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Harnessing the power of lemon (*Citrus limon*) for hypertension: A systematic review of clinical evidence

Memanfaatkan khasiat lemon (*Citrus limon*) untuk hipertensi: Ulasan sistematis bukti klinis

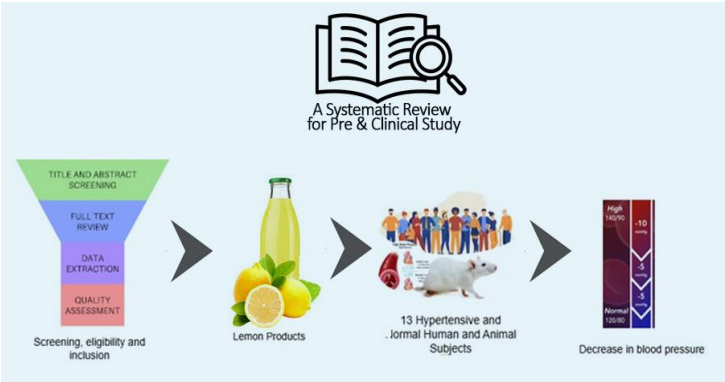
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Abstract
Hypertension prevalence and its cardiometabolic complications continue to rise, yet evidence syntheses have not clearly mapped how lemon (*Citrus limon*) intervention form, dose, and duration relate to blood pressure and biomarker responses, limiting translation into practical dietary guidance. This PRISMA 2020 systematic review synthesized evidence on lemon interventions for systolic/diastolic blood pressure (SBP/DBP) and biomarkers in hypertensive or elevated-blood-pressure populations. Searches of Scopus and PubMed, supplemented by ScienceDirect, relevant platforms, and Google Scholar, were conducted in December 2024–January 2025. Randomized controlled trials of lemon juice, extracts, peel preparations, or essential-oil aromatherapy versus placebo/usual care/other citrus/no intervention were eligible; multi-ingredient regimens containing lemon were extracted but interpreted separately. Screening and extraction used Rayyan, and quality was assessed using the Effective Public Health Practice Project (EPHPP) domains. Thirteen studies met criteria; heterogeneity in formulations, dosing, and outcome reporting precluded meta-analysis, so narrative synthesis was applied. Fresh lemon juice and lemon extracts showed the consistent SBP/DBP reductions, especially with higher doses and durations ≥2–4 weeks, whereas short-term or low-dose regimens more often yielded null results; aromatherapy and peel-powder capsules showed mixed effects. Certainty was limited to moderate due to risk of bias and diversity of interventions. Lemon may be considered a dietary adjunct in lifestyle management, not a replacement for antihypertensive therapy, and may be communicated through *halalan thayyiban* self-care framing.

Abstrak
Prevalensi hipertensi beserta komplikasi kardiometaboliknya terus meningkat, namun sintesis bukti belum memetakan secara jelas bagaimana bentuk, dosis, dan durasi intervensi lemon (*Citrus limon*) berkaitan dengan respons tekanan darah dan biomarker, sehingga membatasi penerjemahannya menjadi panduan diet yang praktis. Tinjauan sistematis ini mengikuti PRISMA 2020 untuk mensintesis bukti mengenai intervensi lemon terhadap tekanan darah sistolik/diastolik (SBP/DBP) dan biomarker pada populasi hipertensi atau tekanan darah meningkat. Pencarian literatur dilakukan pada Scopus dan PubMed, dilengkapi ScienceDirect, platform terkait, serta Google Scholar pada Desember 2024–Januari 2025. Uji klinis terkontrol acak yang mengevaluasi jus lemon, ekstrak lemon, sediaan kulit lemon, atau aromaterapi minyak esensial dibanding plasebo/perawatan biasa/jenis citrus lain/tanpa intervensi dinyatakan memenuhi syarat; regimen multi-bahan yang mengandung lemon diekstraksi tetapi diinterpretasikan secara terpisah. Proses penyaringan dan ekstraksi menggunakan Rayyan, dan kualitas metodologis dinilai menggunakan domain Effective Public Health Practice Project (EPHPP). Tiga belas studi memenuhi kriteria; heterogenitas formulasi, dosis, dan pelaporan luaran membuat meta-analisis tidak memungkinkan sehingga digunakan sintesis naratif. Jus lemon segar dan ekstrak lemon menunjukkan penurunan SBP/DBP yang paling konsisten, terutama pada dosis lebih tinggi dan durasi ≥2–4 minggu, sedangkan regimen jangka pendek atau dosis rendah lebih sering menunjukkan hasil nol; aromaterapi dan kapsul bubuk kulit lemon memberikan hasil yang beragam. Tingkat kepastian bukti terbatas hingga moderat karena risiko bias dan keragaman intervensi. Lemon dapat dipertimbangkan sebagai tambahan diet dalam manajemen gaya hidup, bukan pengganti terapi antihipertensi, dan dapat dikomunikasikan melalui kerangka perawatan diri *halalan thayyiban*.

Graphical Abstract



Keyword
biomarkers; blood pressure; citrus limon; hypertension; lemon

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INTRODUCTION

Hypertension remains a major global public health burden and a leading contributor to cardiovascular disease (CVD), stroke, heart failure, and kidney failure. It affects an estimated 1.4 billion adults worldwide and is associated with ~10.8 million deaths annually (Yang & Cai, 2023). Beyond mortality, hypertension imposes substantial economic costs (≈US$370 billion/year) and is a key driver of the chronic kidney disease (CKD) burden (Song et al., 2021; Chen et al., 2021). Despite global commitments to reduce premature noncommunicable disease (NCD) mortality under the Sustainable Development Goals, progress remains uneven, reinforcing the need for scalable primary-care and community strategies such as WHO's HEARTS initiative (Khan et al., 2023; Suárez-Herrera et al., 2024). In Indonesia, hypertension prevalence among adults aged ≥18 years reportedly declined from 34.1% (2018) to 30.8% (2023), yet reported antihypertensive therapy use remains extremely low (0.7%), indicating persistent gaps in detection, access, adherence, and long-term self-management (Kementrian Kesehatan, 2018; Survei Kesehatan Indonesia [SKI], 2023). Globally, ~1.28 billion adults aged 30–79 years (33%) live with hypertension, most in low- and middle-income countries, underscoring the need for cost-effective, culturally resonant interventions (World Health Organization [WHO], 2023).

