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Review Article

Pharmacological and Phytochemical Activities of Celery Roots and Stems (Apium graveolens L.): Literature Review

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Abstract. Celery (Apium graveolens L.) is an herbaceous plant of the Apiaceae family used in traditional medicine to lower blood pressure, treat digestive disorders, and maintain liver and kidney health. Comparative studies on phytochemical content and pharmacological activities of each plant part remain limited. This study aimed to review antioxidant, anti-inflammatory, and antihypertensive activities and identify phytochemical compounds in each part based on literature from 2020 to 2025. This study used a literature review design with the PICOS framework and secondary data from Google Scholar, PubMed, ScienceDirect, and ResearchGate, conducted at STIKes Al-Fatah Bengkulu over two months. The findings demonstrated that celery roots and stems possess antioxidant, anti-inflammatory, and antihypertensive activities attributed to flavonoids, phenolic compounds, phthalides, essential oils, coumarins, triterpenoids, and minerals. Antioxidant activity was reflected by free radical scavenging capacity and enhancement of endogenous antioxidant defense systems, while anti-inflammatory activity involved inhibition of pro-inflammatory mediators and inflammation-related enzymes. Antihypertensive effects were associated with inhibition of angiotensin-converting enzyme (ACE), vasodilation, diuretic activity, and improved electrolyte balance. Overall, celery stems exhibited more consistent pharmacological evidence, particularly for antihypertensive activity supported by clinical studies, whereas celery roots showed promising potential that requires further experimental and clinical validation. These findings provide scientific evidence supporting the development of celery as a standardized herbal medicine and phytopharmaceutical raw material.

Keywords: Apium graveolens L.; Antioxidant; Anti-Inflammatory; Antihypertensive; Phytochemistry.

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1. Introduction

Indonesia possesses exceptionally rich biodiversity, including a wide variety of medicinal herbs that have long been utilized in traditional medicine. The use of medicinal plants has been passed down through generations, as they are believed to effectively treat various diseases while producing relatively fewer adverse effects than synthetic drugs. Nearly all parts of medicinal plants, including the roots, stems, leaves, fruits, seeds, and flowers, can be utilized for therapeutic purposes. Furthermore, natural products are readily available, affordable, and deeply embedded in the cultural practices of Indonesian society (Ngelu et al., 2022).

One of the most widely recognized and extensively utilized herbal plants, both as a food ingredient and a traditional medicinal remedy, is celery (Apium graveolens L.). This species belongs to the Apiaceae family and is capable of growing in both lowland and highland environments (Minaiyan et al., 2021). Celery is distinguished by its characteristic aroma and is rich in nutrients as well as diverse secondary metabolites that contribute to its medicinal value. In traditional medicine, celery has been widely used to reduce blood pressure, alleviate digestive disorders, and maintain liver and kidney health (González et al., 2024).

Numerous scientific studies have demonstrated that different parts of the celery plant, including the roots, stems, leaves, and seeds, contain distinct phytochemical constituents and exhibit diverse biological activities. Celery roots are rich in phenolic compounds, such as caffeic acid, ferulic acid, and kaempferol glycosides, which function as natural antioxidants and protect cells against oxidative stress (Szarek et al., 2024). Recent studies have further revealed that celery roots contain phthalide compounds, including 3-n-butylphthalide and sedanolide, which possess antioxidant, anti-ulcer, and cytoprotective properties. These bioactive compounds have been shown to alleviate oxidative stress while exhibiting significant gastroprotective and anti-inflammatory activities (Daoud et al., 2025).

Similarly, celery stems and leaves contain numerous bioactive constituents, including flavonoids (apigenin and luteolin), carotenoids, tocopherols, and volatile oils such as limonene and sabinene. These compounds have been reported to exhibit antioxidant and anti-inflammatory properties while protecting tissues against oxidative damage (González et al., 2024). In addition, previous studies have shown that celery stems and leaves are abundant in phenolic compounds, including caffeic acid, p-coumaric acid, and ferulic acid, which contribute to their antioxidant and antimicrobial activities (Khairullah et al., 2021).

Celery seeds represent the primary source of essential oils containing furanocoumarins and phthalides, including 3-n-butylphthalide, limonene, and myrcene, which are associated with antihypertensive, hypolipidemic, hepatoprotective, and anticancer effects (Aboody, 2021). Furthermore, celery seeds contain limonene, myrcene, and sedanolide, which have demonstrated cytotoxic effects against cancer cells and significant antimicrobial activity (Monica & Diana, 2021).

Collectively, these findings indicate that each part of the celery plant possesses distinct yet complementary phytochemical profiles and pharmacological properties. Nevertheless, comprehensive studies comparing the bioactive constituents and biological activities among different parts of the celery plant remain limited, particularly in Indonesia. Such information is essential for advancing the development of safe, effective, and evidence-based herbal medicines and functional food products. Therefore, this literature review was conducted to systematically evaluate and synthesize recent evidence regarding the phytochemical composition and pharmacological activities of different parts of Apium graveolens L., thereby enriching the scientific understanding of this medicinal plant and supporting the optimal utilization of Indonesia's biodiversity in the fields of health and natural pharmaceutical sciences.

