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# Exploring the preservation potential of *Ficus* spp.: Bioactive compounds and their functional roles in food systems

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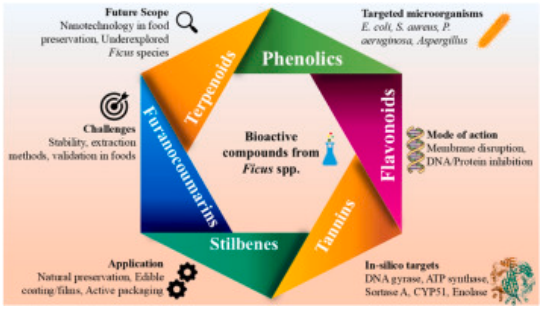
## Abstract

Food safety and shelf life are critical factors for human health and are greatly impacted by microbial spoilage. Despite the widespread use of synthetic preservatives, interest in natural alternatives has grown due to their possible health risks. The plant bioactives as natural alternatives are being explored for extending shelf life of food either via direct addition or in terms of edible coating and packaging films. The *Ficus* spp., having a great ethnobotanical importance, have been used for a long time in traditional medicine. Its rich phytochemical profile exhibits a strong antimicrobial and antifungal property to combat various food-spoilage microorganisms, such as *Escherichia coli, Staphylococcus aureus*, *Pseudomonas* spp., *Candida albicans*, *Aspergillus flavus*, and *Penicillium expansum*. The latex based edible coatings from *Ficus* spp. have shown real-food utility by extending the shelf life and enhancing the quality of dried fruits. The packaging film incorporated with *Ficus carica* leaves extract preserved the quality of apple slices. The addition of its aqueous leaf extract into the milk extends shelf life of pasteurized buffalo milk from 5 to 16 days without altering its properties. Despite the potential antimicrobial effects many of the *Ficus* plants such as *Ficus virens*, *Ficus palmata, Ficus auriculata,* and *Ficus benghalensis* still have not explored in food packaging or food preservation. These challenges can be addressed via various interdisciplinary approaches such as metabolomics, pharmacology, nanotechnology, and computational biology. Additionally, compound stability, standardization, and widespread utilization are some of the research gaps that need to be discussed.

## Graphical abstract

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## Introduction

Food waste is becoming a major challenge in the food system with around 6.25 million tons waste reported in 2024 (Food waste by country 2025). In a food chain, the food loss and waste are influenced by various factors which also includes post-harvest processing, handling, transport, storage and packaging (Karanth et al., 2023). These factors can not only reduce the nutritional quality of food but also leads to food spoilage and shortened shelf-life (Sun et al., 2025a, Sun et al., 2025b). Food spoilage and shelf-life are majorly influenced by various factors such as chemical reactions (5%), packaging quality (10%), oxidation quality (10%), Temperature influence (20%), moisture content (15%), and microbial growth (30%) (Shehzad, 2025). Microbial food spoilage due to bacteria, yeasts, and fungi alters the sensory characteristics and reduce nutritional quality of food (Karanth et al., 2023; Snyder et al., 2024). To ensure the sensory and nutritional properties of food via preservation is an important factor (Mafe et al., 2024). In ancient times salting, drying, and smoking are some methods used for the preservation of food which extended to the novel methods such as packaging, refrigeration and chemical preservatives (Muthuvelu et al., 2023). The present methods of preservation mainly rely on the chemical preservative such as salts of sodium benzoate (E211), acetic acid, nitrites (E249, E250), sorbic acid etc. These preservatives have a strong effect but also raises health concerns on excessive usage (Olatunde & Benjakul, 2018; Rathee et al., 2023). For instance, sorbic acid reported to inhibit beneficial probiotic microbes, while disrupting gut microbiota and immune functions. Similarly, excessive intake of nitrates and nitrites intake is linked with cardiovascular diseases, while processing of sodium nitrites at high-temperature can cause cancer. Moreover, sulfites are reported in the nutrient degradation (Dong et al., 2024).

The rapid consumer awareness forced industry to look for natural alternatives which are generally recognized as safe (GRAS) (Nieto et al., 2023). The main sources of these natural alternatives are plant-based compounds such as raw herbs/spices, vegetable and fruits. The plant-based alternatives are well known for their antioxidant, anti-inflammatory, anticancer, neuroprotective, hepatoprotective, antidiabetic properties along with their promising results in the inhibition of various microorganisms (Chen et al., 2025; Wang et al., 2022; Wu et al., 2024; Zhang, Wang, et al., 2024). The plant bioactive compounds are able to target various active sites of a wide range of microorganisms (Selahvarzi et al., 2021), which can be due to the synergistic or antagonistic effects. For instance, the synergistic effect of gallic acid, coumaric acid, and chlorogenic acid was reported to inhibit the growth of *Staphylococcus aureus* (MIC of 0.625 μg/mL) by disrupting the cell membrane integrity. Whereas, ferulic acid (1.1 mg/mL), caffeic acid (62.5 μg/mL) was reported to inhibit the growth of *S. aureus*, and *Listeria monocytogenes* by disrupting the cell membrane integrity or inhibiting the energy metabolism. Comparing this data from the study of Seo et al. (2023) it can be said the MIC of these bioactive compounds is significantly effective as various synthetic preservatives. Hence, these bioactive can be utilized to protect food quality in terms of nutrient loss, spoilage and oxidative degeneration (Khezrian & Shahbazi, 2018).