Clinical guidelines consistently position lifestyle and dietary modification as essential complements to pharmacotherapy, emphasizing sodium reduction and healthy dietary patterns such as DASH and Mediterranean-style diets (Filippou et al., 2022; Whelton et al., 2022). The DASH diet, rich in fruits, vegetables, and low-fat dairy and low in saturated fat and sodium, has strong evidence for lowering blood pressure and is widely recommended as a core nonpharmacologic strategy (Shao et al., 2023; Lou et al., 2022; Bielopolski et al., 2022). Benefits are enhanced when DASH-type approaches are paired with sodium reduction, highlighting the clinical importance of sodium–potassium balance (Jahan et al., 2024; Awosika et al., 2023; Nakagawa et al., 2021). Population-level measures that increase access to fruits and vegetables and reduce sodium in processed foods can shift blood pressure distributions at scale (Zhou et al., 2021), while structured exercise and weight loss remain prioritized due to favorable safety profiles and potential cost-effectiveness (Hanssen et al., 2021; Wang et al., 2023). Because dietary behaviors are often shaped within households, family- and community-based prevention models are especially relevant. However, implementation is frequently constrained by adherence barriers, inequities in access, and limited availability of culturally tailored household guidance that supports sustained self-management (Jones et al., 2021; Commodore–Mensah et al., 2023). Excess salt intake, low potassium intake, and inadequate fruit and vegetable consumption remain prevalent modifiable risks, and only a minority of countries are on track to meet SDG-related NCD mortality targets (WHO, 2023; Khan et al., 2023; Suárez-Herrera et al., 2024). Accordingly, feasible, acceptable, and affordable dietary options, ideally using familiar foods, are needed to complement guideline-based programs and strengthen family- and community-level prevention (Whelton et al., 2022; Zhou et al., 2021).

From an implementation standpoint, hypertension prevention is strongly shaped by family/community behaviors and modifiable risks, diet-related weight gain, excess sodium with low potassium, physical inactivity, and excess alcohol, supporting household-centered lifestyle modification as a core strategy (Jones et al., 2021). Community-facing salt-reduction actions are particularly actionable given evidence linking high salt intake to elevated blood pressure and incident hypertension (Jiang et al., 2023). Delivery models that strengthen self-management (e.g., chronic-care approaches pairing informed, activated patients with proactive teams) are increasingly emphasized, alongside community-linked innovations such as home blood-pressure telemonitoring integrated with community health workers to improve access and reduce disparities (Commodore–Mensah et al., 2023).

Within this context, familiar household ingredients can be leveraged in nutrition education. Lemon is widely used in foods (Alaşalvar et al., 2022) and is reported among commonly used medicinal plants in community practice (Soudani et al., 2024), aligning with interest in dietary bioactives with vasoprotective and antioxidant potential (Valookaran et al., 2022). Evidence syntheses have also examined lemon essential oil, particularly in aromatherapy; a systematic review reported consistent anxiolytic effects and noted reductions in blood pressure and heart rate, alongside cognitive and oral health benefits. However, this literature is not primarily designed around hypertension as a clinical endpoint, often prioritizes aromatherapy over dietary intake, and is limited by unclear mechanisms and incomplete product quality validation (Gonçalves et al., 2024).

A key gap is the lack of a consolidated, clinically oriented synthesis of RCT evidence on lemon consumption across forms (e.g., juice, extracts, essential oils) specifically targeting blood pressure outcomes, including how dose, duration, and co-interventions influence effect consistency. This gap is especially relevant for family health programming in low- and middle-income settings, where affordable dietary strategies are needed to complement guideline-based approaches amid persistent implementation deficits (WHO, 2023; SKI, 2023; Whelton et al., 2022). In journals emphasizing family health integrity and Islamic values, a further contribution is to situate evidence-based nutrition guidance within the ethical–spiritual lenses of *halalan thayyiban* and *Thibbun Nabawi*, framing wholesome food choices as value-consistent family self-care. This positioning is supported by recent empirical work showing that Islamic religiosity can shape everyday food choices and meanings of purity/wholesomeness (Owais et al., 2024), and by evidence that mosque- and faith-setting platforms can be leveraged for health-promotion messaging in Muslim communities (Abu-Ras et al., 2024). This approach also aligns with communication scholarship indicating that message effectiveness improves when guidance complements cultural norms and the broader messaging environment (Ruxton et al., 2023). Therefore, this study aims to systematically review clinical trial evidence on lemon (*Citrus limon*) interventions for blood pressure regulation, appraise study quality, and identify intervention attributes (form, dose, duration, and combinations) associated with antihypertensive effects, with implications for culturally and faith-aligned family nutrition education and community prevention strategies.

METHODS

Study design and reporting framework

This systematic literature review synthesized empirical evidence on lemon (*Citrus limon*)–based interventions for blood pressure regulation among individuals with hypertension. Methods and reporting followed PRISMA 2020, including updated flow-diagram requirements (see Figure 1). A protocol was developed a priori to specify eligibility criteria, outcomes, and synthesis procedures; however, it was not registered. Any methodological modifications introduced during conduct were documented and reported transparently in the final manuscript (Page et al., 2021).

