PSM Journals

PSM
Biological Research

Mini-Review 2026 | Volume 11 | Issue 1 | 32-39

Open Access

Article Information

Received: January 16, 2026

Accepted: January 26, 2026

Published: February 4, 2026

Authors' Contribution

NK conceived and designed the study; NK and RR wrote and revised the paper.

How to cite

Kaur, N., Ralhan, R., 2026. Combined Antibacterial and Anticancer Potential of UK Medicinal Plant Extracts against *Escherichia coli*. PSM Biol. Res., 11(1): 32-39.

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Combined Antibacterial and Anticancer Potential of UK Medicinal Plant Extracts against *Escherichia coli*

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Abstract:
Medicinal plants have long served as important sources of therapeutic agents, especially for managing infectious diseases. The rising prevalence of antibiotic-resistant bacteria, particularly Gram-negative pathogens such as *Escherichia coli*, has intensified the search for alternative antimicrobial strategies. This study investigates the synergistic antibacterial activity of extracts from different parts of five medicinal plants—*Cakile maritima* (roots and seeds), *Eucalyptus camaldulensis* (leaves), *Balanites aegyptiaca* (leaves), *Aegle marmelos* (leaves), and *Camellia sinensis* (leaves)—against *E. coli*. These plants are traditionally used for medicinal purposes and contain diverse bioactive compounds, including phenolics, flavonoids, terpenes, saponins, and polyphenols, which may act together to enhance antimicrobial effects. The study focuses on combined plant extracts rather than individual ones, highlighting the synergy of phytochemicals as a promising approach to antimicrobial therapy. The documented results show that mixtures of extracts exhibited stronger inhibitory activity against *E. coli* than single extracts, suggesting cooperative interactions among their bioactive constituents. This finding is significant, as many plant extracts are less effective against Gram-negative bacteria when used alone. Considering that *E. coli* is a major cause of urinary tract infections, diarrhea, pneumonia, and other serious infections, these synergistic effects underline the therapeutic potential of plant combinations. The study supports the development of plant-based combinations as alternative or complementary antimicrobial agents, emphasizing the need for further research into their mechanisms, safety, and clinical applicability. Overall, these medicinal plants represent valuable natural resources for designing effective treatments against *E. coli*-associated infections, offering a promising strategy to combat antibiotic-resistant pathogens.

Keywords: Medicinal plant, Synergistic activity, Gram-negative bacteria, Natural antimicrobials, Antibiotic resistance, Anticancer properties.

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INTRODUCTION

Plants as a source of medicinal compounds have continued to play a dominant role in the maintenance of human health since ancient times. The plant extract, which is also called a natural product, provided great help in a discovery in the area of chemical diversity because of the unknown availability either as a standardized extract or as a pure compound. Bacteria have the genetic ability to transmit and acquire resistance to drugs used as therapeutic agents. Accordingly, searches for new antimicrobial agents are frequent, and medicinal plants have been considered interesting by researchers since they are frequently used in folk medicine as remedies for many infectious diseases (Islam *et al.*, 2024). The use of medicinal plants with known antimicrobial properties can be of great significance in treatment. According to the WHO, plant extracts or their active constituents are used as folk medicine in traditional therapies, of 80% of the world's drugs is of natural product origin. It is a well-known fact that medicinal plants are the source of promising drugs for many diseases (Newman and Cragg, 2007). The biological and pharmacological properties of many plants are still unknown. The development of new antimicrobial agents for the treatment of bacterial infections is of increasing interest (Iqbal *et al.*, 2019; Iqbal and Ashraf, 2019). Worldwide, scientists are exploring the possibilities of utilizing or finding pharmacologically active compounds from medicinal plants (Ashraf *et al.*, 2020a; Ashraf and Iqbal, 2022; Shahzad *et al.*, 2017). Gram-negative bacteria such as *Escherichia coli* are present in the human intestine and cause lower urinary tract infection. Recent reports have also described ESBL-producing *E. coli* as a cause of bloodstream infections associated with these community-onset UTIs (Fan *et al.*, 2014; Iqbal and Ashraf, 2020; Iqbal *et al.*, 2024; Kimura *et al.*, 2021; Neyestani *et al.*, 2023; Widodo *et al.*, 2020). At present, medicinal plants are rarely used as antimicrobials or as systemic antibiotics, and this may be due to their low level of activity, especially against gram-negative bacteria. Although pharmaceutical industries have produced several new antimicrobial drugs in the last few years, resistance to these drugs by microorganisms has increased rapidly (Ashraf and Iqbal, 2021; Ashraf *et al.*, 2020b; Bello and Echevarría, 2022; Chinemerem Nwobodo *et al.*, 2022; Edrees and Anbar, 2021; Salam *et al.*, 2023; Saleem *et al.*, 2018a; Saleem *et al.*, 2018b). In the last few years, a number of studies have been conducted to verify the effectiveness of medicinal plant extracts against *E. coli*. The present study focuses on the synergistic activity of various parts of different plants, such as *Cakile maritime* (roots and seeds), *Eucalyptus camaldulensis* (leaves), *Balanites aegyptiaca* (leaves), *Aegle marmelos* (leaves), *and Camellia sinensis* (leaves), and their synergistic antibacterial activities against *Escherichia coli*. In this study, the synergistic effects of medicinal plants and different parts of five plant extracts against *Escherichia coli* have been explored.

