LIFE Science Hub
JOURNAL OF SCIENCE
EXPANDING KNOWLEDGE ABOUT NUTRITION AND HEALTH

ORIGINAL RESEARCH
Volume 1, Issue 4, November 2026

Syzygium aromaticum essential oil and antimicrobial activity: 2024 review results

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1. ABSTRACT

This publication examines the available evidence on the antimicrobial activity of the essential oil of *Syzygium aromaticum*, which is rich in eugenol. It primarily gathers data obtained from laboratory studies on bacteria, fungi, and parasites, clarifying the potential biological mechanisms and the gap that still exists before it can be considered for proven therapeutic use in humans.The authors' summary describes the essential oil from *Syzygium aromaticum* buds as a mixture of volatile substances, in which eugenol is typically the most abundant component. The practical implication is that the observed activity does not necessarily depend on a single molecule: eugenyl acetate, beta-caryophyllene, and alpha-humulene may also contribute to the overall result. The review reports effects against Gram-positive and Gram-negative bacteria, yeasts, fungi, and *Giardia lamblia*, an intestinal protozoan. In many experiments, the oil or eugenol slowed microbial growth. The most frequently cited mechanism involves the microorganism's cell membrane: lipophilic substances—those with an affinity for fats—can alter its function and promote the leakage of internal components. Some studies also report a reduction in the initial formation of biofilms, which are adherent microbial communities that are more difficult to control. However, the authors emphasize that most of the evidence is derived from cell cultures and microbiological tests. These data indicate biological potential but do not demonstrate clinical efficacy, appropriate dosages, or therapeutic safety for human infections.

ONLINE ARTICLE

ARTICLE INFORMATION

Published: November 15, 2026
Updated: November 15, 2026

DOI 10.5281/zenodo.24256506

KEYWORDS

olio essenziale di Syzygium aromaticum attività antimicrobica
eugenolo attività antimicrobica in vitro
olio di garofano composizione eugenolo
azione antimicrobica del garofano
olio essenziale contro batteri e funghi
eugenolo membrana microbica

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Free from political, industrial and commercial influence, the journal stands as an authoritative and independent editorial space, dedicated to promoting scientific culture, professional development and the growth of health awareness among the public.

2. WHAT THIS RESEARCH ANALYZED

This publication is a narrative review, meaning it is a reasoned reading of previously published studies rather than a new experiment on patients. Maggini and colleagues have reconstructed what research shows regarding the essential oil obtained from *Syzygium aromaticum* and its components. The primary interest concerns its ability to limit the growth of microorganisms associated with human infections.The authors discuss bacteria such as *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Porphyromonas gingivalis*; they also report data on *Candida* and *Giardia lamblia*. The minimum inhibitory concentration, or MIC, indicates the lowest amount that prevents visible growth in a culture. It is a useful measure for comparing laboratory tests, but it does not establish an effective or safe dose in the human body.

3. WHAT RESULTS EMERGE FROM THE STUDY

The core biological message is that the essential oil can hinder certain microorganisms when it comes into direct contact with them. The proposed explanation is primarily physical: lipophilic molecules can insert themselves into the microbial membrane, altering its function and promoting the leakage of cellular material.From a chemical perspective, eugenol is described as the dominant constituent, often alongside eugenyl acetate, beta-caryophyllene, and alpha-humulene. However, the review highlights that the whole oil may behave differently than isolated eugenol. This suggests possible interactions between components, but it does not prove that such interactions produce a clinical benefit.The results appear to vary between microbial species. Gram-negative bacteria possess an additional outer membrane and, in several tests, prove to be less sensitive. Biofilms that have already formed also tend to be more difficult to reduce compared to initial adhesion. The next step, therefore, concerns the practical value of these differences.

4. WHY THIS STUDY IS RELEVANT

This review is useful because it separates two levels that are often confused: antimicrobial activity measured in a test tube and the treatment of an infection. Experimental results make it plausible to study local formulations, for example for oral use or for surfaces, but they do not authorize the replacement of antibiotics, antifungals, or medical evaluations.The work also clarifies that the oil's profile is not fixed. Distillation, plant variety, and the part of the plant used can change the proportions of the compounds. Therefore, it is incorrect to automatically transfer the MIC of an oil analyzed in a laboratory to any commercial product or to the spice used in cooking.

5. STUDY LIMITATIONS AND WHAT IT DOES NOT DEMONSTRATE

The main limitation is the type of evidence examined. The majority of the included studies use cultured microbial strains, controlled concentrations, and short exposure times. Within the body, absorption, metabolism, tissues, secretions, and the presence of organic material can profoundly change the observed activity.The publication does not provide sufficient clinical evidence to state that the essential oil prevents or treats infections in people. It also does not define a therapeutic dosage, an appropriate route of administration, or a safety profile valid for self-medication. Concentrated essential oil is not equivalent to the buds used as a spice.