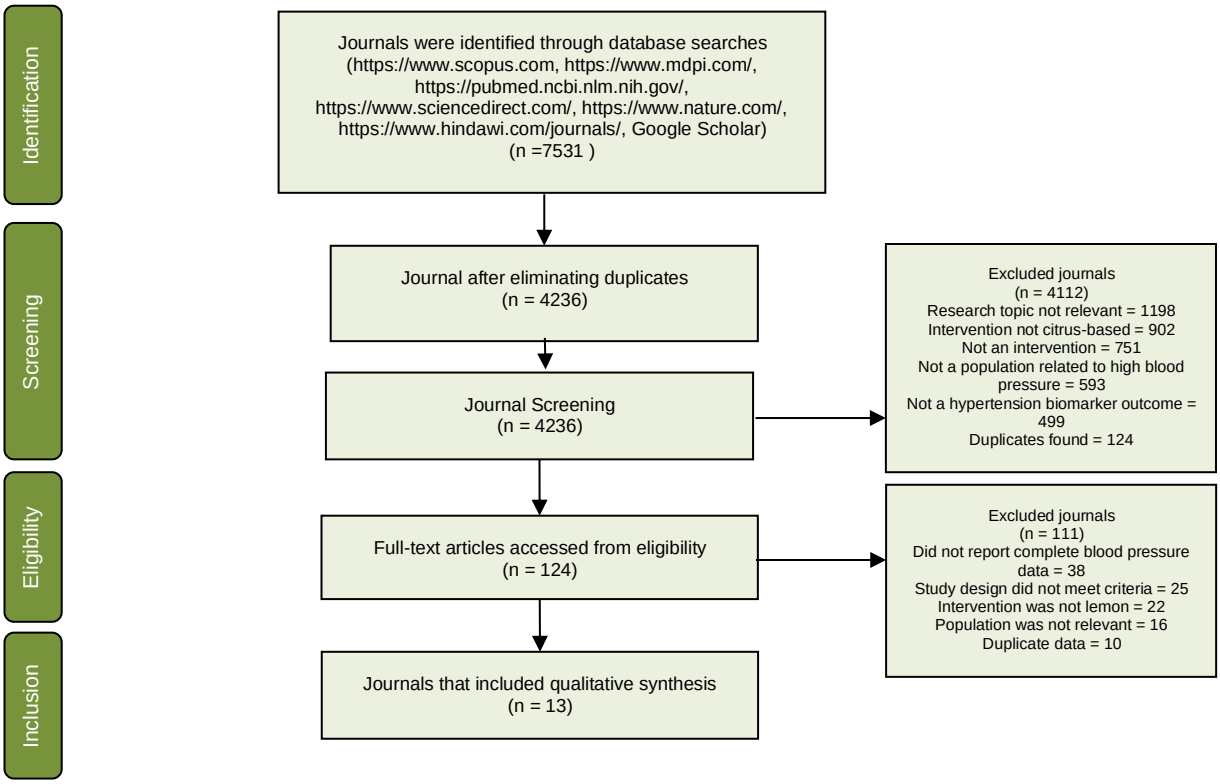
Eligibility criteria and research question

The review question was defined using the PICO framework to ensure a focused and reproducible scope (Chalmers et al., 2021; Goodman et al., 2022). The population included adolescents or adults with hypertension or elevated blood pressure according to study-defined criteria. Interventions comprised lemon (*Citrus limon*) delivered as dietary intake or supplementation in any clinical form (e.g., fresh juice, standardized extracts, or lemon-derived essential oil) when administered to humans with measurable blood pressure outcomes. Comparators were placebo, no intervention/usual care, other citrus interventions, or active non-lemon comparators. Primary outcomes were changes in systolic blood pressure (SBP) and diastolic blood pressure (DBP). Prespecified secondary outcomes included vascular and inflammatory biomarkers (e.g., angiotensin-converting enzyme [ACE] activity; stress-related endocrine markers such as corticosterone/cortisol where applicable; and cytokines including IL-1β, IL-6, and TNF-α), synthesized only when consistently reported across included trials. Animal and in vitro studies, protocols without results, systematic reviews, and meta-analyses were excluded. Additional exclusions were studies involving pregnant participants and interventions delivered mainly as lemon-fortified/functional foods in complex matrices that prevented attribution of effects to lemon as the principal exposure.

Information sources and search strategy

Searches The literature search was performed between December 2024 and January 2025, and the final search date was recorded at the time of last database execution. Searches were conducted in Scopus and PubMed/MEDLINE as core bibliographic databases, complemented by platform-based searches of ScienceDirect and publisher-hosted collections (Nature Portfolio, MDPI, and Hindawi), which were treated as publisher platforms rather than bibliographic databases to maintain methodological clarity. Google Scholar was used as a supplementary source to improve sensitivity, and backward citation tracking of included full-text articles was undertaken to identify additional eligible studies. Search strategies were tailored for each source using controlled vocabulary where available (e.g., MeSH in PubMed) and free-text terms to capture variations in intervention naming and outcomes. In addition to the core concepts “Citrus limon/lemon” and “hypertension/blood pressure,” the strategy incorporated synonyms and related terms

Figure 1
PRISMA flow chart



such as “blood pressure,” “SBP,” “DBP,” “essential oil,” “aromatherapy” (where clinically delivered), “citrus limonum,” and other commonly used descriptors of lemon-derived preparations, with Boolean logic and truncation adapted to each platform. Searches were restricted to English-language publications, consistent with the inclusion criteria, and the complete, database-specific search strings and limits were prepared for reporting in an appendix to enhance reproducibility and compliance with PRISMA 2020 recommendations.

Study selection process

Records were exported to a reference-management workflow and deduplicated before screening. Title/abstract screening was conducted in Rayyan to support blinded screening and efficient conflict management (Barry et al., 2023; Costa et al., 2023). Two reviewers independently screened and assessed full-text eligibility; disagreements were resolved through discussion and, when needed, adjudication by a third reviewer. Where applicable, inter-reviewer agreement was quantified. Reasons for full-text exclusion were recorded systematically and summarized in the PRISMA 2020 flow diagram across identification, screening, eligibility, and inclusion stages.

Data extraction and data management

Data were extracted using a piloted form to standardize procedures and minimize transcription error. Extracted items included publication details (year, country/setting, design), participant characteristics (sample size, age, baseline blood pressure, health status), intervention characteristics (lemon form, dose, frequency, duration, co-interventions), comparator details, and outcome measurement (SBP/DBP methods and timing; eligible biomarkers aligned with secondary outcomes). Units were standardized where needed. When multiple time points were reported, the endpoint closest to intervention completion was prioritized for primary synthesis unless an alternative was justified. For descriptive summaries, percentage change was calculated consistently as ((post − baseline)/baseline) × 100 within each arm, then contrasted between arms when feasible; studies lacking baseline or endpoint variance were retained for narrative synthesis but excluded from quantitative aggregation. For effect estimation, mean differences (MD) were planned for outcomes measured on the same scale (mmHg for SBP/DBP) and standardized mean differences (SMD) for outcomes reported on differing scales, contingent