Based on this background, the present study aimed to evaluate the pharmacological activities of celery (Apium graveolens L.), with particular emphasis on its roots and stems, including their antioxidant, anti-inflammatory, and antihypertensive properties, as reported in scientific publications published between 2020 and 2025. Furthermore, this study sought to identify the phytochemical constituents responsible for these pharmacological activities through a comprehensive synthesis of previous research findings. Finally, this review aimed to determine which part of the celery plant exhibits the greatest pharmacological potential for each biological activity, thereby providing a scientific basis for the future development of celery as a raw material for standardized herbal medicines and phytopharmaceutical products.

2. Literature Review

General Overview of Celery (Apium graveolens L.)

Celery (Apium graveolens L.) is a herbaceous plant widely utilized as both a food ingredient and a medicinal plant. It belongs to the Apiaceae family, which is characterized by hollow stems, pinnately compound leaves, and compound umbels. Celery is well adapted to both tropical and subtropical climates, including Indonesia, where environmental conditions are highly favorable for its cultivation (González et al., 2024).

In addition to its culinary applications, celery has long been employed in traditional medicine. It has traditionally been used to reduce blood pressure, alleviate digestive disorders, and support liver and kidney function (Ngelu et al., 2022). In traditional Chinese and Indian medicine, celery has also been prescribed as a diuretic, sedative, and remedy for rheumatic and joint disorders. These traditional applications have stimulated extensive scientific investigations aimed at elucidating its phytochemical composition and biological activities (Alobaidi & Saleh, 2024).

Phytochemical Constituents of Celery (Apium graveolens L.)

Different parts of the celery plant, including the roots, stems, leaves, and seeds, possess distinct phytochemical profiles. Phytochemicals are secondary metabolites synthesized by plants that primarily function as defense mechanisms against environmental stress, pathogens, and herbivores. These compounds are also responsible for a wide range of biological activities in humans, including antioxidant, anti-inflammatory, and antibacterial effects.

Celery roots are particularly rich in phenolic compounds, such as ferulic acid, caffeic acid, and kaempferol glycosides, all of which exhibit potent antioxidant properties. These phenolic constituents exert their biological effects by scavenging free radicals, thereby protecting cells against oxidative stress-induced damage. In addition, celery roots contain furanocoumarins, which have demonstrated promising antibacterial and anti-inflammatory activities (Foudah et al., 2021).

Celery stems contain abundant flavonoids, including apigenin, luteolin, and apiin, which serve as natural antioxidants. The presence of vitamin C and tocopherols further enhances their antioxidant capacity by protecting cells from oxidative damage. Previous studies have also demonstrated that celery stem extracts suppress the production of inflammatory mediators, highlighting their potential as natural anti-inflammatory agents (González et al., 2024).

Phytochemical Analysis Methods

The reviewed literature indicates that various analytical techniques have been employed to characterize the phytochemical composition of celery. Gas Chromatography–Mass Spectrometry (GC–MS) is commonly used for profiling essential oils, whereas High-Performance Liquid Chromatography (HPLC) and Liquid Chromatography–Mass Spectrometry (LC–MS) are widely applied for the identification and quantification of phenolic compounds and flavonoids (Fadhli et al., 2025). Furthermore, combinations of these analytical techniques have been utilized to identify phthalides and other volatile constituents. Consequently, comparisons among studies should carefully consider the analytical methods employed, as methodological differences may influence the reported phytochemical profiles (Foudah et al., 2021).

GC–MS combines the separation capability of gas chromatography with the molecular identification power of mass spectrometry, making it particularly suitable for analyzing volatile compounds. HPLC is a high-pressure liquid chromatographic technique that separates compounds based on their interactions with the stationary and mobile phases. LC–MS integrates HPLC with mass spectrometry, providing enhanced sensitivity, selectivity, and structural information for the analysis of complex phytochemical mixtures.

PICOS Framework

The PICOS framework is one of the most widely adopted approaches in evidence-based research, particularly in systematic reviews and meta-analyses. PICOS is an acronym representing five essential components: Population, Intervention, Comparison, Outcomes, and Study Design. This framework assists researchers in formulating clear, focused, and structured research questions, thereby facilitating a more efficient and relevant literature search process (Siddaway et al., 2019).

According to Murti (2018), the PICOS framework enables researchers to identify the key methodological elements required to assess the eligibility and quality of scientific evidence, particularly in health and pharmaceutical research. By applying the PICOS approach, researchers can define the scope of a review based on specific and measurable variables, thereby enhancing the rigor, transparency, and reproducibility of the literature review process.

3. Research Method

This study employed a literature review design using the PICOS (Population, Intervention, Comparison, Outcomes, and Study Design) framework to formulate the research question and establish a systematic strategy for identifying relevant scientific literature. The PICOS approach was applied to facilitate the identification and selection of studies that addressed the pharmacological activities and phytochemical constituents of celery (Apium graveolens L.).

The study relied exclusively on secondary data obtained from previously published scientific research rather than primary field observations. The reviewed literature focused on the pharmacological properties of celery, particularly its antioxidant, anti-inflammatory, and antihypertensive activities, as well as the phytochemical constituents present in different plant parts, including the roots and stems.

