooling feasibility matrix is presented in Supplementary Table S4.

The most closely comparable combination involved seed or fruit powder supplementation and final body weight in broilers. Although three studies contributed relevant observations, they investigated different plant parts, inclusion levels ranging from 1 to 40 g/kg, and different environmental conditions, including one trial conducted under cyclic heat stress. Seed powder and fruit powder were each evaluated in only two studies.

The four studies investigating okra meals and processing wastes differed in plant material and poultry growth stage. Three reports contained duplicated numerical tables, while three reported nominal inclusion levels that differed from the concentrations in their dietary formulation tables.

Secondary outcomes also lacked sufficient methodological comparability. Studies evaluated different intestinal segments, microbial groups, biochemical markers, tissues, and product quality characteristics. Several outcomes were reported by only one or two independent studies.

Consequently, individual study effect sizes were presented without pooled estimates, and heterogeneous outcomes were summarized narratively.

Certainty of evidence

The certainty of evidence varied across outcome domains (Table 7).

Table 7: Summary of findings and certainty of evidence for dietary okra supplementation in poultry using the GRADE framework adapted for animal studies.

Outcome domain	Studies (birds)	Direction of effect	Reasons for downgrading	Certainty
Body weight: seed or fruit powder in broilers	3 (816)	Positive estimates in 8 of 11 treatment arms; 95% CI excluded zero for 1 g/kg fruit powder and 1% seed powder	Risk-of-bias; imprecision	Low (⊕⊕◯◯)
Body weight: meals and processing wastes in broilers	4 (586)	No consistent improvement; larger reductions occurred in reports containing duplicated tables	Risk-of-bias (two levels); imprecision	Very low (⊕◯◯◯)
FCR in broilers	5 (1,248)	Improved with 1%–2% seed powder; negative but imprecise estimates under heat stress; no change in three trials	Risk-of-bias; imprecision	Low (⊕⊕◯◯)
Intestinal microbiota and morphology	3 (560)	Increased lactic acid bacterial counts and reduced coliform or *Escherichia coli* counts in two trials; altered villus indices in one; no change in *Campylobacter jejuni* excretion	Risk-of-bias; imprecision	Low (⊕⊕◯◯)
Blood lipids, liver enzymes, and oxidative status	4 (1,116)	Lower cholesterol, ALT, and MDA; higher SOD under heat stress	Risk-of-bias; indirectness; imprecision	Very low (⊕◯◯◯)
Meat quality, pigmentation, and carcass fat	3 (728)	Lower TBA values in stored meat; increased skin pigmentation with 4%–5% stem-and-leaf meal; reduced abdominal fat with encapsulated okra	Risk-of-bias; imprecision	Low (⊕⊕◯◯)
Laying performance and egg quality	2 (375)	No overall improvement in hen-day production; lower egg cholesterol and yolk oxidation markers	Risk-of-bias; inconsistency; imprecision	Very low (⊕◯◯◯)
Fertility and hatchability in turkeys	1 (20)	Higher egg production, fertility, and hatchability	Risk-of-bias; imprecision (two levels)	Very low (⊕◯◯◯)

GRADE = Grading of Recommendations Assessment, Development and Evaluation; FCR = Feed conversion ratio; CI = Confidence interval; ALT = Alanine aminotransferase; MDA = Malondialdehyde; SOD = Superoxide dismutase; TBA = Thiobarbituric acid. Certainty was initially rated as high for controlled feeding experiments and downgraded by one level for each serious concern or two levels for a very serious concern. Low certainty is represented by ⊕⊕◯◯, and very low certainty by ⊕◯◯◯. For body weight and feed conversion with seed or fruit powder, high risk-of-bias judgments arose primarily from inconsistent dose labels and narrative reporting rather than from the numerical tables used to calculate effect sizes; therefore, these domains were downgraded by one level for risk-of-bias. Domain-specific assessments are presented in Supplementary Table S4.