Table 1
Characteristics of the reviewed journal

Journal Name	Article Total	Quartil	SJR	H_index	Publisher
Nutrients	2	Q1	1.473	243	Multidisciplinary Digital Publishing Institute (MDPI)
Nutrition Research	1	Q1	1.017	117	Elsevier Inc.
Complementary Therapies in Clinical Practice	1	Q1	0.92	67	Churchill Livingstone
Journal of Cancer Research and Clinical Oncology	1	Q1	0.91	114	Springer Science and Business Media Deutschland GmbH
Life	1	Q1	0.824	69	Multidisciplinary Digital Publishing Institute (MDPI)
Journal of Nutrition and Metabolism	1	Q1	0.735	61	John Wiley and Sons Ltd
International Journal of Preventive Medicine	1	Q2	0.607	60	Wolters Kluwer Medknow Publications
Journal of Korean Academy of Nursing	1	Q2	0.414	34	Korean Society of Nursing Science
Medical Journal of the Islamic Republic of Iran	1	Q3	0.384	38	Iran University of Medical Sciences
Isra Medical Journal	1	Q4	0.243	64	Israel Medical Association
Journal of Experimental and Clinical Medicine (Turkey)	1	Q4	0.145	9	Ondokuz Mayis Universitesi
Revista Latinoamericana de Hipertensión	1	Q4	0.132	12	Sociedad Latinoamericana de Hipertension

Note: Data sources were collected from https://www.scimagojr.com/

on computability without imputation that could compromise validity.

Risk of bias assessment and certainty considerations

Randomized controlled trials (RCTs) were appraised at the outcome level using the Cochrane Risk of Bias 2 (RoB 2) tool, covering randomization, deviations from intended interventions, missing outcome data, outcome measurement, and selective reporting. This approach was chosen to align with contemporary hypertension and nutrition evidence syntheses and prevailing expectations for RCT appraisal. If eligible non-randomized controlled studies were identified, they were to be assessed using an appropriate non-randomized tool and synthesized separately to avoid conflating certainty levels. Risk-of-bias judgments informed interpretation, and outcome-level limitations were explicitly incorporated when assessing consistency and credibility. A PRISMA 2020 checklist was prepared, with full search strategies and risk-of-bias summaries designated for supplementary materials to enhance transparency.

Data synthesis, heterogeneity, and presentation of results

Given anticipated heterogeneity in lemon preparations (juice, extracts, essential oils), dosing, co-interventions, and measurement schedules, synthesis was prespecified as a structured narrative organized by intervention form, dose, and duration, grouping clinically comparable studies. Where pooling was inappropriate due to heterogeneity or incomplete reporting, synthesis followed structured narrative principles consistent with SWiM-style reporting, explicitly stating grouping decisions, outcome summarization methods, and inference pathways. When sufficient clinical and methodological comparability existed for SBP/DBP, meta-analysis was considered using effect estimates (MD in mmHg) with an a priori preference for random-effects models; however, quantitative pooling depended on homogeneity and availability of dispersion measures. Findings were presented in summary tables of study characteristics, intervention attributes, and outcome direction/magnitude, alongside the PRISMA flow diagram. Because this review involved no primary data collection from human participants, informed consent and institutional ethical approval were not applicable.

RESULTS

Eligible studies were published across 2010–2023, with one article each in 2010, 2012, 2014, 2015, 2017, 2018, 2021, 2022, and 2023 (each 7%); two articles in 2016 (14%) and 2020 (14%). Most studies were conducted in Iran (n = 3, 21%) and Japan (n = 3, 21%), followed by Pakistan (n = 2, 14%) and Korea (n = 2, 14%), with single studies from Germany, Turkey, and Spain.

Table 1 summarizes the outlet characteristics of the included studies, showing that 13 articles were published across 12 journals, with only *Nutrients* contributing two articles and all other journals

contributing one each. Overall, the evidence base is concentrated in higher-ranked outlets: most articles appeared in Q1 journals (e.g., *Nutrients*; SJR 1.473, H-index 243), with additional publications in Q2 journals, and a smaller proportion in Q3 and Q4 journals. The table also reports journal-level impact indicators (SJR and H-index) and publishers, based on ScimagoJR data, providing contextual information on the scholarly visibility and indexing profile of the publication venues.

Intervention characteristics

Across the included articles, 13 unique lemon-related interventions were identified (Table 1). Lemon juice was the most common delivery form (n = 6, 43%), followed by lemon essential oil administered as aromatherapy (n = 3, 21%). Other interventions used lemon peel powder capsules (7%), lemon extracts (14%), or lemon combined with other ingredients (e.g., garlic, ginger) (14%). Most interventions involved direct consumption (n = 10, 71%), fresh juice, capsules, or mixed preparations, whereas aromatherapy was used in three studies (21%). Intervention duration ranged from a single administration to 11 weeks, and fewer than one-third lasted ≥1 month (n = 4, 29%). Delivery was predominantly in-person (n = 12, 86%), with technology-mediated delivery uncommon (n = 2, 14%); only two interventions (14%) explicitly used mixed in-person/technology approaches. Study designs were primarily randomized controlled trials (RCTs) (n = 9, 64%). Consistent with the cardiovascular focus, nearly all interventions targeted participants with elevated blood pressure or related cardiometabolic conditions.

Sample characteristics

As summarized in Table 2, samples were predominantly drawn from clinical populations, including hypertension (n = 6, 43%), heart disease or related conditions (n = 4, 29%), hyperlipidemia (n = 2, 14%), and obesity (n = 2, 14%). Most interventions enrolled adults aged ≥30 years (n = 9, 64%), with fewer studies focusing on adolescents (n = 3, 21%) or older adult populations (n = 2, 14%). Studies were mainly conducted in Asia (n = 9, 64%), followed by Europe (n = 3, 21%), and the Middle East/South America (n = 2, 14%). Intervention settings were largely hospital or health-center based (n = 9, 64%), with fewer community-based programs (n = 3, 21%) and a minority using animal laboratory models (n = 2, 14%).

Funding and theoretical rationale

Most studies did not explicitly report funding sources (n = 8, 57%). When reported, funding commonly came from academic institutions or national health agencies (n = 5, 36%), with one study supported by the private sector (7%). Ten of 14 interventions (71%) described a biological rationale for lemon's potential blood-pressure effects, commonly referencing flavonoids and citric acid as contributors to vasodilation and inhibition of hypertension-related enzymes.