The secondary data were collected from peer-reviewed articles published in reputable national and international journals to ensure the validity and reliability of the evidence. Relevant publications were retrieved from several scientific databases, including Google Scholar, PubMed, ScienceDirect, ResearchGate, and Neliti. The use of multiple databases was intended to maximize the comprehensiveness, accuracy, and relevance of the retrieved literature.

To broaden the scope of the literature search, both English and Indonesian keywords were employed. English search terms included "Apium graveolens", "celery", "phytochemical", "pharmacological activity", "antioxidant", "anti-inflammatory", "antihypertensive", "root", and "stem". Indonesian keywords included "seledri", "fitokimia", "aktivitas farmakologi", "antioksidan", "antiinflamasi", "antihipertensi", "akar seledri", and "batang seledri". These keywords were used individually and in various Boolean combinations to identify studies relevant to the research objectives.

The literature search was restricted to publications published between 2020 and 2025 to ensure that the review reflected the most recent scientific evidence in pharmaceutical and health sciences. Retrieved articles were systematically documented and screened to facilitate the subsequent selection and data analysis processes.

Eligible studies included original research articles and review papers published in English or Indonesian, available in full-text format, and reporting phytochemical constituents or pharmacological activities of celery roots, stems, leaves, or seeds. Studies that did not meet these eligibility criteria were excluded. The selection process involved sequential screening of titles, abstracts, and full texts according to predefined inclusion and exclusion criteria. Data were subsequently extracted using a standardized form containing information on the authors, publication year, plant part investigated, extraction methods, phytochemical constituents, and reported pharmacological activities.

The extracted data were analyzed descriptively through a systematic narrative synthesis. Studies were grouped according to the celery plant part investigated, with particular emphasis on the roots and stems. Similarities and differences in phytochemical composition between these plant parts were identified, followed by a synthesis of scientific evidence regarding their antioxidant, anti-inflammatory, and antihypertensive activities, including the relationships between bioactive compounds and their underlying biological mechanisms. The literature selection was guided by the PICOS framework, in which the Population comprised celery roots and stems (Apium graveolens L.); the Intervention involved phytochemical characterization and pharmacological evaluation of celery extracts; the Comparison consisted of comparisons among plant parts and across different studies; the Outcomes included the identification of phytochemical constituents and evidence of antioxidant, anti-inflammatory, and antihypertensive activities; and the Study Design encompassed in vitro, in vivo, and review studies published between 2020 and 2025, available in full-text format, and written in either English or Indonesian.

4. Results and Discussion

Result

To find articles, the author conducted a search using pre-compiled keywords. After conducting a search based on inclusion and exclusion criteria, nine articles were obtained. These nine articles were then analyzed. A total of nine scientific articles were used as primary reference sources in this study, including three articles on anti-inflammatory activity, four articles on antioxidant activity, and two articles on antihypertensive activity, distributed across both parts of the plant. Below is a list of the nine extracted articles in table form.

Table 1. List of Analyzed Articles.

No	Article Title	Author Name	Part	Method Research	Phytochemical Content	Pharmacological Activity	Research Results
1	Anti-inflammatory and antioxidant effects of Apium graveolens L. extracts mitigate against fatal acetamino phen-	Ayat M. Emad, Sherifa F. Ali, Engy A. Abdel-Rahman, Meselhy R. Meselhy, Mohamed A. Farag,	Root	Methanolic extraction of roots (MCRE) and UPLC-MS profiling. In vivo test in Wistar rats with hepatotoxi	TPC 7.1±0.3 mg GAE/g; TFC 16.2±1 mg RE/g. 98 compounds were identified, mainly flavonoids (apigenin, luteolin,	Anti-inflammatory	MCRE 100 mg/kg significantly reduced TNF-α and IL-1β. Liver enzymes AST, ALT, and ALP approached normal values, and liver histopathology was normal.

