Satureja montana Essential Oil as potential antibacterial agent: study of interaction with model membrane systems

S. Trabalzini[a], F. Rinaldi[b], P.N. Hanieh[a], A. Imbriano[a], F. Bordi[c], M. Carafa[a], S. Sennato[c]

[a] Drug Chemistry and Technology Department, Sapienza University of Rome, Piazzale Aldo Moro 5, Rome, 00185, Italy
[b] Center for Life Nano Science@Sapienza, Istituto Italiano di Tecnologia (ITT), Viale Regina Elena 291, 00161 Rome, Italy
[c] Institute for Complex Systems ISC, National Research Council, Rome, Italy
e-mail: sil.trabalzini@gmail.com

Keywords: Satureja montana Essential Oil, model membrane system, Langmuir monolayers

Essential oils (EOs) are volatile liquids, with a characteristic odour, obtained by distillation or squeeze of aromatic plants. They are known since antiquity and so used in cookery and in traditional medicine [1]. Still now they are often included in cosmetics and perfumes as fragrances, in foods and beverages as flavouring agents and in pharmaceutical products employed for treatment and prevention of infection by millions of people in all the world [2].

EOs are composed of a complex mixture of volatile substances (terpenes, aldehydes, alcohols, esters, phenols, ethers and ketones), produced during secondary metabolism in different plant organs. It is known that they target different structural molecules of microbial cell so that they may act in synergism in the reduction and control of microorganisms.

An important feature of EOs and their components is hydrophobicity, which enables them to accumulate in the lipids of the bacterial cell membrane, interfering with the cell permeability. There are numerous studies about the biological activity of several different EO and their isolated compounds, however there are hardly reports describing the effects of these molecules on the physical properties of biological membranes [3].

Among the several different EOs, *Satureja montana* have recognized biological properties, including analgesic, anti-inflammatory, immunomodulatory, anticancer and antimicrobial activity [4]. A recent investigation has obtained a metabolite profile of commercial *Satureja montana* essential oil (SEO) and has evaluated its antimicrobial properties, both alone and combined with gentamicin towards Gram-negative and Gram-positive bacterial strains [5]. These recent results encouraged further investigations and pointed out that SEO, alone or in combination with antibiotics, could represent a significant tool to control bacteria growth.

In this study, SEO was incorporated in lipid monolayers at the air−water interface, this system being a useful simple model of half cell membrane [6]. Because of SEO acts at the cell membrane level, Langmuir monolayer technique is able to give information about oil-lipid interaction and penetration in lipid membrane. DMPE, DMPG, DMPC and Cardiolipin (CL) lipids, differing for charge of the polar head, length and saturation of the acyl chain and structure, have been chosen as representative of bacterial membrane components. SEO has been inserted under the monolayer at different packing pressures, from a more disordered (gaseous) state from a more closely packed state, close to the condition of a biological membrane.

In all the monolayer investigated, SEO is able to interact by insertion in the gaseous phase where monolayer is loosely packed. As general features, SEO expands lipid monolayers, decreases their surface elasticity and changes their morphology, thus evidencing the incorporation of this compound in the lipid film. At increasing molecular packing, the extent of SEO remaining incorporated in the film is dependent on the nature of the lipid. The highest incorporation has been observed for DMPG and CL monolayers. This result suggest that SEO is maintained within the film by electrostatic interactions with the negatively charged polar heads of the two lipids.

On the other hand, when SEO is inserted under monolayers at the packing condition corresponding to the one of the biological membrane, around 35 mN/m, the highest penetration is observed for CL monolayers, in DMPE and DMPC occurs only at low and high SEO content, respectively, while no interaction occurs for DMPG. These results can be explained by considering that SEO penetration is the result of a joint steric and electrostatic interactions, which are higher in CL film due to the peculiar structure of the lipid, with two heads and four chains. Interestingly, CL is the major component of bacterial membrane and this study gives evidence that essential oil-lipid membrane interaction could be a significant mechanism for explaining antibacterial effect of SEO.

[1] C.F. Carson and K.A. Hammer. "Chemistry and bioactivity of essential oils", in: H. Thormar (Ed.), Lipids and Essential Oils as Antimicrobial Agents, 2010
[2] M.M. Cowan, Clin. Microbiol. Rev. 12 (1999) 564-582
[3] S. Burt, Int. J. Food Microbiol. 94 (3) (2004) 223-253
[4] B. Tepe, M. Cilkiz, Pharm. Biol. 54 (2015) 375-412
[5] L. Vitanza, Microb Pathog 126 (2019) 323-331
[6] R. Maget-Dana, Biochim. Biophys. Acta 1462 (1999) 109-140

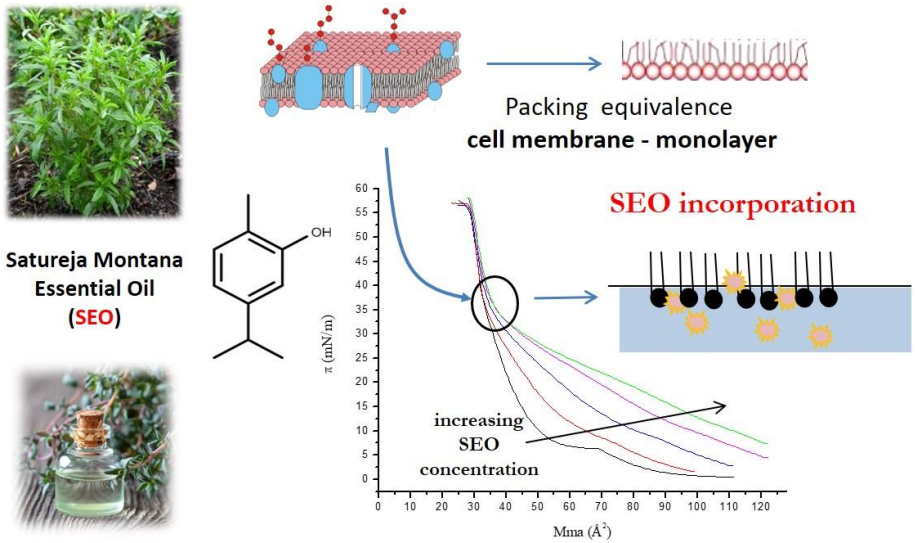

Figure 1. In the figure are represented, from the bottom left clockwise: a bottle of essential oil; the carvacrol, major component of SEO; *Satureja montana* plant; a model of cellular membrane and monolayer; compression isotherm of DMPE monolayers containing increasing concentrations of SEO.