Protocol-only studies versus evaluated interventions

Comparisons between interventions with outcome evaluations and those reporting protocols only suggested meaningful differences. Protocol-only interventions more frequently targeted multiple health domains (single-domain targeting: 21% in evaluated studies vs 14% in protocols; multi-domain targeting: 29% vs 43%). Protocol-only interventions also tended to be longer, more likely to incorporate technology, and more frequently designed as RCTs. They more often focused on adults as the primary population, whereas evaluated interventions more commonly targeted clinically defined groups with specific medical conditions. Overall, evaluated interventions generally reported significant reductions in SBP and DBP versus controls, alongside increased serum nitric oxide and decreased LDL-C; however, significance was sometimes restricted to subgroups, such as participants receiving higher doses or interventions lasting >4 weeks.

Outcome patterns by quality, dose, duration, and combination

Based on Table 3 (risk-of-bias and methodological quality), most included studies demonstrated strong methodological quality. Of 13 included studies, eight were rated "strong" overall, with statistical analysis, data collection methods, and intervention integrity most frequently assessed as strong. In contrast, five studies (including Nakamura et al., Paredes et al., Rana et al., and two others) were rated "weak," mainly due to limitations in selection bias, blinding, and confounding control; weaknesses in handling confounders and reporting withdrawals/dropouts were also observed, which may reduce internal validity. Thus, while overall methodological strength supports the review's conclusions, interpretation should account for limitations in specific studies.

Across studies, most interventions showed beneficial effects on blood pressure, although magnitude and consistency varied by product form, dose, and duration. Nakamura et al. (2023) reported that high-dose lemon juice (equivalent to 35.4 g/day) in spontaneously hypertensive rats reduced SBP by 30.8

Table 2
Data extraction results tabulation

Author	Sample size (N)	Type of administration (dose)	Intervention components & duration	Part of fruit used	Results
Kato et al. (2014)	N = 101 (middle-aged adults)	Citrus limon intake, 1–3 times/day	Lemon ingestion combined with walking (daily lifestyle intervention)	Fruit pulp; most participants consumed lemon as juice	Significant association with systolic blood pressure and daily step count (steps/day p = 0.034; daily lemon intake p = 0.04).
Rambod et al. (2020)	N = 100 (acute myocardial infarction/AMI patients)	Lemon aromatherapy inhalation	Intervention (n=50): 5 drops of lemon essential oil on cotton in an open container placed 20 cm from the patient; applied 7 times/day (every 2 hours) for 4 days. Control (n=50): 5 drops of liquid paraffin with the same procedure.	Lemon essential oil	Day 2: no significant difference in systolic BP. Days 3–4: significant effect on systolic BP (F = 4.68, p = 0.03).
Aslani et al. (2016)	N = 112 (hyperlipidemia patients, 30–60 years)	Lemon juice, 1 tablespoon/day	4 groups for 8 weeks: (1) garlic 20 g/day + lemon juice 1 tbsp/day; (2) garlic 20 g/day; (3) lemon juice 1 tbsp/day; (4) no garlic/lemon.	Lemon juice	Significant reductions in total cholesterol (Group 1: 40.8 ± 6.1, P < 0.001), LDL (29.8 ± 2.6, P < 0.001), and fibrinogen (111.4 ± 16.1, P < 0.001). SBP/DBP: Group 1 vs Groups 3 & 4 showed significant differences (37 ± 10, P = 0.01; 24 ± 1, P = 0.02). BMI: change 1.6 ± 0.1, P = 0.04.
Hashemipour et al. (2016)	N = 60 (overweight/obese children & adolescents; ~30 intervention, ~29 control)	Lemon peel powder capsules	Intervention: lemon peel powder capsules for 4 weeks. Control: placebo (maize starch) capsules for the same duration. Capsules prepared by the Dept. of Pharmacognosy, Isfahan University of Medical Sciences.	Lemon peel	Decreases observed in BMI (0.098), LDL-C (0.228), and SBP (p = 0.223; 3.50 ± 4.70) in the lemon group; however, no significant between-group differences for the studied variables.
Goepfert et al. (2017)	N = 10 healthy controls; 15 conscious palliative patients; 5 unconscious palliative patients	Aromatic stimulation via essential oils	Each session lasted 90 minutes (3 phases; 10-min rest between phases). Stimulus delivered for 10 minutes; measurements taken before/during/after (repeated at 0, 4, and 8 minutes; median used). Two stimuli: lemon essential oil (Citrus medica limonum oil; citral, geraniol, limonene, linalool) and lavender essential oil; water as placebo. Administered as 3–4 drops on a surgical mask loosely covering mouth and nose.	Pure essential oil	Healthy controls: no effect on SBP; DBP increased by 3 mmHg (p = 0.018). Conscious palliative: SBP +10 mmHg (p < 0.001); DBP +5 mmHg (p < 0.003). Unconscious palliative: SBP +10 mmHg (p = 0.043); DBP +5 mmHg (p = 0.043).
Cha JH et al., 2010, Korea	N = 22 (intervention) and N = 22 (control)	Inhalation; lemon oil blend (limonene 35 cc + citral 15 cc for control mixture)	Experimental: blended oils of lemon (Citrus limonum), lavender (Lavandula angustifolia), and ylang-ylang (Cananga odorata) at 2:2:1 ratio. Control: synthetic lemon fragrance (limonene 35 cc + citral 15 cc). Inhalation for 3 weeks, 2 minutes/session, twice daily in both groups.	Lemon oil (essential oil)	Significant between-group difference in systolic BP (p = 0.001) and sympathetic nervous system activity via HRV (p = 0.047). No significant effect on diastolic BP, aortic pulse wave velocity, or aortic augmentation index.
Kim et al., 2015, Korea	N = 84 premenopausal women (20–50 years), BMI > 23; 3 groups: Normal-C (n=34), Positive-C placebo (n=33), Lemon detox (n=33)	Lemon detox juice 2 L/day	Total 11-day intervention: 7 days lemon detox juice or placebo, followed by 4 days transition diet. Lemon-D: 2 L/day containing 140 g Neera syrup + 140 g lemon juice + water (≈409.3 kcal/day; 5.5 g protein). Positive-C: same volume placebo (110 g maple syrup + lemon-flavored drink + water; ≈403.3 kcal/day). Transition diet: formula nutrition package, liquid nutrition, and soy milk (3×/day).	Lemon juice	SBP decreased markedly in Lemon-D (p < 0.001; −6.7 ± 7.3 mmHg) vs normal. DBP decreased in Lemon-D (p < 0.01; −4.6 ± 7.0 mmHg), but placebo showed a larger DBP reduction; both groups were more improved than normal. hs-CRP decreased significantly only in Lemon-D (p < 0.001). No significant hematological changes in Lemon-D (suggesting safety).
Sari et al., 2012, Turkey	N = 18 (chronic effect sample) and N = 80 (acute effect participants), age ≥ 18 years	50 mL lemon juice + sugar	Acute: single dose of 50 mL lemon juice. Chronic: 50 mL lemon juice once daily for 14 days.	Lemon juice	Acute: SBP and DBP decreased significantly in the elevated–lemon juice group (p < 0.05), but no significant difference vs water-only group. Chronic: no significant effect.