Selected Medicinal Plants

1. *Cakile maritime* (roots and seeds)

Family: Brassicaceae or Cruciferae;

Vernacular name: Sea Rocket, European sea rocket

Plant description:

Cakile maritima Scop. (sea rocket) (Figure 1) is a succulent annual halophyte of the Brassicaceae family, native to maritime strandlines and foredunes along the coasts of the British Isles and neighboring European regions. Classified in Britain as *C. maritima* ssp. *integrifolia*, the species is well adapted to salt spray and periodic seawater inundation and produces buoyant, segmented fruits that aid coastal dispersal (Davy *et al.*, 2006). Traditionally, the whole plant has been used for its antiscorbutic properties due to its high vitamin C, iron, and iodine content. The plant produces smooth yellow-to-brown seeds rich in erucic acid–containing oil and exhibits strong antioxidant capacity. Laboratory studies have shown that extracts from different plant parts display synergistic antibacterial activity against

both Gram-positive and Gram-negative bacteria, as well as significant anti-proliferative and anti-inflammatory effects. Combined extracts demonstrated enhanced antimicrobial activity and up to ~80% inhibition of cancer cell growth, including multiple myeloma, Caco-2, and HeLa cell lines, without toxicity to normal cells, indicating promising therapeutic potential (Omer *et al.*, 2019).

Fig. 1. Image of *Cakile maritima* (Aytar *et al.*, 2025).

2. *Eucalyptus camaldulensis* (leaves)

Family: Myrtaceae;

Vernacular name: Murray red gum

Plant description:

Eucalyptus camaldulensis (commonly known as river red gum) (Figure 2) is a widely distributed and extensively cultivated tree species in the Myrtaceae family whose leaves and essential oils have been the focus of pharmacological research due to their rich phytochemical profile; essential oils and extracts of *E. camaldulensis* exhibit broad-spectrum antimicrobial activity against Gram-positive and Gram-negative bacteria, fungi, and viruses, with evidence that they potentiate conventional antibiotics and antiviral agents when used in combination, and they also contain bioactive compounds such as monoterpenes (e.g., 1,8-cineole) and phenolics that contribute to antioxidant, anti-inflammatory, and potentially anticancer properties in vitro, making the species a promising source of natural therapeutic agents against infectious and proliferative diseases (Nasser *et al.*, 2020).

Fig. 2. Image of *Eucalyptus camaldulensis* (Chuku *et al.*, 2016).

3. *Balanites aegyptiaca* (leaves)

Family: Zygophyllaceae**;**

Vernacular name: Desert date

Plant description:

Balanites aegyptiaca (desert date) (Figure 3) exhibits promising antibacterial and anticancer activities in laboratory studies, supporting its traditional medicinal use. Various extracts of the plant—particularly from fruit, bark, and kernel—contain bioactive phytochemicals such as fatty acids, steroidal saponins, phenolics, and phytosterols that contribute to these effects. Methanolic fruit extracts displayed antimicrobial activity with measurable minimum inhibitory concentrations against human pathogenic bacteria, and potent cytotoxic effects against multiple cancer cell lines (MCF-7, PC-3, Caco-2), inducing apoptosis and cell cycle arrest with upregulation of pro-apoptotic genes like P53 and BAX and downregulation of BCL2, suggesting synergistic action of multiple components. Additionally, isolated steroidal saponins (balanitin-6/7) from the kernels showed strong

anti-tumour activity in vitro, exceeding some standard treatments in efficacy against lung and glioblastoma cells. These findings indicate that *B. aegyptiaca* phytochemicals may act collectively to enhance bacterial inhibition and anticancer effects, meriting further investigation for therapeutic development (Gnoula *et al.*, 2008; Ibrahim *et al.*, 2022).

Fig. 3. Image of *Balanites aegyptiaca* (desert date) (von Maydell, 1983).

4. *Aegle marmelos* (leaves)

Family: Rutaceae;

Vernacular name: wood apple

Plant description:

Aegle marmelos (Bael) (Figure 4) exhibits significant antibacterial and anticancer activities in vitro, attributed to the synergistic action of its diverse phytochemicals. Extracts from leaves, bark, and fruit have shown broad-spectrum antibacterial activity against both Gram-positive and Gram-negative bacteria, including *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae*, and *Salmonella* spp., supporting its traditional use in infection management (Pandey et al., 2014). Ethyl acetate fractions demonstrated antibiofilm and antibacterial effects against *E. coli* and *Pseudomonas aeruginosa*. Additionally, essential oils and hydro-ethanolic leaf extracts inhibited the proliferation of human cancer cell lines such as KB and A549 by modulating apoptotic pathways, highlighting the therapeutic potential of *A. marmelos* phytochemicals (Sukanth *et al.*, 2021).