	induced acute liver toxicity	Sameh S. Ali, Essam A. Abdel-Sattar (2020)		city of 2.5 g/kg acetaminophen. MCRE doses of 100 and 200 mg/kg orally for 8 days. TNF-α and IL-1β parameters were measured by ELISA.	chrysoeriol), phenolic acids, polyacetylenes, phthalides, coumarins, lignans, fatty acids, and triterpenes..		Survival was 100% in the MCRE group versus 0% in the APAP group.
2	Chemical Composition and Anti-inflammatory Activity of Apium graveolens var. dulce Essential Oils from Senegal	Abdoulaye Thiam, Momar Talla Gueye, Cheikhna Hamala Sanghare, El Hadji Barka Ndiaye, Serigne Mbacké Diop, Papa Seyni Cissokho, Michel Bakar Diop, Ibrahima Ndiaye, Marie-Laure Fauconnier (2020)	Stem (essential oil)	Steam distillation extraction with Clevenger. Compound identification with GC/FID and GC/MS. In vitro anti-inflammatory test through 5-LOX inhibition, quercetin as a comparison.	α-pinene 69.3%; limonene 9.5%; α-phellandrene 5.5%; β-pinene 4.8%. A total of 22 compounds, dominated by monoterpene hydrocarbons (95.5%).	Anti-inflammatory	The yield of stem essential oil was 0.4±0.1%. Activity tests were conducted on leaf oil, which has a composition almost the same as the stem, with an IC_{50} of 5-LOX inhibition of 29.5±2.0 μg/mL vs. quercetin of 23.7±0.5 μg/mL. α-pinene and limonene act synergistically to inhibit 5-LOX.
3	Evaluation of Anti-Inflammatory Effects of Celery Leaf and Stem Extracts in LPS-Induced RAW 264.7 Cells Using Nitric Oxide	Hazel Lau, Nengyi Ni, Hiranya Dayal, Si-Ying Lim, Yi Ren, Sam Fong-Yau Li (2021)	Stem (extract)	Extraction of 80% ethanol (pH 1) with sonication at 80 °C, 2 hours. LC-MS/MS analysis. In vitro assay on RAW 264.7 cells induced by LPS 1	Flavonoids (apigenin, apigetrin, apiin) and coumarins (bergapten, xanthotoxin) were not detected in CSE.	Anti-inflammatory	CSE 5 mg/mL reduced NO production by approximately 1.5 times compared to the LPS control, with cell viability >90%. Several metabolites (citrulline, histidine, glucose) affecting the

	Assay and LC-MS Based Metabolomics			µg/mL. Stem extract (CSE) 1.25; 2.5; and 5 mg/mL. Parameters: NO production, viability, and metabolomic profile.			glycolysis and pentose phosphate pathways were reversible. CSE was five times less effective than CLE.
4	Anti-inflammatory and antioxidant effects of Apium graveolens L. extracts mitigate against fatal acetaminophen-induced acute liver toxicity	Ayat M. Emad, Sherifa F. Ali, Engy A. Abdel-Rahman Meselhy R. Meselhy Mohamed A. Farag, Sameh S. Ali, EssamA. Abdel-Sattar (2020)	Root	Aqueous and methanol extraction of roots. UPLC-MS analysis. In vitro antioxidant assay using EPR spin trapping technique. In vivo assay on Wistar rats induced by acetaminophen 2.5 g/kg, methanol extract doses of 100 and 200 mg/kg for 8 days. TAC and GSH parameters in liver homogenates.	TPC 7.1±0.3 mg GAE/g; TFC 16.2±1 mg RE/g. 98 compounds were identified, mainly flavonoids (apigenin, luteolin, chrysoeriol, apiin), phenolic acids, polyacetylenes, phthalides, coumarins, lignans, fatty acids, and triterpenes.	Antioxidants	The methanolic extract of the root (MCRE) showed the strongest hydroxyl radical scavenging activity among all celery extracts with 98.45% inhibition at a concentration of 0.5 mg/ml (EPR). In vivo tests, 100 mg/kg MCRE significantly increased TAC and GSH in rat livers back to normal levels, with a 100% survival rate in the extract group vs. 0% control. The mechanism is through hydroxyl radical scavenging (•OH) and increasing the endogenous antioxidant system.
5	Cytotoxic, antioxidant, and antimicrobial activities of Celery (Apium	Mohammed Saleh Al Aboody (2021)	Root	70% ethanol extraction with cold maceration. Antioxidant assay	Positive: glycosides, tannins, flavonoids, terpenoids, carbohydrates, and proteins.	Antioxidants	The root extract showed the weakest antioxidant activity compared to other parts.

	graveolens L.)			using 5 colorimetric methods: DPPH, ABTS, NO, HPO, and LPO (TBARS).	Negative: saponins, steroids, alkaloids, and anthraquinones.		The IC50 values were: DPPH 39.71±0.035; ABTS 48.68; LPO 44.58; NO 92.35±0.458; and HPO 89.48 μg/ml.
6	Cytotoxic, antioxidant, and antimicrobial activities of Celery (Apium graveolens L.)	Mohammed Saleh Al Aboody (2021)	Stem (extract)	70% ethanol extraction with cold maceration. Antioxidant assay using 5 colorimetric methods: DPPH, ABTS, NO, HPO, and LPO (TBARS).	Positive: tannins, saponins, flavonoids, steroids, terpenoids, alkaloids, carbohydrates, and anthraquinones. Negative: glycosides and proteins.	Antioxidants	Stem extract showed moderate antioxidant activity with IC50 values: DPPH 26.28±0.038; ABTS 22.35; LPO 24.56; NO 36.89±0.248; and HPO 44.72 μg/ml. Its activity was stronger than the roots but weaker than the leaves.
7	Evaluation of bioactive components and antioxidant capacity of four celery (Apium graveolens L.) leaves and petioles	De-Kun Liu, Cong-Cong Xu, Lu Zhang, Hui Ma, Xu-Jie Chen, Yu-Cui Sui, Hong-Zhi Zhang (2020)	Stem	Extraction of 95% ethanol for 5 hours. Bioactive profile analysis by HPLC-MS. In vitro antioxidant test using DPPH method, $O_2{\cdot}^-$ radical inhibition, and iron ion/FRP reducing power. Statistical analysis using PLS regression.	In the stalk of the Baoqin variety (highest antioxidant activity), flavonoids (rutin, apiin, apigenin), vitamins (pantothenic acid, choline, riboflavin, phylloquinone), unsaturated fatty acids (α-linolenic acid, oleic acid), coumarins, pigments (safflomin A, diosmetin), carotenoids, and terpenes (α-ionone) were identified.	Antioxidants	The stalks of Baoqin variety showed the highest antioxidant activity among the four varieties tested (DPPH inhibition ratio 39±2%, $O_2{\cdot}^-$ 25±1%, FRP 0.15±0.02), but the levels of antioxidant components were significantly lower ($P<0.05$) than the leaves. PLS analysis showed that the largest contribution to DPPH came from flavonoids (apiin, apigenin, rutin) and α-ionone, while the largest