Various plant sources such as garlic, clove, oregano and rosemary are widely renowned for their preservative potential (Teshome et al., 2022). In this context, genus *Ficus* offers a unique potential due to its rich diversity of bioactive compounds with multipurpose applications. Unlike many commonly studied herbs and spices for their preservation potential *Ficus* genus holds combined potential in terms of traditional medicinal values with broad-spectrum antimicrobial, antioxidant and anti-inflammatory properties (Deepa et al., 2018; Pękala-Safińska et al., 2021; Walia et al., 2022). Plant in this genus were reported to contain many bioactive including gallic acid, ferulic acid, p-coumaric acid, quercetin, kaempferol, catechin, tannic acid, proanthocyanidins, and psoralen which show inhibitory properties for various food spoiling microorganisms such as *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* (Cruz et al., 2022; Hegazy et al., 2023; Kumar et al., 2021; Ma et al., 2024; Pinto et al., 2023). Similarly, the flavanone pinocembroside obtained from the fruit of *Ficus hirta* Vahl was reported to inhibit the growth of blue mold (*Penicillium italicum*) in oranges (Chen et al., 2020). Furthermore, the utilization of *Ficus carica* as an alternative to synthetic preservative was recommended by Bankefa et al. (2019). Moreover, interdisciplinary approaches such as metabolomics, pharmacology, nanotechnology, and computational biology are crucial for exploring the full potential of this species.

This review critically examines the antimicrobial potential of *Ficus* spp. for the possible utilization in food systems. The primary objective of this review is to explore its preservative application in terms of improvement of shelf-life and nutritional quality of the food while addressing consumers' growing concerns about synthetic food preservatives and the associated health risks.

## Section snippets

## Major food-spoiling organisms

Food spoilage is majorly caused by microorganisms, however the particular microbe in any food can vary depending upon the type of food and storage conditions. For instance, the high moisture in food including seafood or milk is majorly spoiled by bacteria whereas the stable food is mainly spoiled by yeasts or molds (Odeyemi et al., 2020). Moreover, bread develop mold due to *Rhizopus nigricans* and *Penicillium* spp., or get spoiled due to *Bacillus subtilis*, whereas pickles are spoiled by …

## Bioactive compounds in *Ficus* spp.

The metabolic profiling of *Ficus* genus reveals the presence of various phytocompounds including phenolics, flavonoids, anthocyanins, carotenoids, organic acids, triterpenes, steroids, sugar fatty acids, and many others which are not limited to one part of the plant. Phenolics compounds are significant secondary metabolites and play crucial roles in various health promoting effects. *Ficus* genus is reported to contain a high number of phenolic compounds (Walia et al., 2022). Cruz et al. (2022) …

## Effect of various *Ficus* species on food-spoiling microbes

*Ficus* species have potential that goes beyond a single plant part; it has been reported that different parts of *Ficus* plants, such as fruits, leaves, bark, and latex, have activity against microorganisms responsible for the spoilage of food (Table 3). …

## In silico targets of bacterial and fungal pathogens

In silico studies have emerged as a potential tool for predicting the molecular interactions between bioactive compounds and their targets. This kind of study provides various insights into the potential of these compounds (Olğaç et al., 2017). Numerous bacterial and fungal enzymes have been investigated in recent years, with encouraging findings as a potential therapeutic target for preventing the growth of the targeted microorganisms. For example, PqsR (PDB ID: 6B8A ↗) and LasR (PDB ID: 3IX3 ↗) …

## Proposed research questions and challenges

Despite the progressive work on *Ficus* species as natural preservatives, there are various problems to be studies for their safer applications. The usage of bioactive compounds in any food system comes with various challenges including effects on health and environment, their stability, sustainability, cost effectives, availability of samples (Novais et al., 2022). The stability and suitability of the compounds is also influenced by the types and characteristics of the food. The synergistic or …

## Conclusion

As consumer demand shifts toward natural, clean-label ingredients, the development of safe, efficient and sustainable food preservatives continues to be a top research priority. Rich in bioactive substances like polyphenols, flavonoids, and terpenoids, *Ficus* species have shown strong antimicrobial and antifungal properties in a variety of plant parts, including latex, leaves, fruits, and bark. These characteristics make them excellent choices for applications involving natural food …

## CRediT authorship contribution statement

**Saurav Chandra Bhatt:** Writing – review & editing, Writing – original draft, Visualization, Formal analysis. **Vijay Kumar:** Writing – review & editing, Writing – original draft, Visualization, Validation, Formal analysis, Conceptualization. **Bindu Naik:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Formal analysis, Conceptualization. **Arun Kumar Gupta:** Writing – review & editing, Writing – original draft, Validation. **Devvret Verma:** Writing – review & …

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. …

Special issue articles

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