



FROM FUNCTIONAL FOOD TO INFLAMMATORY AND METABOLIC REGULATION: A SYSTEMATIC REVIEW OF THE EFFECTS OF OKRA (*Abelmoschus esculentus*) CONSUMPTION IN VARIOUS PROCESSED PREPARATIONS

Mike Permata Sari¹⁾; Cityta Putri Kwarto²⁾; Afifa Radhina³⁾; Nurul Ain⁴⁾

1. mikepermatasari1411@gmail.com, Institut Kesehatan Hermina
2. cityta@unitomo.ac.id, Universitas Dr Soetomo
3. afifa.radhina@upnvi.ac.id, Universitas Pembangunan Nasional Veteran Jakarta
4. nurul.ain@uinjkt.ac.id, Universitas Islam Negeri Syarif Hidayatullah Jakarta

Abstract

Okra (*Abelmoschus esculentus*) is a horticultural crop containing phytochemicals that have the potential to provide health benefits. Several studies have shown that okra consumption can affect the levels of metabolic modulators, oxidative stress, and inflammatory biomarkers. Therefore, this systematic review aims to comprehensively evaluate the scientific evidence regarding the effect of okra consumption on metabolic and inflammatory parameters based on the type of okra and the type of okra preparation. This study is a systematic review that follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, a literature search was conducted in five electronic databases. The article selection process was carried out using the PICOS framework, while the methodological quality was assessed using the Cochrane Risk of Bias (RoB 2) approach. Data were analyzed descriptively due to heterogeneity of study designs that precluded meta-analysis. A total of 124 articles were identified in the initial search phase after removing duplicates. After title and abstract screening, 51 studies met the inclusion criteria and were included in the analysis. Risk of bias assessment indicated that most studies had a low risk of bias in almost all domains assessed. The synthesis results indicate that okra consumption has the potential to have positive effects on lipid profiles, glycemic control, and modulation of inflammatory and oxidative stress biomarkers.

Keywords: *Abelmoschus esculentus*; Glycemic control; Metabolic syndrome; Okra; Oxidative stress

Abstrak

Okra (*Abelmoschus esculentus*) merupakan tanaman hortikultura yang terdiri kandungan fitokimia yang berpotensi memberikan manfaat kesehatan. Beberapa penelitian menunjukkan bahwa konsumsi okra dapat mempengaruhi kadar modulator metabolik, stres oksidatif, serta biomarker inflamasi. Namun, hasil penelitian yang tersedia masih bervariasi karena perbedaan desain studi, model penelitian, serta bentuk olahan okra yang digunakan. Oleh karena itu, tinjauan sistematis ini bertujuan untuk mengevaluasi secara komprehensif bukti ilmiah mengenai pengaruh konsumsi okra terhadap parameter metabolik dan inflamasi berdasarkan jenis okra dan jenis olahan okra. Penelitian ini merupakan tinjauan sistematis yang mengikuti pedoman Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), pencarian literatur dilakukan pada lima basis data elektronik. Artikel yang memenuhi kriteria inklusi merupakan penelitian primer dengan desain eksperimental atau observasional yang mengevaluasi okra pada manusia atau hewan uji. Proses seleksi artikel dilakukan menggunakan kerangka PICOS, sedangkan kualitas metodologis dinilai menggunakan pendekatan Cochrane Risk of Bias (RoB 2). Data dianalisis secara deskriptif karena heterogenitas desain penelitian yang tidak memungkinkan dilakukan meta-analisis. Sebanyak 124 artikel diidentifikasi pada tahap awal pencarian setelah penghapusan duplikasi. Setelah proses penyaringan judul dan abstrak, 51 studi memenuhi kriteria inklusi dan dimasukkan dalam analisis. Penilaian risiko bias menunjukkan bahwa sebagian besar penelitian memiliki risiko bias rendah pada hampir semua domain yang dinilai. Hasil sintesis menunjukkan bahwa konsumsi okra berpotensi memberikan efek positif terhadap profil lipid, kontrol glikemik, serta modulasi biomarker inflamasi dan stres oksidatif.

Kata Kunci: *Abelmoschus esculentus*; Kontrol glikemik; Okra; Stres oksidatif; Sindrom metabolik

INTRODUCTIONS

Okra (*Abelmoschus esculentus*), also known as lady's fingers, is a plant native to East Africa. This plant resembles the luffa or luffa plant but actually comes from a different family, namely Malvaceae (Dantas et al., 2021). Okra plants are often consumed as vegetables or dried fruit so they can be enjoyed as snacks. This plant has nutritional content consisting of polysaccharides, soluble dietary fiber, phytochemical compounds such as flavonoids,



phenolics, vitamin C, important minerals such as magnesium, calcium, potassium and phosphorus, folate and protein. This is what makes okra believed to be a plant with many health benefits. (Tri Putri Wahyuni & Atyka Trianisa, 2024; Yildiz et al., 2025) In several previous studies, okra was reported to have health benefits as an antimicrobial, anti-cancer, antidiabetic, and anti-inflammatory (Azeem et al., 2023).

The polysaccharide content in okra has been shown to provide anti-inflammatory and antioxidant effects by suppressing the expression of pro-inflammatory cytokines such as TNF- α , IL-6, and IL-1 β through inhibition of the nuclear factor kappa B (NF- κ B) pathway, which is a key regulator of the inflammatory response (Ni et al., 2025). In addition, the polysaccharides and soluble dietary fiber found in okra have also been shown to increase endogenous antioxidants such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx), which play a role in protecting cells from oxidative stress and free radicals (Damayanthi et al., 2024). These effects contribute to protecting cells and tissues from oxidative damage and reducing chronic inflammation that underlies various metabolic diseases.

