Review on antimicrobial mechanisms of spices-essential oil constituents.

Mangamma Boya, Soni Komal Laxman, Yugesh Kannth N, Sundara Barathi K, Naveen Saji, Nethavath Akesh, Prateek Ekbote, Usha Amane, Jeepipalli Syam PK*

Department of Skill Development Cell (Food Processing), Central University of Karnataka, Kadaganchi, Aland Road, Kalaburagi District, Karnataka, India

Abstract

Spices have been employed as a flavoring and coloring agents. Essential oils of spices have wide antimicrobial functions. Specific constituents of the essential oils inhibit the synthesis of bacterial cell division proteins, cell membrane depolarization, decrease adenosine triphosphate and disturbing the ionic equilibrium. In the fungal species, the constituents of essential oils decrease the ergosterol synthesis interact with delta-14-sterol reductase, affecting mitochondrial enzymes and accelerating the telomere shortening. Present review discussed the antibacterial and antifungal mechanisms of spices 'essential oil constituents'.

Keywords: Spices, *Cinnamomum cassia*, *Ocimum basilicum*, Antimicrobial, Essential oil.

Introduction

Plants contain numerous chemical components with different biological functions. Aromatically scented herbal products have been used since ancient times to flavor foods. The species of *Cinnamomum cass*ia or Chinese cinnamon, C. *verum* or true cinnamon contain the spice ingredients in their inner bark. Cinnamon barks essential oils containing cinnamaldehyde as an antibiotic ingredient. The seeds of *Thymus vulgaris* or German thyme and *Trachyspermum ammi* or bishop's weed contain essential oils that possess thymol as an antibiotic molecule. Bishop's weeds are widely used in food products due to its pleasant flavor and preservative properties. Cumin or *Cuminum cyminum* contains β-pinene as an active antimicrobial monoterpene. Linalool is an acyclic monoterpene alcohol and antibiotic found in *Ocimum basilicum* plants. The essential oils of *Anethum graveolens* seeds containing carvone and limonene as antibiotic molecules. *Trans*-anethole is an antibiotic molecule found in the fruit essential oils of *Pimpinella anisum* L species. These different plant origin antibiotic molecules have potent inhibitory functions of bacterial species and fungal variants. The present review discusses the antimicrobial mechanisms alone from the selected research articles as part of our academic project, semester-V and subject code: BFP508S in B.Voc. Food processing programme.

Cinnamaldehyde

All bacterial species have a conserved cell division marker termed Filamentous temperature -sensitive protein Z (FtsZ) in the cytoplasm. Bacterial cytokinesis is mediated through the formation of a Z ring that contains the FtsZ of the cell wall component. The formed Z ring associates with other cell division proteins and contracts gradually for the closure of septum and formation of two daughter bacteria cells [1-3]. Cinnamaldehyde inhibits the bundling of FtsZ protofilaments in the Z ring and exerts antimicrobial response in the bacterial species [4,5]. Cinnamaldehyde interfere with the mechanisms of expression of cell wall construction genes which further lead to the damage of cell wall permeability and integrity *Geotrichum citri-aurantii* [6]. Cinnamaldehyde as a component is damaging the cell wall integrity by inhibiting the ergosterol content [7], membrane invaginations, elevating the levels of reactive oxygen species, destruction of organelles and disorganization and leakage of cytoplasm in the fungal spores of *P. expansum* or blue mold decay fungi [8]. Cinnamaldehyde inhibits the spore germination, mycelial growth and fungal biomass production in *A. flavus* by reducing the ergosterol synthesis, mitochondrial membrane potential, elevating Ca^{2+} levels, reactive oxygen species, release of cytochrome c, activation of metacaspase, phosphatidylserine externalization and DNA damage [9]. Trans form of cinnamaldehyde changes the cell membrane permeability in *P. italicum* causing the leakage of cell material [10]. Cinnamaldehyde influences the function of fungal mitochondria by inhibiting the activity of ATPase and SDHase [11].

Thymol

Thymol 2-isopropyl-5-methylphenol is a monoterpene plant compound. Different candida species are susceptible with mean diameter of inhibition zone between 15-21 mm [12]. Thymol and carvone compounds are toxic for the growth of 12 different fungal strains at its lowest concentrations [13]. Phenols located in the ring structure are the vital cause for antifungal activity [14]. Thymol accelerates telomere shortening in the

***Correspondence to:** Jeepipalli Syam P.K. Skill Development Cell (Food Processing), Central University of Karnataka, Kadaganchi, Aland Road, Kalaburagi District, Karnataka, India, E-mail: syamsvu@gmail.com

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yeast and increases the rate of cell senescence and apoptosis [15]. Intracellular Ca+2 ions homeostasis, glycan-mediated post-translational modifications and the levels of endogenous ergosterol content was significantly decreased in the thymol treated *Cryptococcus neoformans* [16]. Furthermore, thymol treatment reduced endogenous ergosterol content by decreasing the expression of ergosterol biosynthesis genes in a high-osmolarity glycerol (HOG) - mitogen-Activated Protein Kinase (MAPK) pathway-dependent manner. Thymol has the ability to integrate into the Lipid layer of the cell membrane, increasing the surface curvature and also affecting the activity of internal membrane enzymes and receptors [17].

Thymol is destroyed the integrity of cell membrane resulting in leakage of intracellular material and eventual death of zoonotic bacteria *Aeromonas hydrophila* [18]. It decreases the intracellular ATP pools of *E. coli* by disrupting the cytoplasmic membrane [19]. Thymol affects the cell membrane depolarization, decrease intracellular ATP concentrations and lowers pHi in the *Enterobacter sakazakii* [20]. Thymol promotes the leakage of proteins and nucleic acids in the vegetative and spore forms of *Alicyclobacillus acidoterrestris* [21].