							contribution to $O_2^{\cdot -}$ came from unsaturated fatty acids (oleic acid, α-linolenic acid) and vitamins.
8	Akar Seledri (Apium graveolens L.) sebagai Obat Antihipertensi: Efektivitas Fraksi Etanol-Air dan Etil Asetat pada Tikus Putih Jantan Hipertensi	Siska, Armenia, Arifin H. (2011)	Root	In vivo test on 21 male Wistar Kyoto rats (250–300 g) induced hypertension with prednisone 1.5 mg/kg bw in 2.5% NaCl for 2 weeks. The rats were divided into 7 groups (3 rats/group). Root extract was obtained from 70% ethanol maceration and then fractionated with hexane and ethyl acetate. The ethanol-water fraction and ethyl acetate fraction were given doses of 20 and 40 mg/kg bw, and captopril 2.5 mg/kg bw as a comparison. TDS, TDD, TAR, and heart rate were recorded	The ethanol-water fraction contains flavonoids, while the ethyl acetate fraction contains triterpenoids and tannins.	Antihypertensive	Ethanol-water and ethyl acetate fractions significantly reduced SBP, DBP, and TAR ($P<0.05$), especially at a dose of 40 mg/kg bw. The SBP of the negative control was 184.67±7.2 mmHg, the ethanol-water fraction of 40 mg/kg bw was 158.0±7.2 mmHg, and the ethyl acetate fraction of 40 mg/kg bw was 16.83±7.2 mmHg. The TAR reduction of the ethanol-water fraction of 40 mg/kg bw was 16.04% and the ethyl acetate fraction of 40 mg/kg bw was 15.10%. Heart rate was not significantly affected ($P>0.05$). The potential hypotensive effect was comparable to captopril 2.5 mg/kg bw.

				with a Biopac System MP 150.			
9	Exploring the Effects of Celery Stem on Blood Pressure, and Associated Parameters as Social Determinants in Hypertensive Individuals: A Randomized Control Trial	Muhammad Umar Zafar, Amna Rasheed, Huda Ismail (2023)	Stem	A randomized controlled clinical trial (RCT) was conducted on 30 female subjects aged 18–45 years, divided into two groups (15 subjects/group). The control group (G0) was untreated; the treatment group (G1) was given 250 mg capsules of 70% ethanol extract of celery stalks/day for 60 days. Parameters: systolic and diastolic blood pressure, heart rate, serum electrolyte levels (Na and K).	TPC 0.31±0.07 mg GAE/g; TFC 12.58±0.21 mg GAE/g. ACE inhibitory activity 62.7±6.01 %. Contains apigenin, n-butylphthalide (NBP), sedanolide, as well as fiber, potassium, magnesium, and calcium.	Antihypertensive	In the treatment group (G1), systolic blood pressure decreased significantly from 142.98±10.86 to 123.67±12.45 mmHg (p<0.05); diastolic from 100.23±10.32 to 83.09±9.03 mmHg. Heart rate decreased from 114±2.12 to 97±1.89 beats/min. Serum sodium decreased from 277±11.10 to 243±15.02 mmol; serum potassium increased from 79±5.87 to 123±2.34 mmol. In the control group (G0) there were no significant changes. Celery stem extract effectively reduces hypertension through ACE inhibition and improvement of electrolyte balance.

Discussion

The anti-inflammatory activity of celery roots was reported by Emad et al. (2020) through an in vivo study using male Wistar rats with acetaminophen-induced hepatotoxicity. Methanolic celery root extract (MCRE) was prepared by methanol extraction, fractionated using an HP-20 column, and subsequently characterized by ultra-performance liquid chromatography–mass spectrometry (UPLC–MS). The evaluated parameters included serum levels of tumor necrosis factor-alpha (TNF-α) and interleukin-1 beta (IL-1β), liver enzyme activities (AST, ALT, and ALP), histopathological alterations, and animal survival rate.

UPLC–MS analysis identified 98 metabolites, including flavonoids (apigenin, luteolin, chrysoeriol, and their derivatives), phenolic acids (caffeic acid, ferulic acid, p-coumaric acid, and quinic acid), polyacetylenes (falcarindiol and its derivatives), phthalides, coumarins, lignans, fatty acids, and triterpenoids. Although the extract exhibited relatively lower total phenolic content (TPC) and total flavonoid content (TFC) than extracts obtained from other celery tissues, the diverse phytochemical composition produced pronounced biological effects through synergistic interactions among these metabolites (Emad et al., 2020).