Other evidence suggests that the role of polysaccharides, fiber, and flavonoid and phenolic compounds, especially quercetin in okra, may be beneficial in improving metabolic disorders, especially those with an increased glycemic index (Apolinário da Silva et al., 2024; Azeem et al., 2023). The thick fiber and mucilage in okra act as a gel-like matrix in the intestinal lumen, creating a physical barrier to slow starch digestion and glucose absorption into the bloodstream, thus preventing post-meal glucose spikes. Flavonoid and phenolic compounds in okra, particularly in the seeds and skin, inhibit enzymes such as α -amylase and β -glucosidase, which are responsible for breaking down complex carbohydrates into glucose (Walsh & Ahmad, 2002). A meta-analysis conducted by Zhang, X et al., stated that okra has the potential to improve glucose and lipid metabolism by increasing insulin sensitivity and supporting the regeneration of pancreatic cells to increase insulin production (Zhang et al., 2024).

Okra is currently consumed in a variety of products, including side dishes, puddings, and dried fruit snacks (Armenia Eka Putriana et al., 2025; Rababah et al., 2023; Yustika Rini et al., 2021). Food processing can affect the nutritional content of the basic food ingredients. Excessive use of high temperatures during food processing, storage temperatures, and storage duration can reduce the nutritional value of food products, especially okra. Although various studies have shown the potential of okra as an anti-inflammatory agent and cell metabolic modulator, if okra is consumed in products that are not properly processed, the benefits of okra for body health cannot be felt optimally (Al-Dabbas et al., 2023; Rababah et al., 2023; Rindiani et al., 2018). This study aims to examine the molecular mechanisms underlying the role of okra as an anti-inflammatory and metabolic modulator. Analysis through observation of lipid profiles, oxidative stress, and inflammatory marker cytokines in respondents who regularly consume okra with a variety of okra products consumed.

METHODS

Search Strategy

The systematic review materials used in this study were collected from several databases, including Google Scholar, Pubmed, Scopus, Web of Science, and EBSCO. This review is available in Prospero No. 1. The search for study materials was conducted directly using Google search and the data-driven search tool Publish or Perish. The search used the following keywords: "Benefits of Okra for Health" AND "Benefits of Okra as an Anti-Inflammatory Agent" OR "Cytokine" OR "Oxidative Stress" AND "Benefits of Okra as a Metabolic Modulator" OR "LIPID Profile" OR "GLYCEMIC INDEX" AND "Various Okra Products" AND "Effect of Okra Product Serving on Nutritional Value".



Framework

Data analysis in this study was based on the PICOS (Population, Intervention, Comparison, Outcome, and Study Design) framework to ensure clarity in defining the research question and inclusion criteria. The study population was respondents who consumed okra, both humans and experimental animals. Exposure focused on measuring lipid profile concentrations, blood glycemic index, inflammatory and pro-inflammatory cytokines, and oxidative stress. This review did not have a comparison or control; the outcomes measured were concentrations of several inflammatory parameters and profiles. Lipid changes observed after consuming okra in various products. Study designs included observational cross-sectional, case-control, true-experimental, quasi-experimental, and cohort studies. This research has also been registered in Prospero with the number CRD420261330016.

Eligibility Criteria and Screening Process

Inclusion and exclusion criteria based on the PICOS framework are described in detail below:

Inclusion Criteria.

1. The studies examined were primary data with observational cross-sectional, case-control, true-experimental, quasi-experimental, and cohort study designs.
2. The study subjects were humans or experimental animals.
3. Respondents were healthy or had prediabetic conditions, type 2 diabetes mellitus, obesity, dyslipidemia, or mild to chronic inflammatory conditions.
4. Respondents consumed okra in the following forms: fresh or boiled vegetables, okra flour, okra extract, okra juice, okra-based capsules or supplements, or other processed okra food products such as pudding, functional drinks, snacks, or other food fortifications.
5. Studies that examined inflammatory parameters such as TNF- α , IL-6, IL-1 β , CRP, NF- κ B, and TGF- β .
6. Studies examining oxidative stress parameters such as MDA, SOD, Catalase, and GPX.
7. Studies examining lipid profile and glycemic index parameters such as triglycerides, cholesterol, HDL, LDL, blood glucose, and HbA1c.
8. Articles in English and Indonesian published within the last 15 years (2010-2026) and available in full-text form with complete data.

Exclusion criteria

1. Research using non-primary data, such as review articles, systematic reviews and meta-analyses, and literature reviews.
2. Research not using human participants or test animals, such as in-vitro studies using cell culture or molecular models.
3. Research with respondents whose health status is unclear.
4. Research not using okra (*Abelmoschus esculentus*) as the main intervention, research using a combination of various herbal plants without distinguishing the specific effects of okra, research not clearly explaining the form, dosage, or method of okra administration.
5. Studies that did not measure inflammatory parameters, oxidative stress, lipid profiles, or glycemic index in participants receiving the okra intervention were excluded.
6. Articles not in English or Indonesian.
7. Articles published before 2010.
8. Articles not available in full text, or for which data was incomplete or could not be extracted.

The initial screening process followed the PRISMA flowchart (Figure 1). This figure illustrates the sequential stages of article selection: initial identification, title and abstract screening, and full-text assessment. To ensure objectivity and minimize bias, the screening process was conducted independently by two reviewers (CPK and MPS). Initially, titles and abstracts were screened against the inclusion criteria, followed by a rigorous full-text



assessment of potentially relevant articles. Any discrepancies or disagreements regarding study eligibility were resolved through discussion between the authors.