Evidence certainty was rated as low for body weight following seed or fruit powder supplementation, feed conversion, intestinal outcomes, and meat quality or pigmentation. Very low certainty was assigned to body weight following supplementation with meals and processing wastes, blood and physiological outcomes, laying performance, and reproductive outcomes.

All outcome domains were downgraded for risk-of-bias and imprecision. Most treatment arms included only two to six independent replicate units, and many CIs were sufficiently wide to encompass both beneficial and unfavorable effects.

The meal and processing waste domain was downgraded by two levels for risk-of-bias because of duplicated numerical tables and inconsistencies between nominal and formulated inclusion levels.

Blood and physiological outcomes were downgraded for indirectness because most reported variables were surrogate biomarkers rather than direct functional outcomes.

Laying performance was downgraded for inconsistency across the available studies. Statistical assessment of publication bias was not feasible because too few independent studies contributed to each outcome domain.

Sensitivity analyses

The narrative sensitivity analyses did not materially change the principal conclusions. The favorable growth pattern associated with low-dose seed and fruit powders was supported by three studies identified through the principal database searches. Giving less weight to the heat stress study, which contained inconsistent dose labels, did not alter the overall interpretation because the two thermoneutral trials reported similar directions of response.

Giving less weight to the three meal and processing waste reports containing duplicated tables left the stem-and-leaf meal study as the principal independent source of interpretable growth evidence. That study reported no consistent improvement in growth. Therefore, the conclusion that meals and wastes had not demonstrated growth benefits remained unchanged, although evidence for a dose-related decline in performance became insufficient.

Excluding reports identified exclusively through supplementary searching removed the laying-hen leaf meal study, turkey-breeder study, drinking water extract trial, encapsulated okra trial, and three of the four meal and processing waste studies.

Under this restriction, findings for low-dose powders remained unchanged. However, the evidence concerning intestinal morphology was no longer available, and the gastrointestinal outcome domain was represented by only two studies evaluating microbial counts and *C. jejuni* excretion.

Companion reports had already been combined at the study-family level to prevent double counting of the same experimental populations.

DISCUSSION

Effects of okra preparation and inclusion level on growth performance

The findings of this systematic review indicate that okra should not be regarded as a single, compositionally uniform poultry feed additive. The effects of supplementation differed according to the plant part, preparation method, inclusion level, and intended nutritional function. Among the evaluated interventions, low-dose seed and dried fruit powders provided the most consistent indications of improved growth performance in broilers, although the certainty of evidence remained low. Favorable responses were generally confined to the lower inclusion levels: dried fruit powder at 1 g/kg and seed powder at 1%–2% were associated with improved final body weight or FCR, whereas higher inclusion levels produced smaller, negligible, or negative estimates [14, 15]. Under cyclic heat stress, seed and fruit powders produced consistently positive but imprecise body weight estimates, with CIs encompassing no effect [28].

In contrast, okra meals and processing wastes did not demonstrate consistent improvements in broiler growth performance [13, 18]. Although larger reductions in body weight were reported at higher inclusion levels, these findings originated primarily from reports containing duplicated numerical tables, making the magnitude and dose dependence of the apparent reductions uncertain [31, 32]. Consequently, the available evidence does not establish that increasing dietary okra inclusion necessarily causes progressive growth suppression.

These findings refine the conclusions of an earlier narrative mini review, which suggested that low-to-moderate dietary okra supplementation could improve broiler growth and feed efficiency [19]. The present systematic evaluation indicates that this potential benefit is more specifically associated with selected low-dose seed and fruit powder preparations rather than with okra-derived ingredients generally. However, the limited number of independent studies, small experimental units, and methodological concerns prevent firm conclusions regarding an optimal inclusion level.

Studies involving the related species *Abelmoschus manihot* have reported a broadly comparable pattern. Recent broiler experiments evaluating flower powder and extracts of this species identified favorable responses at very low inclusion levels but no consistent growth improvement at 0.5%–1% supplementation [36, 37]. Nevertheless, differences in botanical species, plant parts, phytochemical composition, and preparation methods limit direct extrapolation to *A. esculentus*.