Oral administration of MCRE at 100 mg/kg body weight for eight consecutive days significantly reduced TNF-α and IL-1β concentrations, restored AST, ALT, and ALP activities toward normal levels, and markedly improved hepatic histopathological architecture with minimal evidence of necrosis. Kaplan–Meier survival analysis demonstrated that all animals receiving this dose survived until the end of the experiment, whereas complete mortality occurred in the untreated control group. Interestingly, increasing the dosage to 200 mg/kg body weight resulted in reduced anti-inflammatory efficacy, indicating that higher doses do not necessarily produce greater therapeutic benefits (Emad et al., 2020).

The anti-inflammatory properties of celery roots are attributed to the synergistic actions of multiple bioactive compounds. Apigenin, luteolin, and ferulic acid inhibit cyclooxygenase-2 (COX-2), thereby reducing prostaglandin E_2 synthesis. Falcarindiol protects hepatic tissue by preventing excessive transaminase elevation, while phthalides suppress reactive oxygen species (ROS) generation and lipid peroxidation. In addition, apiin and lignans contribute to the downregulation of TNF-α and IL-1β production (Emad et al., 2020).

The anti-inflammatory activity of celery stems has been reported by Thiam et al. (2020) and Lau et al. (2021) using different experimental approaches. Thiam et al. investigated steam-distilled stem essential oil, which was chemically characterized using GC/FID and GC/MS, followed by evaluation of its inhibitory activity against the 5-lipoxygenase (5-LOX) enzyme. In contrast, Lau et al. employed an 80% ethanolic stem extract analyzed by LC–MS/MS and assessed its anti-inflammatory activity in lipopolysaccharide (LPS)-stimulated RAW 264.7 macrophages by measuring nitric oxide (NO) production.

The essential oil was composed predominantly of α-pinene (69.3%), limonene (9.5%), α-phellandrene (5.5%), and β-pinene (4.8%), together accounting for more than 89% of the total volatile constituents. The essential oil inhibited 5-LOX activity with an IC_{50} value of 29.5 ± 2.0 μg/mL, which was comparable to that of quercetin, the positive control. The authors proposed that α-pinene and limonene exert their anti-inflammatory effects by inhibiting the 5-LOX activating protein, chelating iron ions at the enzyme's catalytic site, and competitively interfering with substrate binding, thereby suppressing the biosynthesis of inflammatory mediators (Thiam et al., 2020).

In the study conducted by Lau et al. (2021), celery stem extract retained significant anti-inflammatory activity despite the absence of major flavonoids such as apigenin and apiin according to LC–MS/MS analysis. Treatment with the extract reduced nitric oxide production by approximately 1.5-fold compared with the LPS-treated group while maintaining cell viability above 90%, indicating that the observed effects were not attributable to cytotoxicity. Metabolomic profiling further demonstrated normalization of citrulline, histidine, and glucose metabolism, suggesting suppression of glycolysis and the pentose phosphate pathway, which consequently reduced NADPH availability and inducible nitric oxide synthase (iNOS) activity (Lau et al., 2021).

Although the anti-inflammatory efficacy of celery stems was lower than that of celery leaves in the latter study, both investigations consistently identified monoterpenes, particularly α-pinene and limonene, as the principal constituents responsible for stem anti-inflammatory activity through distinct molecular mechanisms (Thiam et al., 2020; Lau et al., 2021).

The antioxidant activity of celery roots has also been investigated by Emad et al. (2020) and Al Aboody (2021). Emad et al. evaluated methanolic root extract characterized by UPLC–MS and assessed its hydroxyl radical scavenging capacity using Electron Paramagnetic Resonance (EPR) spectroscopy. In addition, in vivo antioxidant activity was examined in acetaminophen-induced rats by measuring hepatic glutathione (GSH) levels and total antioxidant capacity (TAC).

UPLC–MS profiling identified 98 metabolites, including flavonoids, phenolic acids, polyacetylenes, phthalides, coumarins, lignans, fatty acids, and triterpenoids. Despite its relatively low total phenolic content, the methanolic root extract exhibited remarkably strong hydroxyl radical scavenging activity, suggesting that antioxidant capacity is mediated not only by flavonoids and phenolic compounds but also by the synergistic contributions of other metabolite classes (Emad et al., 2020).

In the EPR assay, the methanolic root extract inhibited hydroxyl radical formation by 98.45% at 0.5 mg/mL and achieved complete (100%) inhibition at 10 mg/mL. Notably, the pure methanolic fraction displayed the greatest antioxidant activity even at relatively low concentrations. In the in vivo experiment, administration of 100 mg/kg body weight significantly increased hepatic GSH and TAC levels to values approaching or even exceeding those observed in the normal control group, while maintaining a 100% survival rate. Similar to the anti-inflammatory findings, increasing the dose to 200 mg/kg body weight resulted in diminished antioxidant efficacy, indicating a dose-dependent response in which higher concentrations did not confer additional therapeutic benefits (Emad et al., 2020).