Author	Sample size (N)	Type of administration (dose)	Intervention components & duration	Part of fruit used	Results
Shahabeddin et al. (2020)	N = 101 total: garlic (n=33), lemon juice (n=33), control (n=35)	Lemon juice 10 cc, twice daily	Garlic group: 10 g fresh garlic after breakfast and dinner for 20 days, 1-week washout, then another 20 days. Lemon group: 10 cc fresh lemon juice (no additives) after breakfast and dinner with the same schedule. Control: routine treatment only. All participants continued prescribed medicines; BP and comfort assessed before, during, and after intervention.	Lemon juice	Baseline: no SBP/DBP differences between groups. During/after intervention: garlic and lemon groups showed significant reductions vs control (SBP: $P < 0.001$; DBP: $P = 0.018$). No difference between garlic and lemon (SBP: $P = 0.793$; DBP: $P = 1.00$). Control showed no meaningful change.
Aslam et al. (2021)	N = 88 (44 control; 44 intervention)	15 mL before breakfast	2-week administration of a prepared mixture: equal amounts (40 mL each) of garlic, ginger, lemon juice, and apple cider vinegar + 40 mL honey; taken as 15 mL before breakfast.	Lemon juice (in mixture)	Mixture significantly reduced BP from 149/90 mmHg to 131/70 mmHg ($p < 0.05$).
Nakamura et al., 2023	N = 30 male spontaneously hypertensive rats (SHR). Groups: low-dose lemon (n=6; citric acid eq 10 mg/kg), high-dose lemon (n=6; citric acid eq 100 mg/kg), low-dose citric acid (n=6; 10 mg/kg), high-dose citric acid (n=6; 100 mg/kg), control (n=6)	Citric acid equivalent 10–100 mg/kg (high dose corresponds to 35.4 g lemon juice in the study rationale)	Comparative intervention across lemon-juice and citric-acid dosing groups; BP assessed at 3, 6, and 9 hours after administration (as reported).	Lemon juice	High-dose lemon juice: significant reductions in SBP (3h −18.4; 6h −24.4; 9h −30.8 mmHg) and DBP (3h −14.7; 6h −19.8; 9h −24.8 mmHg); significant at all time points (SBP: $p < 0.01$; DBP: $p < 0.05$). High-dose lemon vs high-dose citric acid showed similar reductions (no significant difference: SBP $0.361 < p < 0.724$; DBP $0.147 < p < 0.589$). Low-dose lemon/citric acid: no significant BP reduction vs control. Lemon juice–induced vasorelaxation: 77.7% ± 3.31 (reported).
Paredes et al. (2018)	N = 42 Sprague–Dawley rats (8–9 weeks; 300–325 g); groups n=6 each	Lemon extract 2.84 mg/kg/day	Groups: control; chronic L-NAME (10 mg/kg/day); L-NAME + apigenin (1.44 mg/kg/day); L-NAME + lemon extract (2.84 mg/kg/day); L-NAME + grapefruit + bitter orange extract (9.28 mg/kg/day); L-NAME + cocoa extract (2.52 mg/kg/day); L-NAME + diosmin (7.16 mg/kg/day).	Lemon extract	Mean arterial pressure (MAP) decreased with lemon extract treatment compared with control ($p < 0.05$), in the context of chronic NOS inhibition (L-NAME model).
Rana et al. (2022)	Rats divided into 7 groups (n=6/group): control; disease (sodium arsenate); positive control (vitamin C); Citrus sativum extract; Citrus limon extract; low-dose; high-dose combination	Lemon extract 100 mg/kg body weight	Plant extracts administered during the last 4 weeks of a 12-week experimental period (as stated). Combination groups included low and high dose (C. sativum + C. limon).	Peel extract	High-dose combination (CS + CL): significantly reduced BP ($p < 0.001$) and significantly increased serum NO from 36.00 ± 2.08 µM/mL (disease) to 49.67 ± 3.71 µM/mL. Both CS and CL alone and in combination reduced BP significantly vs control ($p < 0.001$), with the high-dose combination showing the strongest effect.

mmHg ($p < 0.01$) and DBP by 24.8 mmHg ($p < 0.05$) within nine hours. In humans, Kim et al. (2015) found that a lemon detox diet (2 L/day lemon juice for 7 days) reduced SBP by 6.7 ± 7.3 mmHg ($p < 0.001$) and DBP by 4.6 ± 7.0 mmHg ($p < 0.01$), with a significant reduction in hs-CRP (Kim et al., 2015).

Combination approaches also appeared effective: Aslam et al. (2021) reported that a herbal mixture containing lemon juice, garlic, ginger, and apple cider vinegar for two weeks reduced blood pressure from 149/90 mmHg to 131/70 mmHg ($p < 0.05$), suggesting potential synergy (Aslam et al., 2021). Similarly, Shahabeddin et al. (2020) showed that 10 cc fresh lemon juice twice daily for 20 days significantly reduced SBP and DBP versus control ($P < 0.001$ for SBP; $P = 0.018$ for DBP), with effects comparable to garlic (Shahabeddin et al., 2020). Not all trials reported significant effects. Sarı et al. (2012) observed no significant differences when 50 ml lemon juice was administered acutely and daily for 14 days. Hashemipour et al. (2016) reported reduction in BMI, LDL-C, and SBP after 4 weeks of lemon peel powder

capsules, but differences versus controls were not statistically significant. Overall, several patterns emerged: higher doses tended to yield larger effects (Nakamura et al., 2023; Kim et al., 2015); longer duration was associated with more stable improvements (Aslam et al., 2021; Shahabeddin et al., 2020) compared with short-term interventions (Sarı et al., 2012); combinations with other ingredients (garlic, ginger, apple cider vinegar) may enhance effectiveness (Aslam et al., 2021); and product form likely matters, with lemon juice and extracts appearing more consistently effective than lemon peel powder capsules (Hashemipour et al., 2016).