Article Selection Process

Extracting insights from the data involved reviewing the title, year of publication, author information, study design, study data, significance of the results, and discussion. Each author (CPK and MPS) independently collected and extracted the data, followed by joint discussion to resolve any discrepancies. Two researchers worked independently to perform the data extraction in a blinded manner to ensure unbiased data collection. The extraction process included collecting information on (1) title, (2) year of publication, (3) study design, (4) study data, (5) significance of the results, (6) type of respondents and respondent groups, (7) type of okra processed product, (8) name of the biomarker analyzed, and (9) biomarker analysis method.

Data Analysis

Due to heterogeneity of data from various study designs, meta-analysis was not possible. The authors conducted a narrative analysis, tabulating, and categorizing the data based on the parameters examined, the units used, and their association with inflammatory status, metabolic disorders, and glycemic index. Results and discussion are presented per subsection. Given the limited number of studies remaining after screening, data were identified individually.

Risk of Bias Assessment

To assess the risk of bias in this review, the authors used a critical appraisal tool that is Cochrane Tools application, which helps highlight various aspects to assess the overall study quality and study limitations. Each criterion in the JBI tool is coded as "low" for no risk of bias, "Some concerns" for low risk of bias, and "high" for high risk of bias. A proportional quality assessment score is calculated for each research project, considering the entire set of relevant questions or elements.

RESULT AND DISCUSSION

Study Selection and Risk of Bias Assessment

The process of identifying and selecting articles in this review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A search of five electronic databases—Google Scholar, EBSCO, Scopus, Web of Science, and PubMed—resulted in a total of 84 records after removing duplicates. Next, a title and abstract screening process yielded 39 potential articles, of which 13 reports were searched for full text. After an eligibility evaluation, several articles were eliminated due to non-conformity to the inclusion criteria, such as being unrelated to the topic, not being in English, and not being experimental research. Ultimately, 51 studies met the criteria and were included in the final analysis (Figure 1).

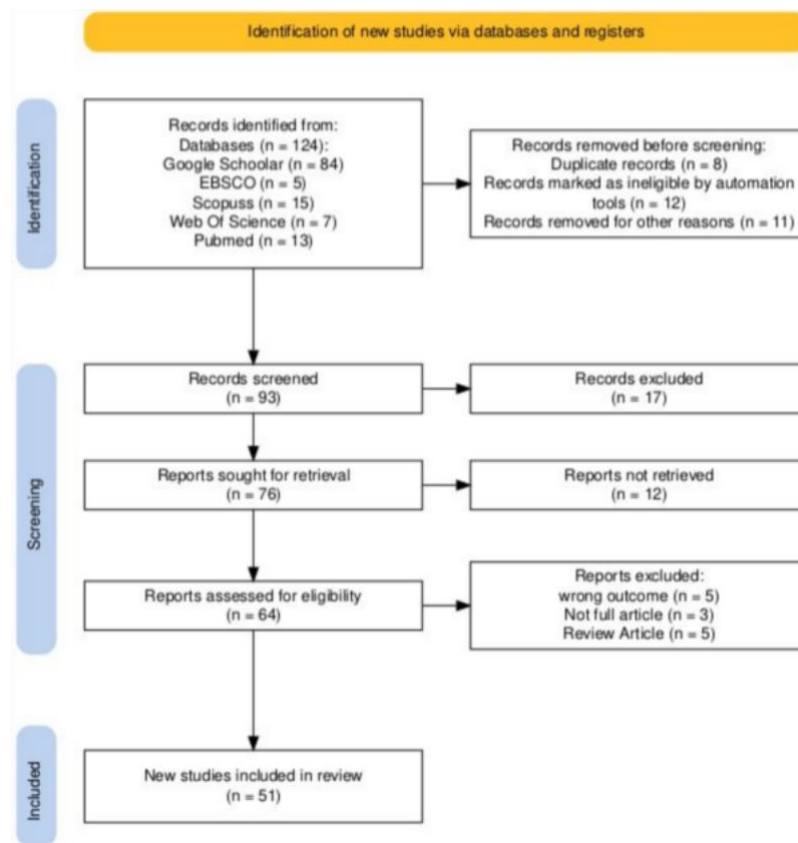
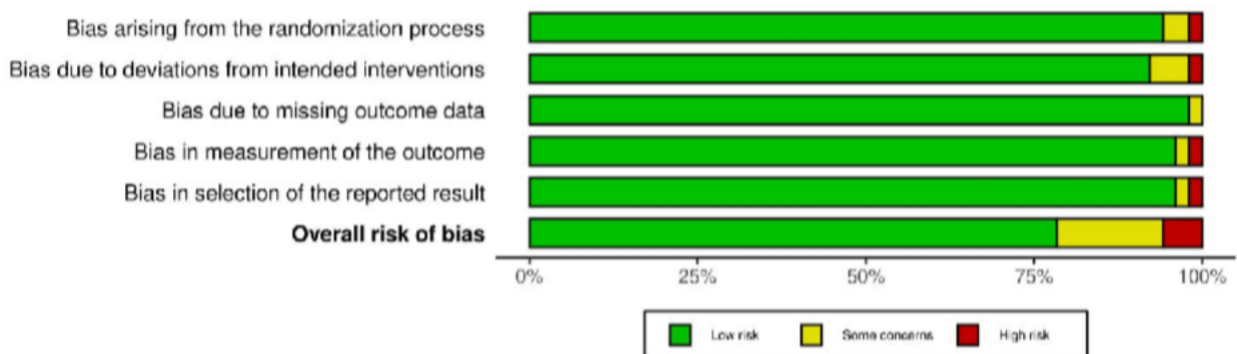


Figure 1. PRISMA Study Selection Flowchart

The risk of bias assessment for the 51 included studies was conducted using the Risk of Bias (RoB 2) approach, which covers five main domains: bias due to randomization, deviation from the planned intervention, missing outcome data, outcome measurement, and selection of outcome reporting. Overall, the majority of studies demonstrated a low risk of bias across nearly all domains assessed. The largest proportion fell into the low-risk category, with only a small number of studies showing some concerns and very few classified as high-risk. The overall risk of bias was also predominantly low, indicating that the methodological quality of the analyzed studies was relatively good and the synthesis results had a reasonable level of confidence (Figure 2).