The antioxidant mechanism of celery roots has been attributed to the synergistic interactions among multiple bioactive constituents. Apiin enhances the activities of endogenous antioxidant enzymes, including superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px). Luteolin strengthens both enzymatic and non-enzymatic antioxidant defense systems, while ferulic acid functions as a potent free radical scavenger and inhibitor of lipid peroxidation. In addition, phthalides suppress the generation of reactive oxygen species (ROS), whereas falcarindiol and lignans contribute to cellular protection against oxidative damage (Emad et al., 2020).

Al Aboody (2021) further investigated the antioxidant potential of celery roots using a 70% ethanolic extract evaluated by five antioxidant assays, namely DPPH, ABTS, nitric oxide (NO), hydrogen peroxide (HPO), and lipid peroxidation (LPO). Phytochemical screening revealed the presence of flavonoids, tannins, glycosides, terpenoids, carbohydrates, and proteins, whereas saponins, steroids, alkaloids, and anthraquinones were absent. The extract exhibited IC_{50} values of 39.71 μg/mL (DPPH), 48.68 μg/mL (ABTS), 92.35 μg/mL (NO), 89.48 μg/mL (HPO), and 44.58 μg/mL (LPO). Although the antioxidant activity of the root extract was lower than that of other celery organs, the study concluded that flavonoids and phenolic acids remained the principal contributors to its antioxidant capacity (Al Aboody, 2021).

The antioxidant activity of celery stems has been investigated by Al Aboody (2021) and Liu et al. (2020). Al Aboody evaluated a 70% ethanolic stem extract using the same five antioxidant assays applied to the root extract. Phytochemical screening demonstrated the presence of tannins, saponins, flavonoids, steroids, terpenoids, alkaloids, carbohydrates, and anthraquinones. The extract exhibited IC_{50} values of 26.28 μg/mL (DPPH), 22.35 μg/mL (ABTS), 36.89 μg/mL (NO), 24.56 μg/mL (LPO), and 44.72 μg/mL (HPO), indicating greater antioxidant potency than the corresponding root extract (Al Aboody, 2021).

Liu et al. (2020) compared four celery petiole cultivars using HPLC–MS-based metabolomic profiling. The Baoqin cultivar demonstrated the highest antioxidant activity and contained abundant flavonoids, including rutin, apiin, and apigenin, together with vitamins, unsaturated fatty acids, coumarins, carotenoids, pigments, and terpenes. Partial Least Squares (PLS) regression analysis identified flavonoids as the primary contributors to DPPH radical scavenging through hydrogen atom donation, whereas vitamins and unsaturated fatty acids played major roles in superoxide radical scavenging and inhibition of lipid peroxidation (Liu et al., 2020).

Collectively, these studies demonstrate that celery stems possess substantial antioxidant activity, with flavonoids representing the major bioactive constituents responsible for this effect. The principal difference between the studies lies in their analytical approaches. Al Aboody (2021) evaluated antioxidant potency primarily through IC_{50} measurements without quantifying individual metabolites, whereas Liu et al. (2020) quantitatively correlated the concentrations of specific phytochemicals with antioxidant activity using HPLC–MS coupled with PLS regression analysis (Ahmad et al., 2023).

The antihypertensive activity of celery roots was reported by Siska et al. (2011) through an in vivo study using 21 Wistar Kyoto rats with hypertension induced by prednisone and sodium chloride. Root extract was prepared by 70% ethanol maceration and subsequently fractionated into ethanol–water and ethyl acetate fractions. Systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and heart rate were measured using the Biopac MP150 physiological recording system following carotid artery cannulation.

The experimental animals were randomly assigned to seven groups, including a normal control group, a hypertensive control group, a positive control group receiving 2.5 mg/kg body weight captopril, and treatment groups administered ethanol–water or ethyl acetate fractions at doses of 20 and 40 mg/kg body weight. Blood pressure measurements were obtained after two administrations at 15-minute intervals to evaluate the acute antihypertensive effects of celery root extract (Siska et al., 2011).

Both fractions significantly reduced blood pressure ($P < 0.05$), with the greatest effect observed at 40 mg/kg body weight. The ethanol–water fraction reduced systolic blood pressure to 158.0 mmHg, whereas the ethyl acetate fraction lowered it to 162.83 mmHg, compared with 184.67 mmHg in the hypertensive control group. Diastolic blood pressure was similarly reduced, approaching the antihypertensive efficacy of captopril. Mean arterial pressure decreased by approximately 15–16%, while heart rate remained unchanged ($P > 0.05$) (Siska et al., 2011).

The authors proposed that the antihypertensive activity of celery roots involves multiple complementary mechanisms. The ethyl acetate fraction, rich in triterpenoids and tannins, is believed to inhibit angiotensin-converting enzyme (ACE), thereby reducing angiotensin II formation and vascular constriction. Meanwhile, the ethanol–water fraction, enriched with flavonoids, provides cardioprotective effects through its antioxidant properties. Blood pressure reduction may also be associated with a diuretic effect that enhances sodium excretion, leading to decreased extracellular fluid volume and peripheral vascular resistance. Based on these findings, Siska et al. (2011) concluded that celery root fractions at their optimal dose exhibited hypotensive effects comparable to those of 2.5 mg/kg body weight captopril.