DISCUSSION

This review suggests that lemon-based interventions are generally associated with lower SBP and DBP, with the most consistent effects observed for fresh lemon juice and selected extracts and more variable findings for processed products such as lemon peel powder capsules. Across studies, effects appear dose-, duration-, and formulation-dependent and may differ when lemon is used alone versus within multi-ingredient regimens. Larger reductions tend to occur with higher-intensity exposure and longer interventions, implying that adequate bioactive delivery and sufficient time may be required to yield clinically observable hemodynamic changes. However, null results indicate that meaningful BP reductions are not universal and likely depend on context, including baseline cardiometabolic status, concurrent diet and lifestyle, and methodological differences in BP measurement.

Comparison with prior literature and the contribution of the present review

The findings align with broader nutritional evidence that diets rich in fruits and plant bioactives are associated with lower blood pressure and improved vascular function, consistent with guidance emphasizing dietary patterns such as DASH that increase fruit intake and reduce cardiometabolic risk (Filippou et al., 2022; Whelton et al., 2022). Observational and mechanistic studies cited within the included evidence base further support plausibility, particularly through endothelial pathways involving nitric oxide bioavailability and oxidative stress modulation. For instance, Nakamura et al. (2023) reported increased nitric oxide–related responses alongside acute blood pressure reductions in hypertensive animal models, and Rana et al. (2022) similarly highlighted nitric oxide increases following lemon peel extract exposure, reinforcing a mechanistic narrative in which vasodilatory signaling contributes to blood pressure regulation. However, the present synthesis also underscores that mechanistic consistency does not automatically translate into uniform clinical efficacy. Sarı et al. (2012) reported no significant effects after 14 days of lemon juice intake, and Hashemipour et al. (2016) reported non-significant between-group differences for lemon peel powder capsules relative to placebo, indicating that formulation and exposure parameters may be decisive. Relative to earlier work emphasizing lemon essential oil outcomes beyond hypertension (e.g., anxiolysis and physiological changes), this review contributes by foregrounding blood pressure outcomes across lemon product types and by identifying dose, duration, and co-intervention contexts as key moderators that should be explicitly addressed in future clinical trial design and synthesis.

Scientific, practical, and faith-aligned public health implications

From a public health standpoint, the findings support cautious consideration of lemon, particularly fresh juice or standardized extracts, as a potentially useful adjunct within broader lifestyle-based hypertension management, rather than as a substitute for guideline-based care. The observation that longer interventions and higher doses are more consistently associated with benefit suggests that pragmatic recommendations, if developed, should emphasize realistic and sustainable consumption patterns and should be evaluated within culturally typical dietary contexts. The evidence of enhanced effects in combination regimens, such as lemon administered with garlic and ginger (Aslam et al., 2021) or comparisons suggesting effects comparable to garlic (Shahabeddin et al., 2020), raises the possibility that lemon may be most effective when integrated into multi-component dietary strategies, although multi-ingredient designs limit causal attribution and require confirmatory trials that isolate lemon's independent contribution.

In family health programming, lemon is an accessible household ingredient and can be incorporated into nutrition education emphasizing reduced sodium intake and increased consumption of fruits and plant-based foods, consistent with population strategies to shift blood pressure distributions and reduce noncommunicable disease burden (Zhou et al., 2021; Jiang et al., 2023). These implications can be framed within ethical–spiritual

Table 3
Assessment of bias risk and methodological quality in included studies

Study	Bias	Study Design	Confounders	Blinding	Data collection methods	Withdrawals and dropouts	Intervention Integrated	Statistical analysis	Global Ranking
Kato et.al	strong	moderate	strong	moderate	strong	strong	weak	strong	moderate
Rambood et.al	strong	strong	strong	moderate	strong	strong	strong	strong	strong
Aslani et.al	strong	strong	strong	moderate	strong	strong	strong	strong	strong
Hashemipour et al.	strong	strong	strong	moderate	strong	strong	strong	strong	strong
Goepfert et.al	strong	strong	strong	moderate	strong	strong	strong	strong	strong
Cha et.al	strong	strong	strong	moderate	strong	strong	strong	strong	strong
Kim et.al	strong	strong	strong	moderate	strong	strong	strong	strong	strong
Shahabeddin et.al	strong	strong	strong	moderate	strong	strong	strong	strong	strong
Aslam et.al	strong	strong	strong	moderate	strong	strong	strong	strong	strong
Nakamura et.al	weak	strong	moderate	weak	strong	weak	strong	strong	weak
Paredes et.al	weak	strong	moderate	weak	strong	weak	strong	strong	weak
Rana et.al	weak	strong	moderate	weak	strong	weak	strong	strong	weak

commitments to preserving health as an amanah and to consuming halalan thayyiban foods, in which wholesome dietary choices are understood as value-consistent practices that support physical wellbeing and responsible self-care. The Qur'an's guidance on the diversity of fruits and plants can be used as a starting point to strengthen culturally relevant health communication. In QS. An-Nahl [16]:11, Allah SWT says:

> *"He causes to grow for you thereby the crops, olives, palm trees, grapevines, and from all the fruits. Indeed in that is a sign for a people who give thought."*

This message is in line with the words of the Prophet in HR. Al-Bukhari: 5199, which emphasize the fulfillment of bodily rights, namely:

> *"… Your body has a right over you..."*

These arguments can be used to reinforce the message of consuming a variety of fruits and vegetables as part of a balanced diet. However, the scientific limits still need to be emphasized. Religious references serve primarily as a framework that supports relevance, motivation, and compliance, not as evidence of effectiveness. while claims of effectiveness (e.g., the nutritional benefits of fruits/vegetables or the impact of interventions) must still be supported by scientific evidence and program evaluation, given that interventions in faith-based settings also show varying results, making design and impact measurement crucial (Chan et al., 2023). Practically, such framing may improve acceptability of family-centered dietary interventions and strengthen sustained self-management, which is central to hypertension control as a chronic condition (Zoccali et al., 2023).