Morphological Characteristics and Nutritional Content of Various Okra Varieties

Okra (*Abelmoschus esculentus* L. Moench) is a horticultural species with numerous varieties. This is because this type of fruit adapts to its environment to enhance stem growth productivity, maintain fruit quality, and adapt to the environment, resulting in changes in its



genetic makeup that have resulted in the development of several new varieties. Okra varieties are often distinguished based on fruit color and morphology, which are also important factors in selecting varieties for both consumption and processing. Okra varieties are typically distinguished based on fruit morphology, such as pod color or chlorophyll content. Morphological differences in okra fruit also influence substantial variations in fresh fruit mass and nutritional content (Yildiz et al., 2025).

Based on research by Yildiz, M et al. in 2025, who conducted a characterization study of okra with the latest generics using various types of okra from various regions in Asian countries, 66 okra accessions were obtained which were analyzed based on morphometric characteristics and fruit quality such as fresh fruit weight, fruit diameter, and vitamin C and chlorophyll content. This showed that there were phenotypic variations in each accession, which were then classified into several clusters that indicate a variety of varieties that reflect agronomic diversity (Yildiz et al., 2025). In addition to phenotypic diversity in okra, another study also assessed the performance of 12 okra cultivated in Sundarharaicha, Morang, Nepal based on the biomass and yield of 12 okra plants in each field plot. The results of this study indicate that okra fruit has various varieties such as Arka Anamika, Chandani, Chiranjeevi F1, F1 Glory, Gunjan, JK1666, OH-940, Punjab Selection, R35 Selection, and Swastik-2 based on significant variability in yield and biomass. Some varieties such as F1 Glory and Punjab Selection have the highest potential biomass yield compared to other varieties, indicating that variety choice greatly influences okra plant productivity and the feasibility of its cultivation in certain agroecological conditions (B. Yadav et al., 2024). According to research by Yadav et al., differences in okra fruit varieties affect the nutritional components contained therein. Table 1 explains the okra fruit varieties with regard to their nutritional content.

Table 1. Characteristics and Nutritional Profile of Selected Okra Varieties

Variety	Pod Morphology	Major Nutritional Components	References
Arka Anamika	Elongated pods with medium diameter, bright green color, smooth and uniform surface.	High dietary fiber, vitamin C, phenolic antioxidants.	(Timsina et al., 2025)
Chandani	Medium-sized pods, moderate length, bright green, relatively straight and uniform.	Rich in mucilage polysaccharides and soluble fiber.	(B. Yadav et al., 2024; Yildiz et al., 2025)
Chiranjeevi F1	Green pods with uniform morphology and medium size; early maturity hybrid cultivar.	Soluble fiber, vitamin C, phenolic antioxidants.	(S. P. S. Yadav et al., 2023)
F1 Glory	Average plant height ~106.4 cm; pod length ~15.85 cm; large and productive pods.	Soluble fiber, potassium, magnesium, flavonoids, phenolic compounds.	(S. P. S. Yadav et al., 2023)
Gunjan	Medium-sized green pods; relatively resistant to plant diseases; uniform shape.	Soluble fiber, flavonoids, phenols, minerals, high mucilage.	(S. P. S. Yadav et al., 2023)
Punjab Selection	High-yield cultivar; uniform pod size; bright green; adaptable to agroclimatic conditions.	Dietary fiber, vitamins C and A, potassium, magnesium, folate, polysaccharides, antioxidants.	(S. P. S. Yadav et al., 2023)
R35 Selection	Green pods adapted to hot climates with stable growth performance.	High polysaccharide and antioxidant content.	(S. P. S. Yadav et al., 2023)
Swastik-2	Vigorous growth with high fresh biomass; uniform green pods.	Soluble fiber, folic acid, calcium, magnesium.	(Ranga & Darvhankar, 2022; S. P. S. Yadav et al., 2023)
Carmin Splendor	Red-purple pods; 9–11 cm length; diameter ~1.6–1.7 cm.	Dietary fiber, vitamins C and A, potassium, magnesium, phosphorus, anthocyanins.	(Ranga & Darvhankar, 2022; S. P. S. Yadav et al., 2023)



Based on Table 1, most okra varieties have elongated green fruit morphology with relatively uniform size and shape as a result of breeding programs to increase productivity and market quality, such as F1 Glory, Punjab Selection, and Swastik-2 which show high yield and biomass. Although visually similar, there are variations in the composition of nutrients and bioactive compounds between varieties. In general, all varieties are rich in dietary fiber and mucilage polysaccharides, which play a role in glycemic and lipid modulation. They also contain vitamins C and A, minerals (potassium, magnesium, calcium), and phenolic compounds with antioxidant and anti-inflammatory activities. Varieties such as Chandani and Gunjan are distinguished by their soluble fiber and mucilage content, while Carmin Splendor boasts the additional advantage of anthocyanins, which enhance antioxidant capacity. Thus, genetic differences between varieties influence not only agronomic characteristics but also determine their biomedical potential in preventing inflammation and metabolic diseases.