In absolute terms, the largest improvements in final body weight reported with low-dose okra powders were approximately 67–94 g, corresponding to about 5% of final body weight, while the largest improvements in FCR were approximately 0.07–0.09 units. These estimates originated from trials containing only three to six replicate units per treatment group. Although such differences may be relevant to production efficiency, their commercial importance remains uncertain because none of the powder supplementation studies reported the associated ingredient, processing, or supplementation costs.

Nutritional composition and potential explanations for variable responses

The differences between low-dose functional preparations and higher inclusion meals or processing wastes are compatible with the known compositional characteristics of okra. However, the included feeding trials did not directly establish the mechanisms responsible for the observed responses.

Okra processing residues contain substantial amounts of CF [11], while okra mucilage contains polysaccharides capable of forming viscous aqueous solutions [8, 9]. At relatively high dietary inclusion levels, these characteristics could influence dietary nutrient density, digesta properties, and nutrient utilization. In several studies evaluating okra meals and processing wastes, increasing inclusion was accompanied by higher dietary fiber concentrations or reduced energy density because the experimental diets were not formulated to be nutritionally equivalent [17, 18, 32].

Consequently, nutrient dilution, changes in dietary palatability, and differences in feed formulation represent plausible explanations for the absence of consistent growth improvements. The available evidence does not establish a specific toxic effect of okra meals or processing wastes.

The effects attributable to individual plant parts also remain difficult to distinguish from those associated with inclusion level, basal diet composition, poultry population, environmental conditions, and experimental design. None of the included trials directly compared different okra plant parts under otherwise equivalent experimental conditions.

Seed and fruit powders administered at relatively low concentrations contribute comparatively little bulk to the complete diet but may provide phenolic compounds and soluble polysaccharides [7, 10]. These constituents could contribute to biological responses without substantially changing dietary nutrient density. Nevertheless, this explanation remains hypothetical because the included trials generally lacked detailed compositional characterization and did not simultaneously evaluate nutrient digestibility, intestinal fermentation, and growth performance.

Controlled experiments using chemically characterized preparations and nutritionally equivalent diets are therefore necessary to determine whether the observed differences reflect specific bioactive constituents, dietary formulation effects, or interactions between these factors.

Intestinal microbial responses and gastrointestinal morphology

The gastrointestinal findings suggest that certain okra preparations can influence selected intestinal microbial populations and morphological measurements. However, the available evidence does not establish whether these changes directly contribute to improved growth performance.

Dietary seed powder and maltodextrin-encapsulated okra were associated with increased lactic acid bacterial counts, reduced coliform or *E. coli* counts, lower intestinal pH, and changes in intestinal villus measurements [14, 16]. Similar combinations of microbial and morphological responses have been reported following supplementation with other phytogenic feed additives [38, 39].

Nevertheless, the included okra trials did not simultaneously measure intestinal fermentation products, epithelial barrier function, nutrient digestibility, and growth performance. Therefore, a causal relationship between the reported gastrointestinal changes and production outcomes cannot be established.

The encapsulated okra study also lacked both an unencapsulated okra comparator and a maltodextrin-only control [16]. As a result, the effects attributable specifically to okra, the encapsulation process, and the carrier material cannot be distinguished. This limitation is particularly relevant because encapsulation may alter the stability, delivery, and availability of bioactive compounds [40].

The discrepancy between laboratory and animal findings further illustrates the importance of distinguishing biological activity from demonstrated efficacy. Okra polysaccharides inhibited *C. jejuni* adhesion to isolated chicken colonic tissue *in vitro*, but administration through drinking water did not reduce bacterial excretion in experimentally challenged broilers *in vivo* [12].

Potential explanations include dilution or degradation of the polysaccharides within the gastrointestinal tract, differences between the experimental challenge conditions and the laboratory adhesion model, and the predominance of cecal colonization, which may not be adequately represented by adhesion to isolated colonic tissue. However, these mechanisms were not investigated in the included study and should be regarded as possible explanations rather than established findings.