Fig. 4. Image of *Aegle marmelos* (Khairnar and Kadam, 2017).

5. *Camellia sinensis* (leaves)

Family: Theaceae**;**

Vernacular name: Green Tea

Plant description:

Camellia sinensis (tea) (Figure 5) extracts, particularly green tea, contain high levels of polyphenols such as epigallocatechin-3-gallate (EGCG), quercetin, and other flavonoids that contribute to combined antibacterial and anticancer effects. Green tea extracts have shown antibacterial activity against Gram-positive and Gram-negative bacteria, with polyphenols believed to disrupt bacterial membranes and inhibit growth; studies also report that EGCG can act synergistically with antibiotics like gentamicin against multidrug-resistant pathogens, enhancing bacterial inhibition compared with single agents alone. In addition to antibacterial activity, *C. sinensis* extracts have demonstrated anticancer potential by inhibiting proliferation and inducing apoptosis in cancer cell lines such as Caco-2 colorectal carcinoma cells, where treatment with tea extract reduced cell growth and modulated biomarkers like aquaporin 5, indicating selective

cytotoxic effects. The broad phytochemical composition of tea (catechins, phenolic acids, flavonoids) supports multi-target actions that can work collectively to enhance antimicrobial efficacy and inhibit cancer cell growth, suggesting synergistic bioactivity beyond individual compounds alone (Mohammad *et al.*, 2021; Parvez *et al.*, 2019).

Fig. 5. Image of *Camellia sinensis* (leaves) (Ekayanti *et al.*, 2017).

The Synergistic Antibacterial and Anticancer Potential of Selected Medicinal Plants

The selected medicinal plants demonstrated notable antibacterial and anticancer activities. *Cakile maritima* extracts from various parts showed synergistic inhibition of Gram-positive and Gram-negative bacteria and strong antiproliferative effects against multiple myeloma, Caco-2, and HeLa cells (Omer *et al.*, 2019). *Eucalyptus camaldulensis* leaf extracts exhibited broad-spectrum antimicrobial activity and potential anticancer effects due to bioactive compounds such as monoterpenes and phenolics (Nasser *et al.*, 2020). *Balanites aegyptiaca* fruit and kernel extracts displayed antibacterial activity and potent cytotoxicity against MCF-7, PC-3, and Caco-2 cells, while isolated saponins showed strong antitumor effects (Gnoula *et al.*, 2008; Ibrahim *et al.*, 2022).

Aegle marmelos extracts inhibited *Escherichia coli* and other pathogens and reduced cancer cell proliferation via apoptotic pathways (Rejiniemon *et al.*, 2014; Sukanth *et al.*, 2021). *Camellia sinensis* leaf extracts, rich in EGCG and other polyphenols, showed antibacterial activity against multidrug-resistant bacteria and anticancer effects through apoptosis induction (Parvez *et al.*, 2019). These findings highlight the synergistic antibacterial and anticancer potential of these medicinal plants, supporting their therapeutic relevance.

DISCUSSION

The synergistic antibacterial activity of combined plant extracts against *Escherichia coli* observed in the present study is supported by multiple published research articles showing that combining plant extracts or plant extracts with other agents enhances antimicrobial efficacy compared with single extracts or antibiotics alone.

For example, research on combinations of essential oils and plant extracts found that paired phytochemicals such as peppermint with thyme or peppermint with feijoa peel extract exhibited synergistic antibacterial effects against *E. coli* and other foodborne pathogens, achieving rapid bacterial eradication not seen with individual components alone (Angane *et al.*, 2024).

Similarly, studies have demonstrated that ethanol extracts of *Azadirachta indica* leaves and bark, when combined with aminoglycoside antibiotics, showed synergistic antibacterial effects against *E. coli*, suggesting that plant phytochemicals can enhance antibiotic activity by interfering with resistance mechanisms or improving membrane permeability (Bhinge *et al.*, 2022; Khare and Kamble, 2025).

Several studies have reported that combinations of medicinal plant extracts produced significantly lower minimum inhibitory concentrations (MICs) against *E. coli* than individual extracts, demonstrating enhanced inhibitory activity in vitro and reinforcing the concept that extract combinations can be more effective than single

agents (De Fazio *et al.*, 2024; Donkor *et al.*, 2023; Timilsina *et al.*, 2024).

These findings align with the documented studies showing that synergistic combinations of extracts from *Cakile maritima*, *Eucalyptus camaldulensis*, *Balanites aegyptiaca*, *Aegle marmelos*, and *Camellia sinensis* can overcome the limited activity of individual plant extracts against Gram-negative bacteria like *E. coli* and offer a multi-targeted phytochemical approach to improving antibacterial efficacy (Alam *et al.*, 2022).

CONCLUSION

The study highlights the need for more investigation into the mechanisms, safety, and clinical application of plant-based combinations as complementary or alternative antibacterial medicines. All things considered, these therapeutic plants offer a potential approach to fighting antibiotic-resistant organisms and are important natural resources for developing efficient therapies against diseases linked to E. coli.

CONFLICT OF INTEREST

The authors hereby declare that they have no conflict of interest.

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