The antihypertensive activity of celery stems was subsequently demonstrated by Zafar et al. (2023) in a 60-day randomized controlled trial (RCT) involving 30 women aged 18–45 years with blood pressure values exceeding 120/80 mmHg. Participants were randomly allocated to either a control group or an intervention group receiving 250 mg/day capsules containing celery stem extract. Blood pressure, heart rate, and serum sodium and potassium concentrations were monitored weekly throughout the intervention period.

The stem extract was prepared using 70% ethanol, followed by drying and encapsulation. Phytochemical analysis revealed the presence of crude protein, dietary fiber, total flavonoids (12.58 ± 0.21 mg GAE/g), total phenolics (0.31 ± 0.07 mg GAE/g), substantial antioxidant activity, and ACE inhibitory activity of $62.7 \pm 6.01\%$. The major bioactive constituents identified included n-butylphthalide (NBP), sedanolide, and apigenin, all of which are believed to contribute to the antihypertensive effect (Zafar et al., 2023).

After 60 days of supplementation, the intervention group exhibited a significant reduction in systolic blood pressure from 142.98 ± 10.86 mmHg to 123.67 ± 12.45 mmHg, while diastolic blood pressure decreased from 100.23 ± 10.32 mmHg to 83.09 ± 9.03 mmHg ($P < 0.05$). In contrast, no significant changes were observed in the control group. Heart rate decreased from 114 to 97 beats/min, accompanied by reduced serum sodium and increased serum potassium concentrations, indicating improved electrolyte homeostasis that likely contributed to blood pressure reduction (Pari et al., 2024).

According to Zafar et al. (2023), the antihypertensive activity of celery stems involves several complementary biological pathways. First, ACE inhibition reduces the production of angiotensin II, thereby attenuating vasoconstriction. Second, apigenin exerts vasodilatory effects through calcium channel inhibition. Third, n-butylphthalide (NBP) functions as both a vasodilator and diuretic while simultaneously acting as a calcium channel blocker. Furthermore, the high potassium and magnesium contents of the extract contribute to electrolyte regulation and maintenance of normal blood pressure. Based on these findings, the authors concluded that supplementation with 250 mg/day celery stem extract for two months may serve as a safe adjunctive therapy for individuals with hypertension.

Overall, the available scientific evidence demonstrates that both celery roots and stems possess antihypertensive properties through distinct yet complementary mechanisms. The antihypertensive efficacy of celery roots is primarily supported by in vivo evidence demonstrating ACE inhibition, antioxidant activity, and diuretic effects. In contrast, celery stems are supported by clinical evidence in humans, showing significant reductions in systolic and diastolic blood pressure, improvements in heart rate, and normalization of serum sodium and potassium levels. Consequently, celery stems currently provide a higher level of evidence as a promising source for the development of antihypertensive herbal medicines, whereas celery roots require further clinical investigations to confirm their therapeutic efficacy in humans.

5. Conclusion

Based on the synthesis of scientific literature published between 2020 and 2025, the roots and stems of Apium graveolens L. exhibit considerable pharmacological potential as antioxidant, anti-inflammatory, and antihypertensive agents. These biological activities are attributed to their ability to scavenge free radicals, enhance endogenous antioxidant defense systems, inhibit pro-inflammatory mediators and enzymes, and reduce blood pressure through angiotensin-converting enzyme (ACE) inhibition, vasodilation, and diuretic mechanisms. The observed pharmacological effects are closely associated with the presence of major phytochemical constituents, including flavonoids (apigenin, luteolin, and apiin), phenolic compounds, phthalides, essential oils, coumarins, triterpenoids, and essential minerals, which act synergistically to produce these therapeutic effects. Overall, the literature indicates that celery stems provide more consistent pharmacological evidence, particularly regarding antihypertensive activity supported by clinical studies, whereas celery roots demonstrate promising therapeutic potential that still requires confirmation through additional experimental and clinical investigations. Therefore, both celery roots and stems represent promising sources of raw materials for the development of herbal medicines and phytopharmaceutical products targeting degenerative diseases.

Future research should expand the scope of literature to include more recent publications and conduct standardized experimental studies directly comparing the pharmacological activities of celery roots and stems using uniform extraction procedures, solvents, and analytical parameters to enable more objective comparisons. Furthermore, comprehensive in vivo studies and well-designed clinical trials, particularly involving celery roots, are required to strengthen the current evidence. Isolation and characterization of key bioactive compounds, such as apigenin, luteolin, and 3-n-butylphthalide, are also recommended to elucidate their individual contributions to the observed biological activities. The findings of this review are expected to provide a scientific foundation for the development of standardized herbal medicines and phytopharmaceuticals derived from celery root and stem extracts with well-defined quality standards. From a public health perspective, incorporating celery into a healthy dietary pattern may contribute to health maintenance and serve as an adjunctive approach, particularly for individuals with mild hypertension. However, its use should be undertaken responsibly and should not replace conventional medical therapy prescribed by qualified healthcare professionals.

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