Moreover, the microbial outcomes were based on culture-dependent enumeration of selected bacterial groups rather than comprehensive characterization of intestinal microbial communities. Accordingly, the evidence supports changes in specific measured populations but does not establish broader improvements in intestinal microbial diversity, ecological stability, or resistance to pathogen colonization.

Antioxidant responses, physiological indicators, and product quality

Several secondary outcomes suggest potential physiological effects of okra supplementation, although most findings were derived from individual studies and require independent confirmation.

Lower malondialdehyde concentrations and higher superoxide dismutase activity were reported in selected groups of heat-stressed broilers receiving seed or fruit powder [29]. Reduced malondialdehyde concentrations were also observed in laying hens supplemented with pod powder [33]. These findings are compatible with a possible contribution from okra-derived phenolic constituents, particularly because dietary quercetin has demonstrated antioxidant-related effects in broilers [41].

However, the heat stress experiment did not include a thermoneutral okra-supplemented group, and inconsistencies in treatment-dose labels limited dose-specific interpretation. Consequently, the available findings do not establish whether okra specifically mitigated heat stress-associated oxidative responses or produced

similar effects under normal environmental conditions.

Reduced thiobarbituric acid values in frozen meat from broilers receiving dried fruit powder provide an additional indication of possible effects on lipid oxidation [15]. Nevertheless, the relationship between dietary okra composition, systemic antioxidant responses, and oxidative stability of stored meat has not been established through replicated mechanistic investigations.

Changes in serum cholesterol, triglycerides, urea, creatinine, and selected enzyme activities were also reported [14, 15, 33]. However, these outcomes were not consistently evaluated across studies, and the reported concentrations were not interpreted against appropriate age- and species-specific reference intervals. Furthermore, biochemical measurements were generally not accompanied by histopathological or functional assessments. They should therefore be interpreted as preliminary physiological observations rather than evidence of improved organ function or metabolic health.

Pigmentation represents a potentially distinct application of okra-derived ingredients. Stem-and-leaf meal increased yellow pigmentation of broiler shanks, skin, and abdominal fat, while leaf meal increased yolk color intensity in laying hens [13, 17]. These responses occurred without corresponding improvements in overall production performance.

The pigmentation findings are compatible with the deposition of dietary carotenoids, a recognized mechanism influencing poultry skin and yolk coloration [42]. However, none of the included studies quantified the carotenoid content of the okra preparations. Consequently, the relationship between dietary pigment concentration, inclusion level, and observed coloration remains uncertain.

The commercial relevance of pigmentation changes also depends on consumer preferences and regional market requirements. Increased pigmentation should not automatically be interpreted as improved nutritional quality or economic value.

Laying performance and reproductive outcomes

The available evidence does not demonstrate a consistent improvement in overall egg production following dietary okra supplementation.

In laying hens, leaf meal and pod powder altered selected egg quality characteristics, including yolk pigmentation, eggshell thickness, lipid concentrations, and oxidation-related measurements [17, 33, 34]. However, neither intervention produced a consistent improvement in overall hen-day egg production.

The leaf meal study also reported reduced body weight gain at higher dietary inclusion levels [17], suggesting that any potential egg quality benefits should be considered alongside possible changes in nutrient supply and bird performance.

Interpretation is further complicated by differences in the biological samples used for lipid analysis. One study measured egg yolk lipids, whereas another primarily evaluated serum lipid concentrations. These outcomes are not interchangeable and should not be combined as equivalent indicators of egg lipid composition.

The reproductive findings in turkey breeders were derived from a single experiment involving 20 hens [35]. Although higher egg production, fertility, and hatchability were reported following administration of aqueous okra seed extract, the small sample size and inconsistencies among the reported fertility, embryo mortality, and hatchability percentages substantially limit confidence in these results.

Therefore, the turkey findings should be considered preliminary and should not be extrapolated to chickens or other poultry species without independent replication.