Beta pinene

Beta-pinene (β-pinene) is a monoterpene, essential oil found in Cumin or *Cuminum cyminum*. Derivatives of β-pinene are antimicrobial to the bacterial strains of *Klebsiella pneumoniae*, *Enterobacter aerogenes*, *Staphylococcus aureus*, *Staphylococcus epidermidis* and fungus of *Candida albicans*. Change in substituent on the pyridine ring and benzene ring of 3-cyanopyridine derivatives is an important factor for inducing antimicrobial activity [22]. The bacterial strains of staphylococcus lost viability significantly 2-8 hours of β-pinene exposure [23]. (+)-β-pinene is an effective molecule in reducing the candida biofilm formation. The crucial antifungal activity is mediated through interference with the cell wall; through molecular interaction with Delta-14-sterol reductase and, to a lesser extent, with the 1,3-β-glucan synthase [24].

Linalool

Linalool also known as 3,7-dimethyl-1,6-octadien-3-ol is an acyclic monoterpene alcohol found in *Ocimum basilicum* with reported antimicrobial and antifungal properties [25]. Linalool affects the bacterial cells by losing the cell membrane polarization, wrinkling, glue together and broken conditions. Additionally, linalool is causing the intracellular nucleic acid leakage and decreasing the activity of bacterial respiratory dehydrogenases, ATPase's, pyruvate kinase activities and disturbing the central carbon chain metabolism [26,27]. Linalool is affecting the biofilm formation in the fungal strain of *C. albicans* ATCC 14053. Linalool is affecting the expression of adhesin genes and the genes responsible for germ tube formation which potentially inhibits the growth of *C. albicans* fungal strain [28].

Carvone and Limonene

Anethum graveolens (Dill) seeds containing essential oils of carvone and limonene possessing antimicrobial activity. Essential oils increase relative electric conductivity, extracellular ATP concentration and cell constituent of *Campylobacter* species [29]. Dill compounds inhibiting the bacterial strains of *Staphylococcus aureus* ATCC25923, clinical *Vibrio cholerae*, *E. coli* ATCC 25922 and *Pseudomonas aeruginosa* 8821M [30]. *E. coli* and *S. aureus* strains facing alterations in hydrophobicity, surface charge and membrane integrity that subsequently promote the K+ ions leakage [31]. Dill seed oils also cause morphological changes in the cells of *Aspergillus flavus* and a reduction in the ergosterol quantity. Fungal cells losing the mitochondrial membrane potential, decreasing ATPase and dehydrogenase activity which indicates dill seed essential oils inhibiting fungi through induction of reactive oxygen species [32]. Derivatives of carvone effective against *E. coli* and weak antifungal over *C. tropicalis* and *C. parapsilosis* [33]. The essential oils containing 78.76% of carvone and 11.50% of limonene are effectively inhibiting the growth of gram positive bacteria [34]. Carvone of *Anethum sowa* is inhibiting the growth of human pathogenic bacteria and fungi [35]. The components of carvone and limonene significantly inhibit the growth of the *Colletotrichum gloeosporioides*, *Lasiodiplodia theobromae* and *Alternaria fungal* isolates [36]. Carvone is a versatile antifungal compound promoting the cell surface roughness, formation of pores and leakage of cellular content in the candida species [37]. Carvone is an effective inhibitor for the formation of germ tubes in the *Candida albicans* [38]. Thymol and carvone compounds are toxic for the growth of 12 different fungal strains at the lowest concentrations of 0.017% to 0.051% [13].

Trans-anethole

Pimpinella anisum L fruits containing *trans*-anethole as the major essential oil component [39,40]. Aqueous decoction of aniseed is 18.1% effective against 176 oral bacteria isolated from 200 individuals [41]. Aromatic compounds could potentially inhibit bacterial growth by precipitating cell wall proteins of *Staphylococcus aureus* NCTC6571 and Escherichia coli NCTC 5933 [42]. Seed aqueous extracts inhibiting the strains of *Bacillus cereus*, *Staphylococcus aureus, Salmonella typhimurium*, and *Escherichia coli* [43]. Additionally, anise seed oil extracts inhibiting the fungal mycelial growth of *Alternaria alternata, Aspergillus niger* and *Aspergillus parasiticus* [40]. Anethole is exhibiting the strong synergism as bacteriostatic with polygodia, an aldehyde phytocompound [44]. The fungal strains of *Candida albicans, C. parapsilosis, C. tropicalis, C. pseudotropicalis* and *C. krusei* are effectively inhibiting by anise seed components [45]. Anethole is blocking the recovery of S. cerevisiae and C. albicans from fungistatic effects of dodecanol [46]. Plant pathogenic fungal strains significantly inhibited by the trans-anethole contained essential oil [47]. *Trans*-anethole disrupts the cell wall integrity of *Bacillus cereus* and promotes the leakage of nucleic acid components [48]. Anethole, an antivirulence compound- inhibiting the *in vitro* expression of cholera toxin and toxin coregulated pilus through by over expressing *crp* genes of cyclic AMP receptor signaling system [49,50].

Conclusion

Essential oil extracts of spices effectively inhibiting or killing the microbial flora of bacterial and fungal species. Hence, food industry is more beneficial to use spices as condiments and its essential components as controlling agents for bacteria and fungi. Active components of spices-essential oils significantly disrupting the biological systems of bacteria and fungi, hence suggested as preservatives in the food industry. Further studies about the antimicrobial mechanisms and their molecular events of spices-essential oil active components were needful.

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