ARTISANEFOOD

Innovative Bio-interventions and Risk Modelling Approaches for Ensuring Microbial Safety and Quality of Mediterranean Artisanal Fermented

Report on Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) Values of Natural Antimicrobials against Indicator Microorganisms

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1. Introduction

The use of antimicrobials is a common practice for preservation of foods. Incorporation, in a food recipe, of chemical antimicrobials towards inhibition of spoilage and pathogenic micro-organisms results in the compositional modification of food. This treatment is nowadays undesirable for the consumer, who likes natural products. Scientific community reflecting consumers demand for natural antimicrobials has made efforts to investigate the possibility to use natural antimicrobials such us essential oils of plant origin to inhibit microbial growth. In addition, to the compositional modification of a food, antimicrobials are also used for a food surface treatment or for incorporation in the packaging material. This is especially important for cooked meat products, to decontaminate them from post-thermal processing cross-contamination. Antimicrobial substances are also used in certain stages of food process corresponding to critical control points; their presence contributes to the safety design of a food with other existing hurdles of microbial growth.

This report is mainly focused on natural antimicrobials and specially the use of essential oils as food additives, providing in parallel basic information on their mode of action and their antimicrobial activity against selected foodborne pathogens.

1.1. Essential oils as natural antimicrobials

Since ancient times (with the earliest report in 1550 BC), spices and herbs have been used for their perfume and flavor as seasoning additives and as preservatives due to their strong antimicrobial and antioxidant properties (Tassou, Lambropoulou, & Nychas, 2004; Coma, 2008). The antimicrobial activity of spices and herbs is primarily attributed to the phenolic component of their essential oil fraction (phyto-phenols; Davidson & Naidu, 2000). Although EOs usually contains more than sixty individual components, the phenolic components are chiefly responsible for their antibacterial properties (Cosentino et al., 1999). More specifically, essential oils mainly consist of terpenes (e.g. mono terpenes, sesquerpitenes), terpenoides and other aromatic compounds (e.g. simple phenols, such as eugenol and thymol, aldehydes, esters and alcohols) (**Figure 1**) (Burt, 2004; Davidson, 1997; Smid & Gorris, 1999; Bakkali, Averbeck, Averbeck, & Idaomar, 2008). Other plant extracts include isothiocyanate derivatives (e.g., found in cabbage, horseradish, mustard, broccoli) and phenolic compounds, such as di- or tri-phenols, phenolic acids, such as hydroxucinnamic acid, and flavonoids (Davidson, 1997). Based on toxicological studies, the majority of active components of herbs and spices are considered as food-grade or generally recognized as safe (GRAS) (Smid & Gorris, 1999).

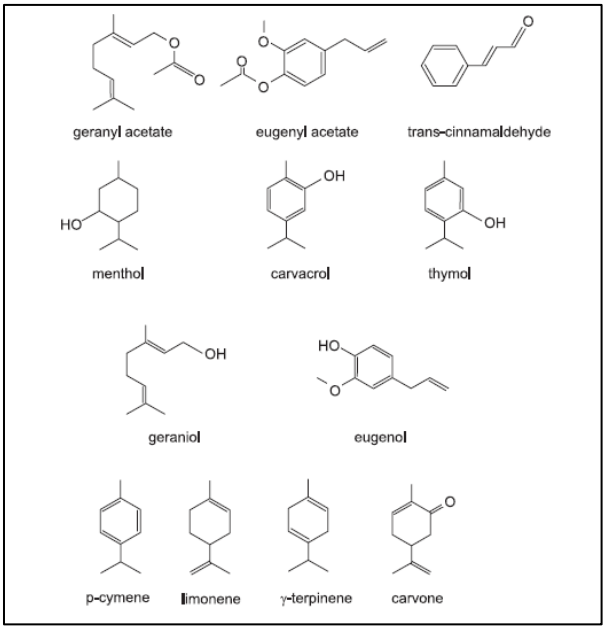

Figure 1: Structural formulae of selected components of EOs (*Adapted from Burt, 2004*)

1.1.1. Mode of Action of EOs

The mechanisms of action of essential oils have not been clearly identified but it seems to be related with their hydrophobic nature (Nazzaro et al., 2013; Khorshidian et al., 2018; Swamy et al., 2016). In fact, the lipophilic nature of the hydrocarbon skeleton and hydrophilic nature of functional groups of EOs (**Figure *1***) has been suggested of having substantial role in the antimicrobial effects of these compounds.