Sources of heterogeneity and methodological uncertainty

Heterogeneity across the included studies occurred at biological, intervention-related, and methodological levels.

Biological heterogeneity included differences in poultry species, genetic strain, age, sex, production stage, and environmental conditions, particularly exposure to cyclic heat stress.

Intervention heterogeneity involved differences in plant part, processing method, inclusion level, dose unit, administration route, and dietary formulation. These differences were particularly important when interpreting growth performance because low-dose functional preparations and higher inclusion meals or processing wastes represented nutritionally distinct interventions.

Methodological heterogeneity included differences in experimental unit selection, replication, randomization reporting, dietary formulation, outcome measurement, statistical analysis, and numerical consistency.

Methodological limitations were especially important for interpreting meal and processing waste studies,

several of which contained discrepancies between nominal and formulated inclusion levels or duplicated numerical data across reports [18, 31, 32]. Such inconsistencies prevented reliable estimation of dose-dependent growth effects.

The laying-hen evidence was also affected by differences in intervention type, outcome measurement, and reporting consistency [17, 33, 34].

Selective outcome reporting may have further influenced the apparent frequency of favorable findings. Several reports emphasized beneficial effects in their abstracts that were not fully supported by their numerical tables or corresponding methods [15, 17, 18].

These limitations reinforce the importance of distinguishing statistically reported treatment effects from findings that are independently reproducible and supported by reliable experimental methods.

The absence of sufficiently comparable intervention–outcome combinations also justified the decision not to conduct a quantitative meta-analysis. Combining biologically and methodologically heterogeneous studies could have produced pooled estimates with limited interpretability.

Safety considerations and economic implications

The safety of dietary okra supplementation remains insufficiently characterized. Mortality was reported in seven studies. Six reported zero mortality or mortality comparable to the control, while one reported lower mortality in the okra-treated group [30]. However, the absence of reported adverse effects does not establish safety, particularly when studies are small, relatively short, and not designed specifically to detect toxicological outcomes.

None of the included studies systematically evaluated antinutritional factors, contaminants, or storage stability of the administered okra material. The longest feeding period was 12 weeks, limiting conclusions regarding long-term exposure.

Potential unfavorable findings included increased serum creatinine concentrations at selected dried fruit powder inclusion levels [15] and reduced body weight gain in laying hens receiving high concentrations of leaf meal [17].

Although three studies recorded organ weights [14, 15, 32], none included histopathological evaluation. Consequently, the available evidence does not support definitive conclusions regarding the absence of organ-specific or long-term adverse effects.

Economic considerations also require careful evaluation. Three meal and processing waste studies reported feed cost per kilogram of feed, feed cost per kilogram of body weight gain, and production cost per bird. One study additionally reported profit per bird.

Although inclusion of okra processing wastes reduced the cost per kilogram of feed in some experiments, lower feed prices did not necessarily translate into improved economic returns. In the study reporting profit, profit per bird decreased as okra waste inclusion increased [32].

Furthermore, none of the included studies conducted a comprehensive economic evaluation accounting for ingredient procurement, processing, drying, transportation, storage, nutrient variability, and production performance.

Okra processing residues may warrant further investigation as potential circular-feed resources. However, their commercial suitability will depend on whether the value of replacing conventional ingredients exceeds the costs associated with processing, handling, and any reduction in animal performance.

Seasonal availability, competing food uses, and variation in raw material composition may also influence feasibility. These considerations have not been adequately evaluated under commercial poultry production conditions.

Strengths and limitations of the evidence synthesis

The present review provides a structured assessment of dietary okra supplementation across poultry production systems, intervention classes, and outcome domains.

An important strength was the expanded literature search covering three major bibliographic databases without language restrictions, supplemented by searches of agricultural information resources, regional journals, and citation networks.

The review also distinguished independent studies from companion reports, evaluated the feasibility of quantitative synthesis, presented standardized effect estimates for treatment arms with sufficient numerical information, and assessed certainty of evidence separately for each outcome domain.