Evidence gaps and heterogeneity in intervention design

Important gaps remain across geography, populations, and intervention standardization. Most included studies were conducted in Asia and Europe, while evidence from low- and middle-income settings with rapidly rising hypertension burdens remains limited; this is notable because hypertension in developing contexts is complex and multifactorial, shaped by dietary transitions, urbanization, and health-system constraints (Hunter et al., 2021; Masilela et al., 2020). Additional trials in diverse settings are needed to assess generalizability across dietary patterns and lifestyle contexts and to inform locally appropriate policy and program design. Moreover, most studies targeted participants with existing cardiometabolic conditions such as hypertension or hyperlipidemia, whereas preventive evidence among normotensive or otherwise healthy individuals remains scarce; accordingly, the potential role of lemon as a preventive dietary measure requires further clarification.

Heterogeneity in formulation also represents a central limitation: fresh juice and extracts more frequently produced significant results than lemon peel powder capsules, raising questions about bioavailability and the influence of processing on active compound profiles, as suggested by the null between-group findings in capsule-based interventions (Hashemipour et al., 2016). These inconsistencies indicate that future studies should standardize lemon products, quantify bioactive content, and report

adherence and exposure metrics with greater precision to enable meaningful cross-study comparison.

This review included both animal and human evidence, and the differences between these bodies of work require careful interpretation. Animal studies, such as those by Nakamura et al. (2023) and Paredes et al. (2018), reported pronounced blood pressure reductions following lemon juice or extract administration, and related work suggested nitric oxide increases after lemon peel extract exposure (Rana et al., 2022). While these results support mechanistic plausibility and can help identify candidate pathways, translation to humans is constrained by interspecies differences in metabolism, dosing equivalence, and environmental variability. Experimental animals typically exhibit more uniform physiological responses than humans, whose blood pressure is shaped by complex interactions among diet, stress, physical activity, medication use, and socioeconomic determinants (Benlebna et al., 2020; He et al., 2024). In addition, animal studies may use exposure intensities that are not readily achievable or sustainable in routine human diets. Human trials in this review did demonstrate significant reductions in blood pressure in some contexts, including multi-ingredient mixtures (Aslam et al., 2021) and short-to-medium duration lemon juice regimens (Shahabeddin et al., 2020), but other studies reported null findings after 14 days (Sarı et al., 2012), indicating that human efficacy is conditional and may require adequate duration, product standardization, and careful control of background diet and lifestyle factors.

Several limitations of the included evidence constrain the strength of inference. The overall number of studies remains limited and geographically concentrated, which restricts external validity and necessitates cautious generalization. Intervention heterogeneity in product form, dose, co-interventions, and duration complicates direct comparisons and may explain divergent results across trials. Most interventions were shorter than one month, which is a critical concern because hypertension is a chronic condition requiring sustained lifestyle modification, and short-term trials may capture only transient hemodynamic responses rather than stable long-term blood pressure control (Zoccali et al., 2023). Additionally, mechanistic outcomes were inconsistently measured; although flavonoids and citric acid have been proposed to influence blood pressure through nitric oxide enhancement and anti-inflammatory effects, few trials directly and comprehensively assessed these pathways in humans, limiting causal interpretation of mechanisms. Future research should prioritize longer-duration, adequately powered RCTs using standardized lemon preparations with quantified bioactive profiles, pre-specified primary outcomes (SBP/DBP) and harmonized secondary biomarkers, and rigorous control or measurement of background dietary sodium–potassium intake and lifestyle factors. Trials should also clarify the independent effect of lemon in multi-ingredient interventions through factorial or multi-arm designs, and expand to understudied populations and regions to strengthen applicability for family-based hypertension prevention and management programs.

CONCLUSIONS

This review indicates that *Citrus limon*–based interventions—particularly fresh lemon juice and selected extracts—may reduce SBP and DBP, with more consistent effects at higher exposure intensity and longer duration. Larger reductions are sometimes observed when lemon is delivered within multi-ingredient regimens (notably with garlic and ginger), but such designs limit causal attribution and should be considered supportive rather than definitive. Accordingly, lemon is best positioned as a plausible adjunct to lifestyle-based hypertension management and healthy dietary patterns, not a replacement for guideline-based pharmacotherapy or clinical care.

Generalisability and translation are constrained by key gaps: geographic concentration of studies with limited LMIC representation, few preventive trials in healthy/normotensive populations, and substantial heterogeneity in product form/processing, dose, duration, and outcome assessment. These limitations underscore the need for standardized preparations with quantified bioactive profiling and harmonized reporting of BP outcomes and relevant biomarkers. Future research should prioritize adequately powered, longer-duration RCTs using standardized lemon interventions, prespecified SBP/DBP endpoints, consistent secondary biomarker panels, and rigorous assessment of background diet and lifestyle to clarify sustained effectiveness, safety, and mechanisms.

From a public health perspective, lemon is an accessible, culturally familiar, and environmentally feasible dietary component that can be integrated into family-centered nutrition education and community-based risk-reduction strategies. For journals emphasizing Islamic values, the findings can be operationalized within *halalan thayyiban* and *Thibbun Nabawi*–aligned health communication by framing

prudent use of wholesome natural foods (e.g., lemon) as value-consistent family self-care (*ikhtiar*) to protect health.

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AUTHORS' CONTRIBUTIONS

Yusma I. Jayadi led the conceptualization of the review question and protocol, conducted the literature searches and study screening, and performed data extraction and narrative synthesis. Ahmad Sulaeman supervised the study, contributed to methodological design and critical interpretation of findings, and led manuscript review and final approval. Eny Palupi contributed to eligibility criteria development and quality appraisal using the EPHPP domains, and reviewed the manuscript for intellectual content. Mira Dewi supported data interpretation and contributed to manuscript drafting and editing. Hardinsyah Hardinsyah provided senior academic oversight, strengthened the framing for dietary guidance and critically revised the manuscript. All authors read and approved the final manuscript.

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COMPETING INTERESTS

The author(s) declare no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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