Okra plays an important role in health, primarily due to its content of dietary fiber, mucilage polysaccharides, vitamins, minerals, and bioactive antioxidant compounds. The soluble fiber and mucilage in okra slow the absorption of glucose in the intestine, thus helping control blood sugar levels and improving insulin sensitivity, which is beneficial in prediabetes and type 2 diabetes. Fiber also plays a role in lowering total and LDL cholesterol levels through binding to bile acids, thus supporting cardiovascular health. Antioxidant content such as flavonoids, phenolics, and in certain varieties anthocyanins, work by suppressing oxidative stress by increasing the activity of antioxidant enzymes such as SOD and catalase and inhibiting inflammatory pathways such as the activation of NF- κ B which is related to the production of pro-inflammatory cytokines namely TNF- α , IL-6. In addition, vitamins C and A support the immune system and protect cells from free radicals, while minerals such as potassium, magnesium, and calcium play a role in regulating blood pressure, nerve function, and energy metabolism. With this combination of components, okra consumption has the potential to provide anti-inflammatory, hypoglycemic, hypolipidemic effects, as well as protection against metabolic and cardiovascular diseases. (Zhang et al., 2024)

The Effect of Okra on Metabolic Modulators

Metabolic modulators are compounds capable of regulating or controlling the body's metabolic pathways to repair damaged cell physiology, thereby inhibiting and preventing metabolic syndrome. The impacts of metabolic syndrome include insulin resistance, dyslipidemia, obesity, and chronic inflammation. Metabolic syndrome involves more than just changes in a single parameter, but encompasses several health parameters, including abnormalities (Leziak et al., 2025). Metabolic syndrome parameters can be described through lipid profiles, blood glucose, oral glucose tolerance (OGTT), HbA1C, and related factors (Shimu et al., 2025). In this study, we discuss the effects of phytochemical compounds in okra, such as polyphenols, flavonoids, vitamin C, folic acid, and other minerals, on metabolic parameters in respondents who were given or consumed any variety of okra, in various okra preparations and in varying amounts (Table 2).



Table 2. Morphological Characteristics and Bioactive Nutritional Components Of Selected Okra (*Abelmoschus esculentes*) Varieties Reported in Previous Studies.

Okra Type	Okra Part	Preparation / Treatment	Study Subject	Observed Outcomes	Study Design	Reference
Green okra	Seeds and mucilage	Peel–seed extract (150 mg/kg); peel–seed extract (200 mg/kg); mucilage (150 mg/kg); mucilage (200 mg/kg)	Alloxan-induced rats	Decreased lipid profile and blood glucose levels after oral glucose tolerance test (OGTT) during 3 days of observation	Cross-sectional study	(Uddin Zim et al., 2021)
Green and purple okra	Whole fruit	Green okra extract (GOE) containing 5 mg/kg BW quercetin and 10 mg/kg BW quercetin; purple okra extract (POE) containing 5 mg/kg BW quercetin and 10 mg/kg BW quercetin	Streptozotocin (STZ)-induced diabetic rats	Decreased blood glucose levels during approximately 14 days of observation	Pre-test–post-test controlled group design	(Damayanthi et al., 2018)
Green okra	Whole fruit	Dried and powdered okra peel	Adults aged ≥ 35 years with fasting blood glucose (FBS) 100–125 mg/dL	Decreased blood glucose levels and body weight	Quasi-experimental pre-test–post-test design	(ADAP et al., 2019)
Green okra	Whole fruit	Okra pudding	Participants registered at Kalibawang Community Health Center, Kulon Progo	Decreased blood glucose levels after 7 days of observation	Quasi-experimental study	(Nurjanah et al., 2020)
Green okra	Whole fruit	Okra fruit-infused water (6 mL/head)	Alloxan-induced rat model	Decreased blood glucose levels during 30 days of observation	True experimental design	(Zaenab, 2024)
Green okra	Whole fruit	Soaking water of okra fruit	Adults aged 40–60 years	Decreased blood glucose and total cholesterol levels during 14 days of observation	Quasi-experimental design	(Haryati et al., 2021)
Green okra	Whole fruit	Okra capsules	60 participants with type 2 diabetes mellitus randomly	Decreased blood glucose, total cholesterol (TC), triglycerides (TG), LDL, and HbA1c levels during 14	Double-blind randomized clinical trial	(Raiesifar et al., 2025)



			allocated by dice tossing	weeks of observation		
Green okra	Whole fruit	Okra fruit-infused water	32 individuals with hypercholesterolemia	Decreased total cholesterol levels during 1 week of observation	Quasi-experimental non-equivalent control group design	(Farida & Cahyanto, 2022)
Green okra	Whole fruit	Okra cake (8.4 g/rat/day for 14 days)	18 male Wistar rats induced with a high-fat diet (HFD)	Decreased total cholesterol and LDL levels during 10 weeks of observation	True experimental pre-test–post-test control group design	(Prima et al., 2025)
Green okra	Whole fruit	Okra powder blended in yogurt	Patients with type 2 diabetes mellitus diagnosed with fasting plasma glucose ≥ 126 mg/dL	Improved lipid profile and glycemic markers in T2DM patients	Double-blind single-center randomized clinical trial	(Moradi et al., 2020)
Green okra	Whole fruit	Okra extract	Albino rats	Decreased liver enzyme levels, TC, TG, LDL, glucose, and HbA1c after 4 weeks of observation	True experimental pre-test–post-test control group design	(Agoro & Anyiam, 2023)
Green okra	Whole fruit	Dried okra extract (DOE)	Patients diagnosed with diabetic nephropathy	No significant effects on renal function indices, lipid profile, inflammatory markers, or RAGE-related gene expression after 10 weeks	Triple-blind randomized placebo-controlled clinical trial	(Bahreini et al., 2024)
Green okra	Whole fruit	Okra immersion water	30 Wistar rats (<i>Rattus norvegicus</i>)	Decreased LDL levels and increased HDL levels after 28 days of observation	Pre-test–post-test control group design	(Setyawati, 2022)
Green and purple okra	Whole fruit	Okra extract	Streptozotocin (STZ)-induced diabetic rats	Decreased TC, TG, and LDL levels after 2 weeks of observation	Pre-test–post-test control group design	(Nabila et al., 2018)