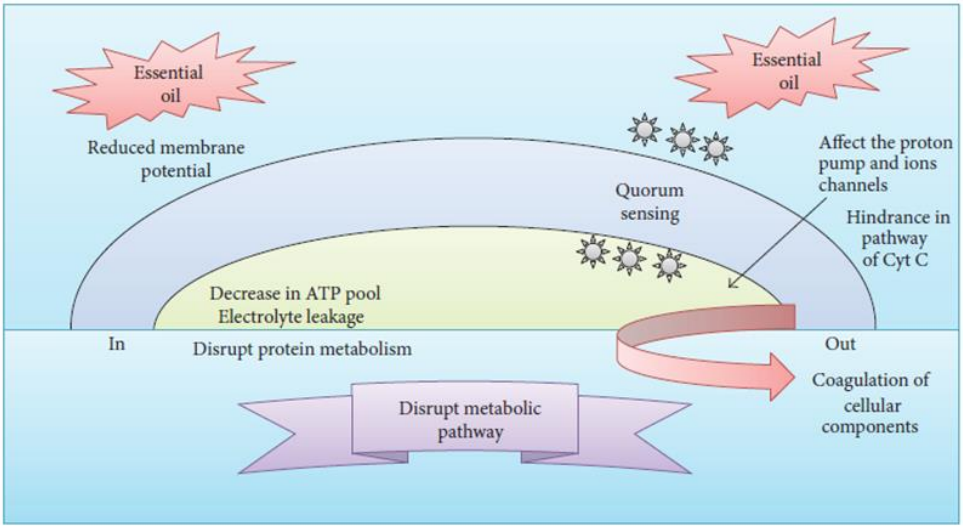

Figure 2: Antimicrobial mechanisms of essential oils (*Adapted from Swamy et al., 2016*)

Table 1 illustrates some examples of different mechanisms of action found to be used by different EOs and their compounds.

Table 1: Different mechanisms of the antimicrobial action of some essential oils and their active compounds

Essential Oil- Active Compound	Mechanism of Antimicrobial Action
Tea tree oil	Alter cell permeability, increase the leakage of intracellular K+ ions and disrupt cell respiration.
Thymol, menthol, and linalyl acetate	Cause perturbation of the lipid fractions of bacterial plasma membranes
Carvacrol	• Alter the composition of fatty acids which then affects the membrane fluidity and permeabiblity • Deplete the internal ATP • Induced the leakage and loss of ATP from bacterial cells • Abolish the enterotoxin production of S.aureus • Disturb the insertion and folding of proteins such as DnaK and GroEL
Methyl carvacrol, menthol, citronellol, and thymol	Cause an enlargement of the cell membrane that leads to passive diffusion of ions between the expanded phospholipids
Trans-cinnamaldehyde	Enters the periplasm of the cell and disrupts cellular functions
p-cymene	Disturb the membrane integrity
Phenylpropene, eugenol,	Modify the fatty acid outline to alter the cytoplasmic membrane of different bacteria. In addition, they can destroy various bacterial enzymes such as ATPase, amylase, histidine carboxylase, and proteases
Vanillin	Obstruct the pathways of bacterial respiration and disrupting the flux of K+ ions and pH gradient

Generally, the ability of EOs to damage structural and functional properties of bacterial membranes is probably the main mechanism of inhibition (Nazzaro et al., 2013). It has been suggested that EOs disrupt the proton pumps, the arrangement of dissimilar fatty acids, phospholipids bilayers and polysaccharides molecules (Swamy et al., 2016). EOs deplete ATP, may cause cascade effect, and finally lead to the coagulation of inner cellular components in the cytoplasm and ultimately cell-death. Additionally, some EOs have been found to inhibit the quorum sensing communication network between cells which is mediate by different bacterial signal molecules **(Figure 2*)*** (Swamy et al., 2016).

Moreover, recent research has shown that essential oils may not cause cell death but instead may cause damage to cells by turning them into a ***Viable But Non Culturable*** (VBNC) state, a microbial response to stress conditions (Paparella et al., 2008). The later was also shown in a recent research were *Origanum vulgare L*. and *Rosmarinus officinalis L*. essential oils caused loss of culturability in *Listeria monocytogenes* cells in Phosphate buffer solution (PBS) and meat broth, forcing *L. monocytogenes* to enter a VBNC state (Barbosa et al., 2020).