6. INDEPENDENT CONFIRMATORY EVIDENCE

Experimental research by Teles and colleagues supported the initial step of the chain, from the oil's composition to the bacterial response. In cultures of Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa, the oil and eugenol showed antibacterial activity; against S. aureus, the oil had a MIC of 50 micrograms/mL, lower than that of isolated eugenol, which was 250 micrograms/mL. This data is directly consistent with the hypothesis of a contribution from the phytocomplex, but it remains an in vitro experiment [1].In the oral context, Zhang and colleagues observed that eugenol and Syzygium aromaticum leaf oil reduced the viability of Porphyromonas gingivalis and interfered with the initial stages of biofilm formation. This supports the membrane-microbial response pathway, with direct relevance but without human participants and without clinical outcomes [2]. Chaieb and colleagues

also documented the antifungal activity of the oil against numerous clinical isolates of Candida. The isolates were derived from people, but the test was still conducted outside the organism: the confirmation is therefore biologically relevant, not therapeutic [3].

7. CONFLICTING EVIDENCE

Somrani and colleagues confirm that eugenol-rich oil can hinder *Listeria monocytogenes* and *Salmonella Enteritidis*, but they highlight an important limitation: the effect on already mature biofilms was lower compared to blocking initial adhesion. After one hour at the MIC, the reduction of preformed biofilm was 30.2% for *Listeria* and 20.3% for *Salmonella*. This result scales back the idea of a uniform action on biofilms and concerns food environments, not human infections [4].Another study on *Candida* found antifungal activity, but also cytotoxicity of the oil and eugenol on human cell lines at concentrations lower than the MICs reported for some strains. In the *Galleria mellonella* larva model, no acute toxicity emerged up to 10 mg/mL, but this does not equate to safety in humans. The discrepancy therefore concerns the margin between antimicrobial activity and tolerability [5].No directly conflicting evidence of sufficient relevance was identified; this does not prove the absence of contrary results.

8. QUADRO COMPARATIVO E SINTESI DELLE EVIDENZE

The following publications help compare the review's narrative with independent experimental data.

Quadro comparativo

Publication	Model and main result	Relationship to the study	Interpretative limitation
Teles et al., 2021 [1]	Cultures of three bacterial species; activity of the oil and eugenol, with greater sensitivity of S. aureus.	Direct confirmation of in vitro activity and the possible role of the mixture.	No clinical data.
Zhang et al., 2017 [2]	Porphyromonas gingivalis in vitro; reduction of growth and initial biofilm formation.	Direct confirmation in an oral pathogen.	Does not evaluate patients or periodontitis.
Chaieb et al., 2007 [3]	Clinical Candida isolates evaluated in the laboratory; antifungal activity of the oil.	Direct confirmation of antifungal plausibility.	Human isolates are not equivalent to human treatment.
Somrani et al., 2022 [4]	Listeria and Salmonella; strong effect on adhesion, more limited on mature biofilms.	Downsizes the extent of the anti-biofilm effect.	Food environment, not clinical.
Vasconcelos et al., 2024 [5]	Candida, human cell lines, and larvae; antifungal activity with signs of cellular cytotoxicity.	Highlights the critical relationship between experimental efficacy and safety.	Preclinical models without clinical trials.

9. SINTESI EDITORIALE E CONCLUSIONI

EDITORIAL CONCLUSION

The review by Maggini and colleagues describes the essential oil of Syzygium aromaticum as a mixture rich in eugenol with antimicrobial activities observed primarily in laboratory settings. The collected data are consistent with a direct action on the membranes of certain bacteria, fungi, and protozoa. Independent studies confirm that the oil or eugenol can reduce microbial growth and interfere with the initial adhesion of some biofilms. However, the effect is not identical for every species, formulation, or biofilm stage. Furthermore, concentrations active against microorganisms may also be relevant to human cell tolerability. The body of evidence therefore supports biological plausibility and interest in further controlled formulations, rather than a proven

therapeutic use. The food spice, the essential oil, and purified eugenol represent different types of exposure. For applications regarding infections, clinical evaluation remains essential.

Aggiornato al 17/11/2026. Questo contenuto riflette una sintesi divulgativa delle evidenze scientifiche al momento della pubblicazione e non sostituisce il parere medico.

10. TRANSPARENCY AND SCIENTIFIC RESPONSIBILITY

Artificial Intelligence was used solely as a tool for editorial and documentary support. All content, interpretations, bibliographic citations and conclusions have been verified, reviewed and approved by the author, who assumes full scientific responsibility for them.

The manuscript was also subjected to independent peer review prior to publication.

To ensure the greatest transparency, the complete history of the article, including the dates of submission, revision, acceptance and publication, as well as information on the peer review process, is available on the dedicated Article History page.

11. RIFERIMENTI BIBLIOGRAFICI

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