TC = Total cholesterol; TG = Triglycerides; LDL = Low-density lipoprotein; HDL = High-density lipoprotein; HbA1c = Glycated hemoglobin; OGTT = Oral glucose tolerance test; STZ = Streptozotocin; T2DM = Type 2 diabetes mellitus; RAGE = Receptor For Advanced Glycation End Products.



Table 2 shows that most studies on the effects of okra consumption in various forms such as extracts, capsules, powders, infused water, and processed products such as pudding, cake, and yogurt mixes can provide an improvement in metabolic disorders, as evidenced by metabolic modulator parameters such as blood glucose, lipid profiles, HbA1C, and molecular indicators of metabolic disorders, namely RAGE. Research conducted on test animals induced by alloxan or streptozotocin (STZ), administration of okra extract at a dose of 150–200 mg/kgBW or preparations of okra soaking water and powder has been shown to reduce blood glucose, triglyceride, total cholesterol, and LDL levels, and increase HDL within an observation period of 3 days to 10 weeks. This effect is also supported by human studies, including quasi-experimental designs and randomized clinical trials (RCTs), which showed a significant decrease in fasting blood glucose, HbA1C, total cholesterol, and LDL after 2–14 weeks of intervention. Capsule dosage forms and standardized extracts showed more consistent results than simple preparations such as infused water, although both still showed a trend of metabolic improvement. However, in patients with diabetic nephropathy, administration of dried okra extract did not show significant improvements in kidney function parameters, indicating that okra's effects are more dominant in glycemic and lipid modulation than in advanced kidney protection. Overall, these findings strengthen the role of okra as a natural metabolic modulator with potential as an adjuvant therapy in metabolic disorders such as type 2 diabetes mellitus and dyslipidemia, although dose standardization and long-term clinical studies are still needed to confirm its effectiveness and safety (Bahreini et al., 2024).

The Effect of Okra on Inflammatory Markers

Metabolic disorders such as diabetes mellitus, obesity, dyslipidemia, and other metabolic syndromes can be correlated with chronic inflammation. This condition is characterized by increased levels of inflammatory markers such as TNF- α , IL-6, IL-1 β , and C-reactive protein (CRP), as well as activation of proinflammatory transcription pathways such as NF- κ B. (Choi et al., 2025; Gkrinia & Belančić, 2025) A persistent inflammatory response can exacerbate insulin resistance, endothelial dysfunction, and liver and kidney tissue damage. Efforts to improve inflammatory conditions based on functional foods that have anti-inflammatory activity are of interest in complementary prevention and therapy strategies for metabolic diseases. (Gkrinia & Belančić, 2025; Sepehrinia et al., 2025) Okra (*Abelmoschus esculentus*) is known to contain various bioactive compounds such as flavonoids, polyphenols, soluble fiber (mucilage), and natural antioxidants that have the potential to suppress the production of pro-inflammatory cytokines and inhibit the activation of the NF- κ B pathway. (Ko et al., 2022) Therefore, discussing the effect of okra administration on inflammatory markers is important for understanding its role as an inflammatory and metabolic modulator in the context of chronic metabolic disorders (Table 3).

Table 3. Summary of Experimental Evidence on the Anti-Inflammatory Effects of Okra and Its Bioactive Components.

Okra Preparation and Plant Part	Inflammatory Marker / Parameter	Observed Effect	Proposed Mechanism	Reference
Flavonoid isolate from okra fruit	RBC membrane stability (protein denaturation model)	Reduced protein denaturation	Flavonoids, particularly quercetin, stabilize inflammatory cell membranes	(Farmasi et al., 2025)
Okra fruit extract gel	Neutrophil infiltration	Significant reduction in neutrophil infiltration	Acceleration of the inflammatory phase during wound healing in hyperglycemic conditions	(Panca Bayu Chandra et al., 2022)
Okra extract (review study)	Pathogenic bacteria colonization	Reduced bacterial colonization	Phenolic compounds disrupt bacterial cell walls, contributing to anti-infective activity	(Ramadan & Sumiwi, n.d.)