Seven of the 15 included reports were identified exclusively through supplementary searching, highlighting the limited indexing of relevant regional poultry research. However, this finding also indicates that additional eligible studies published in poorly indexed journals may have been missed.

The exclusion of theses, preprints, and other unpublished reports may have reduced coverage of studies reporting nonsignificant or unfavorable results. Publication bias could not be assessed statistically because too few independent studies contributed to individual intervention–outcome combinations.

Another limitation was retrospective protocol registration. Although the methodological amendments were documented, the registration did not provide the safeguards against post hoc decisions associated with prospective registration.

The second assessment of eligibility, risk-of-bias, and principal outcome data was AI-assisted and subsequently verified by a co-author rather than being conducted through fully independent duplicate review. This approach provided an additional verification procedure but should not be considered equivalent to independent dual assessment.

Most importantly, the certainty of the synthesized evidence was constrained by limitations of the primary studies. Small numbers of experimental replicates, incomplete methodological reporting, inconsistent dietary formulations, limited intervention characterization, and numerical discrepancies reduced confidence in the reported treatment effects.

These limitations were particularly consequential for estimating dose responses, distinguishing preparation-specific effects, and determining whether observed physiological changes were reproducible.

Accordingly, the findings should be interpreted as an assessment of the currently available evidence rather than as definitive recommendations for commercial poultry feeding.

Future research priorities

Future poultry feeding trials should provide comprehensive characterization of the okra materials used. Essential information includes plant part, cultivar, harvest stage, processing method, drying conditions, storage duration, and chemical composition.

Compositional analyses should include relevant nutrients and bioactive constituents, particularly CF, soluble polysaccharides, phenolic compounds, and pigments where these are central to the study hypothesis. Evaluation of antinutritional factors and potential contaminants, including pesticide residues and mycotoxins, is particularly important when processing wastes are considered as feed ingredients.

Researchers should report both nominal and formulated inclusion levels, ensure consistency between dietary formulations and treatment descriptions, and quantify the amount of okra dry matter consumed per bird.

Nutritionally equivalent diets are necessary to distinguish the biological effects of okra-derived constituents from changes caused by energy or nutrient dilution.

Experimental designs should use appropriate independent experimental units, generally replicate pens or cages, with adequate replication and clearly documented randomization procedures. Studies should also report mortality, the statistical model, treatment group means, measures of variability, and sample sizes for all evaluated outcomes.

Graded-dose experiments comparing seed and fruit powders under equivalent conditions would help determine whether the apparent low-dose benefits are reproducible and identify the inclusion levels beyond which favorable responses diminish.

Similarly, direct comparisons between encapsulated and unencapsulated preparations, including appropriate carrier-only controls, are needed to distinguish the effects of okra constituents from those of encapsulation and delivery materials.

Mechanistic studies should evaluate nutrient digestibility, intestinal fermentation products, epithelial barrier function, microbial populations, and oxidative indicators alongside growth performance. Investigations conducted under both thermoneutral and heat stress conditions would help determine whether responses depend on environmental challenges.

The proposed relationships among okra preparation, dietary composition, intestinal responses, oxidative status, and production outcomes are summarized conceptually in Figure 5. These pathways remain hypotheses requiring experimental validation.

For laying hens, studies extending across a complete laying cycle are needed to determine whether changes in egg quality can be sustained without adverse effects on production or body condition.

The preliminary reproductive findings in turkey breeders require independent replication using larger populations, clearly defined reproductive endpoints, and internally consistent fertility and hatchability calculations.

Finally, economic evaluations should express costs and returns per unit of marketable poultry product rather than relying solely on feed price. Such analyses should incorporate ingredient processing, storage, transportation, feed efficiency, mortality, and product quality before commercial recommendations are considered.