Flavonoid isolate from okra fruit	Protein denaturation (in vitro)	50.65% inhibition of protein denaturation at 50 ppm	Flavonoids suppress inflammatory processes by inhibiting protein denaturation	(Astutiningsih et al., 2024)
Purple okra pudding and supplement	Not specifically reported (focused on antioxidant status)	Increased superoxide dismutase (SOD) activity	Anti-inflammatory effect mediated through enhancement of systemic antioxidant status	(Damayanthi et al., 2024)
Okra fruit polysaccharides	IL-6, TNF- α , sP-selectin	Significant reduction of pro-inflammatory cytokines in serum	Inhibition of TLR4/NF- κ B pathway activation and downregulation of CD36/p-p38 MAPK expression	(Ni et al., 2025)
Okra extract (review study)	NF- κ B pathway, nitric oxide, cytokines	Systemic anti-inflammatory effects across various disease models	Modulation of inflammatory signaling pathways by flavonoids and polysaccharides	(Kwok et al., 2025)
Aqueous okra fruit extract	Edema, hemorrhage, inflammation score	Significant reduction at 500 mg/kg ($p < 0.05$)	Gastroprotective activity through modulation of oxidative and antioxidant pathways	(Ortaç et al., 2018)
ORPE (Okra pod extract)	Cytokines (IL-10, TNF- α , IFN- γ)	Modulation of systemic cytokine levels in cancer conditions	Immunomodulatory effects involving CD4 ⁺ and CD8 ⁺ immune cells and cytokine regulation	(Hayaza et al., 2021)
Okra polysaccharides (review study)	Inflammatory signaling pathways	Inhibition of LXR and PPAR signaling	Interaction with nuclear receptors regulating inflammatory gene expression	(Elkhalifa et al., 2021)
Okra extract	β -catenin signaling pathway	Increased expression of AXIN2 and COL1 proteins	Stimulation of tissue regeneration via activation of cellular signaling pathways	(Tosun et al., 2025)
Okra pectin (review study)	Anti-inflammatory activity	Inhibitory effects on inflammatory responses	Acid-soluble pectin preparations exhibit high bioactivity	(Achhlam et al., 2024)

IL-6 (interleukin-6); TNF- α (tumor necrosis factor-alpha); NF- κ B (nuclear factor kappa B); TLR4 (Toll-like receptor 4); MAPK (mitogen-activated protein kinase); SOD (superoxide dismutase); LXR = Liver X Receptor; PPAR= Peroxisome Proliferator-Activated Receptor; AXIN2 = Axis Inhibition Protein 2; CD4⁺ = Cluster of Differentiation 4 Positive T Cells; CD8⁺ = Cluster of Differentiation 8 Positive T Cells; COL1 = Collagen Type 1; IFN- γ = Interferon-gamma; TLR4 = Toll-Like Receptor 4; NF- κ B = Nuclear Factor Kappa B (Nuclear Factor- κ B); CD36 = Cluster of Differentiation 36; p-p38 = Phosphorylated p38 Mitogen-Activated Protein Kinase; MAPK = Mitogen-Activated Protein Kinase.

Okra shows significant potential in regulating the body's inflammatory response through various complex molecular pathways. The polysaccharide content in okra has been shown to provide a strong anti-inflammatory effect by suppressing the expression of key pro-inflammatory cytokines such as TNF- α , IL-6, and IL-1 β (Luo & Yu, 2022). This mechanism works specifically through inhibition of the nuclear factor kappa B (NF- κ B) pathway, which is a key regulator in triggering inflammatory responses within cells. Recent findings even show that okra polysaccharides can reduce serum pro-inflammatory cytokine levels by inhibiting the activation of the TLR4/NF- κ B pathway and reducing the expression of CD36/p-p38 MAPK (Ni et al., 2025). In addition to polysaccharides, flavonoid compounds such as quercetin also play an active role in maintaining the stability of inflamed cell membranes and have been shown to effectively inhibit protein denaturation by up to 50.65% at low concentrations. (Hayaza et al., 2021) Clinically, this effectiveness is also seen in the acceleration of the inflammatory phase in the wound healing process by reducing neutrophil infiltration (Luo & Yu, 2022).

In addition to being an anti-inflammatory agent, okra plays an important role in overcoming oxidative stress and preventing cell damage by strengthening the endogenous antioxidant defense system. Consumption of okra in various forms has been shown to increase the activity of antioxidant enzymes such as Superoxide Dismutase (SOD), Catalase (CAT), and Glutathione Peroxidase (GPx) (Luo & Yu, 2022). The increase in the activity of these protective enzymes is directly proportional to the decrease in Malondialdehyde (MDA) levels, which are the main indicators of lipid peroxidation and cell damage due to free radicals. This protective



effect has been observed in various vital organs, including histological improvement of the kidneys from tubular damage due to sodium nitrite exposure and a decrease in MDA levels in liver tissue. This benefit has even been confirmed in human subjects with high body fat levels, where consumption of functional food preparations such as purple okra pudding was able to significantly increase systemic SOD activity (Ali et al., 2023; Peng et al., 2025).

The Effect of Processed Okra on Nutrient Bioactivity

Modifications in food processing can alter the nutritional content and bioactivity of functional food components, including okra (*Abelmoschus esculentus*). The phytochemical and antioxidant compounds found in okra are susceptible to heat during cooking processes such as sautéing, blanching, and drying. Even freezing has been shown to affect the total phenolic and flavonoid levels and antioxidant activity of okra, potentially increasing or decreasing its nutritional and protective potential against oxidative stress if not processed properly. Research by Dabbas et al. showed that okra processed by blanching and then freezing retained higher phenolic levels and free radical scavenging capacity compared to sun-dried okra, which experienced a significant decrease in its bioactive content and antioxidant capacity (Al-Dabbas et al., 2023). This indicates that the processed okra significantly influences nutrient retention and bioactivity, which play a crucial role in the expected health effects of okra consumption as a functional food (Table 4).



Tabel 4. Processing Methods and Functional Effectiveness of Various Okra (*Abelmoschus esculentus*) Preparations

Processed Form	Processing Method	Effectiveness	Nutritional Notes	Reference
Combination pudding	Mixing with guava	High (synergistic effect)	Addition of guava increases vitamin C and dietary fiber content	(Ulfa et al., 2023)
Liquid extract	12.5% extraction	High (topical/dental application)	Effective as a root canal irrigation agent (alternative to EDTA)	(Aulia Nissa et al., 2024)
Ethanol extract	Maceration using 96% ethanol	High (cytotoxic activity)	Effective in inhibiting HeLa cancer cells at 1600 ppm	(Achmad, 2022)
Purple okra pudding vs. supplement	Pudding (functional food) vs. extract (supplement)	Both show antioxidant activity, but pudding significantly increased SOD levels in subjects	Supplement contains higher total phenols (24.49 mg GAE/g) than pudding	(Damayanthi et al., 2024)
Fresh vs. dried okra	Blanching and dehydration at various temperatures	Blanching reduces viscosity but preserves color and vitamin C during drying	Blanching in sulfite solution improves ascorbic acid retention	(Reid-Fitten et al., 2026)
Dried okra slices	Variation in slice size (1–4 cm) and drying temperature (50–80°C)	Drying at 60°C with 2 cm slices provides the best protein and fiber retention	Excessively high temperatures significantly reduce nutritional quality	(Pendre et al., 2012)
Fresh, frozen, and dried okra	Freezing vs. thermal drying	Freezing preserves phenolic compounds and antioxidant activity better than drying	Long-term storage reduces total flavonoid content in all methods	(Al-Dabbas et al., 2023)
Tempeh–okra nuggets	Substitution in nugget formulation	Increased crude fiber and protein content in the final product	Enhances the functional value of fermented foods	(Yustika Rini et al., 2021)
Dry extract capsules	Extraction from okra fruit	Reduces energy intake and appetite	Practical for long-term clinical trials (10 weeks)	(Nikpayam et al., 2022)
Raw polysaccharide extract (ORPE)	Extraction of crude polysaccharides from okra pods	Effective immunomodulatory activity in vivo	Rich in water-soluble polysaccharide fiber	(Hayaza et al., 2021)
Aqueous extract (lyophilized)	Fruit sliced, soaked in water, frozen, then freeze-dried	Inhibits ulcer formation by up to 81%	Non-toxic up to a dose of 5000 mg/kg	(Ortaç et al., 2018)
Ethanol extract	Maceration with 70% ethanol	High antioxidant activity (DPPH/ABTS methods)	Efficiently extracts polyphenols and flavonoids	(Faisal & Handayani, 2019)
Nanoemulsion	Formulated with Tween 80 and glycerin	More effective in reducing cholesterol than crude extract	Small particle size enhances bioactive compound absorption	(Djamil et al., 2020)
Okra flour	Blanching and drying (40°C, 50°C, 60°C)	Blanching reduces protein and fat content in flour	Drying at 50°C is considered optimal for maintaining proximate composition	(Rindiani et al., 2018)



Mucilage	Extraction of okra mucilage as a fat substitute	Successfully reduces fat content in Mozzarella cheese	Increases dietary fiber without affecting product texture	(Purcell et al., 2015)
Fruit filtrate	Okra fruit sliced and soaked in water (filtration)	Effective in reducing blood glucose and oxidative stress at low doses	Simple processing method that preserves antioxidant bioavailability	(Herliani et al., 2018)
Ethanol extract and pectin	Extraction using ethanol solvent or pectin isolation	Highly effective in extracting phenolic and flavonoid compounds	Exhibits broad bioactivity (anticancer, antibacterial, antidiabetic)	(Tri Putri Wahyuni & Atyka Trianisa, 2024)

SOD = Superoxide Dismutase; GAE/g = Gallic Acid Equivalent per gram; DPH = 2,2-diphenyl-1-picrylhydrazyl; ABTS = 2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid).



The effectiveness of okra's health benefits depends heavily on the processing method and the preparation method used. The use of modern technology such as nanoemulsion has been proven to be superior in reducing cholesterol levels compared to crude extracts because the very small particle size facilitates the absorption of active substances in the body (Djamil et al., 2020). However, traditional processing must still pay attention to temperature aspects, because high heating above 60°C is known to damage the content of protein, fat, and other sensitive antioxidant compounds (Rindiani et al., 2018). Although supplement preparations or ethanol extracts have a more concentrated total phenol concentration of up to 24.49 mg GAE/g, innovative food processing forms such as pudding or the use of okra mucus as a substitute for fat in cheese remain effective alternatives to increase daily fiber intake without damaging the sensory value of the product (Faisal & Handayani, 2019; Nasution et al., 2022; Sepehrinia et al., 2025). Therefore, the selection of processing methods such as freezing is more recommended than heat drying to maintain the integrity of flavonoid compounds and the maximum nutritional bioactivity of okra.

CONCLUSION

Overall, okra (*Abelmoschus esculentus*) has significant potential as a natural metabolic modulator and anti-inflammatory agent. Various preparations have been shown to improve glycemic parameters and lipid profiles. Okra's anti-inflammatory and antioxidant activities work through suppression of pro-inflammatory cytokines and inhibition of the NF-κB and TLR4/NF-κB pathways, accompanied by an increase in endogenous antioxidant enzymes. However, its effectiveness is significantly influenced by processing methods and dosage forms. Thus, okra has potential as an adjuvant therapy for metabolic diseases, although dosage standardization and long-term clinical trials are still needed.

Suggestions

Special attention is needed in processing okra as a consumption ingredient because the benefits of okra as an antioxidant can be influenced by the technique, processing temperature and storage time

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