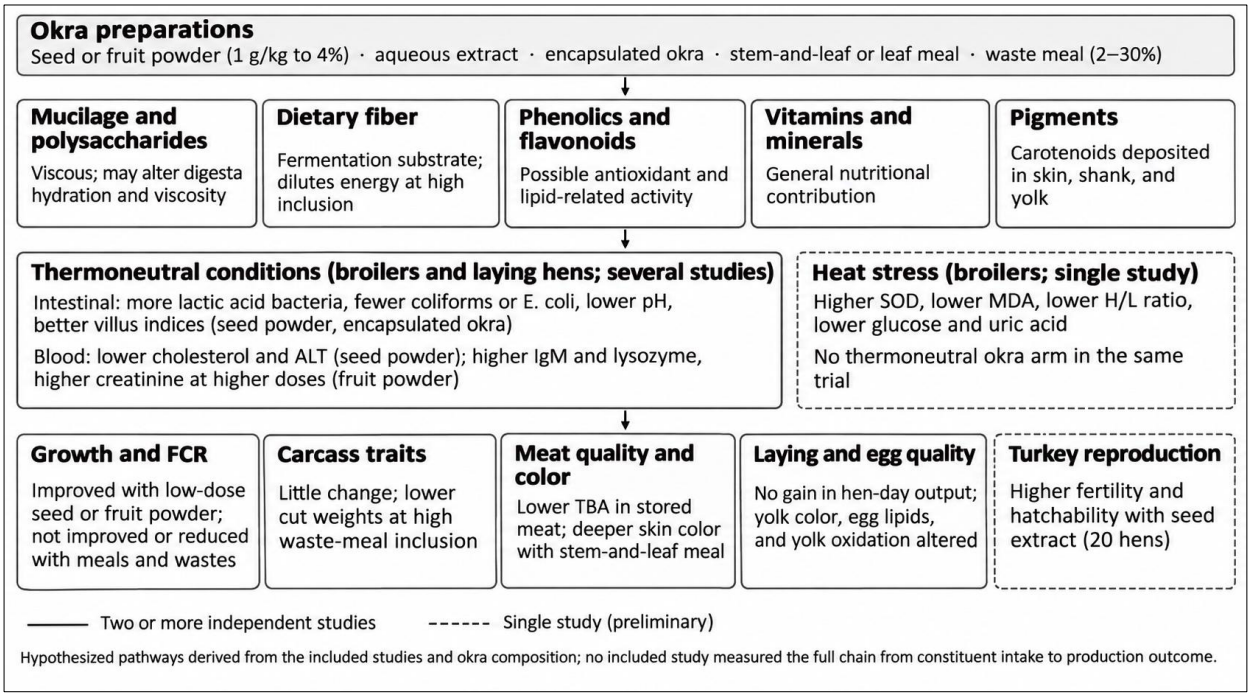


Figure 5: Conceptual summary of the proposed pathways linking okra preparations to poultry production and physiological outcomes. Solid borders identify findings supported by two or more independent studies, whereas dashed borders indicate findings reported in a single study, including heat stress-related responses and turkey reproductive outcomes. The proposed pathways are based on observations from the included studies and the reported composition of okra-derived materials. They represent mechanistic hypotheses and have not been experimentally confirmed. FCR = Feed conversion ratio.

CONCLUSION

This systematic review of 13 independent controlled poultry feeding studies, reported in 15 publications, demonstrated that the effects of dietary okra (*Abelmoschus esculentus*) depend on the plant part, preparation method, inclusion level, and experimental conditions. Low-dose seed and dried fruit powders showed the most consistent indications of improved broiler growth performance and feed utilization. Favorable responses were observed particularly with 1 g/kg dried fruit powder and 1%–2% seed powder, although the certainty of evidence was low. In contrast, okra meals and processing wastes did not consistently improve growth performance, and the magnitude of reported reductions at higher inclusion levels remained uncertain because of methodological and numerical inconsistencies. Selected studies reported changes in intestinal microbial populations, intestinal morphology, antioxidant indicators, meat oxidation, pigmentation, and egg quality. However, these findings were supported by limited independent evidence. Reproductive benefits reported in turkey breeders were preliminary. No intervention–outcome combination met the prespecified criteria for meta-analysis, and no definitive optimal inclusion level could be established.

Low-dose okra seed and fruit powders may have potential as functional feed ingredients in broiler diets, but the current evidence is insufficient to recommend their routine commercial supplementation. The apparent benefits should be interpreted in relation to preparation-specific composition, dietary inclusion level, feed efficiency, and production costs. Okra meals and processing wastes should not be considered nutritionally equivalent to concentrated seed or fruit powders. Their incorporation into poultry diets requires particular attention to dietary fiber concentration, energy density, nutrient balance, and potential effects on growth performance. Although selected preparations may influence pigmentation and other product quality characteristics, their commercial value remains uncertain. Available safety and economic data are also insufficient to establish practical inclusion limits or demonstrate cost-effectiveness under commercial production conditions.

Dietary okra supplementation shows preparation-dependent potential in poultry nutrition, with the most promising but still uncertain evidence relating to low-dose seed and dried fruit powders in broilers. Current findings do not support generalizing these benefits to all okra-derived materials or recommending a universal supplementation level. The absence of consistent growth benefits from higher inclusion meals and processing wastes, together with substantial methodological limitations and insufficient safety and economic evidence, warrants caution. Standardized, adequately replicated, and independently validated feeding trials are essential before okra-derived preparations can be recommended confidently for routine poultry production.

DATA AVAILABILITY

Supplementary materials are available from the corresponding author.

Supplementary Table S1: Search strategies, search dates, restrictions, and record yields for all information sources.

Supplementary Table S2: Reports excluded following full-text assessment and reports awaiting classification.

Supplementary Table S3: Study-level risk-of-bias judgments using the adapted SYRCLE tool, including supporting information.

Supplementary Table S4: Individual study effect sizes, quantitative pooling feasibility matrix, and GRADE certainty assessments.

Supplementary Table S5: Study-family mapping identifying related and companion reports.

Supplementary Table S6: PRISMA 2020 and PRISMA-S checklists.

Supplementary Table S7: Structured data extraction form used for the systematic review.

Supplementary File S8: Screening decisions, supplementary-search log, extraction dataset, and effect-size calculations.

Supplementary Figure S1: PRISMA 2020 flow diagram showing the study selection process for the original literature searches.

Supplementary Figure S2: Distribution of risk-of-bias judgments across assessment domains.

The data supporting the findings of this systematic review include the extraction dataset containing study identifiers, interventions, comparators, numerical outcomes, and measures of variability; effect-size calculations; screening decisions for all identified records (Supplementary File S8); study-level risk-of-bias judgments with supporting quotations (Supplementary Table S3); and study-family mapping (Supplementary Table S5). These materials are provided in the supplementary files and will also be deposited in the OSF project associated with the review registration (DOI: 10.17605/OSF.IO/UD8YQ).

The screening dataset contains bibliographic identifiers and eligibility decisions only. Abstracts exported from Scopus and Web of Science are not shared because of database licensing restrictions.

GENERATIVE AI DECLARATION

OpenAI Codex was used to generate a second assessment of study screening, eligibility, risk-of-bias, and principal outcome data. The AI-generated decisions and extracted information concerning records, included reports, risk-of-bias judgments, and outcome data were verified against the original records and available full texts by a co-author, except for the full-text exclusions described in the Materials and Methods section. Generative AI tools were also used to assist with language editing. The authors reviewed and verified the manuscript content and accept full responsibility for the accuracy, integrity, and scientific conclusions of the work.

AUTHORS' CONTRIBUTIONS

WN: Conceptualization, methodology, literature search, study screening, data extraction, risk-of-bias assessment, evidence synthesis, and preparation of the original manuscript draft. NL: Methodology, validation of the artificial intelligence (AI)-assisted second assessment of screening, eligibility, risk-of-bias, and outcome data against the original reports, and critical revision of the manuscript. SS, RB, WAST, and IMA: Interpretation of the synthesized evidence and certainty ratings, and critical revision of the manuscript for important intellectual content. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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