Although the results of most in vitro assays suggest that essential oils have a substantial antimicrobial effectiveness, several factors may limit their commercial application in foods. More specifically, studies have shown that factors such as

i) the intrinsic properties of foods (such as fat, pH, salt, water and proteins, which determine the solubility of EOs in the water phase) ;
ii) the structure and viscosity of the foods (solid vs. liquid foods) (Skandamis et al., 2000);
iii) the decomposition of some EOs constituents (e.g. allyl isothiocyanate) in aqueous face and/or their interaction with certain hydrophilic substances, such as thiols, and sulphydryl or terminal amino groups of proteins (Ward, Delaquis, Holley, & Mazza, 1998); and
iv) factors affecting the physiology of the micro-organisms, such as composition of bacterial membranes, availability of nutrients, oxygen tension and incubation temperature (Kabara, 1991; Juven et al., 1994; Smid & Gorris, 1999; Gill, Delaquis, Russo, & Holley, 2002; Nychas & Skandamis, 2005),

may affect the antimicrobial efficacy of EO in foods.

To overcome the above-mentioned limitations on the application of EOs in foods, researchers have focused on the inclusion of EOs in formulations (emulsions, powders) which will protect essential oil. In such formulations the EO (core material) is being encapsulated in a carrier material (wall material) (Sagalowicz & Leser, 2010) to form a colloidal dispersion. Commercially colloidal dispersions (nanoemulsions and microemulsions) are produced to encapsulate lipophilic compounds to be dispersed into an aqueous medium, the so-called **Oil-in-Water** (O/W) type system. Reverse type systems, **Water-in-oil** (W/O) type systems, may also applied in certain

industries (McClements, 2012). Droplet size of these encapsulation systems are of importance as it affects the antimicrobial activity of the system. Specifically, the strength of the net attractive forces acting between droplets usually decreases with decreasing droplet diameters, reducing aggregation phenomena in nanoemulsions. As droplets' size decreases, the antimicrobial activity of encapsulated lipophilic compound increases because the ratio surface area/volume increases. That improves the reactivity of the compound with the microbe as it enhances the transport of active molecules (Donsì and Ferrari, 2016). Droplet size is highly related to the delivery system (carrier) (**Table 2**) and the method of encapsulation applied (such as molecular inclusion, spray drying, liposome encapsulation etc) (Sagalowicz & Leser, 2010).

Table 2: Size of Different Oil-in-Water Systems

Delivery System	**Size**
Powder particles (glass encapsulation, core-shell capsules, matrix capsules)	10μm-1mm
Emulsions (ordinary emulsions, multilayered emulsions, double emulsions, nanoemulsions, Solid Lipid Nanoparticles -SLNS)	100nm-10μm
Liposomes, Vesicles	20nm-100μm
Microemulsions	5-100nm
Dispersed reversed surfactant systems (Cybosomes, hexosomes, Dispersed reversed Microemulsions, Micellosomes	100nm-1μm

Liposomes and nanoliposomes are attractive encapsulation systems for the delivery of both lipophilic and hydrophilic functional compounds. They are spherical-shell structures consisting of a phospholipid bilayer (or more such bilayers) enclosing a liquid core. They can be categorized according to their lamellarity and their size. Small Unilamellar Visicle (SUV) is between 20-100nm, Large Unilamellar Vesicles (LUV) are >100nm and the size of Giant Unilamellar Visicle (GUV) is >1000nm. As it has already been mentioned, essential oils are able to be entrapped in liposomes. There are many methods which are used to formulate these liposomes, such as the thin-film hydration, Extrusion, Sonication, Melting, Freezing- thawing etc. (Emami et al., 2016).

1.2. *In vitro* tests of antibacterial activity of EOs

Several methods can be applied to determine the antibacterial activity of compound; however, for EOs most commonly applied methods are:

a) The agar diffusion methods (disk diffusion or agar well) (qualitative method)

b) The dilution methods (agar dilution method or broth dilution) (quantitative method) (Kalemba & Kunicka, 2003; Burt, 2004).

Both type of methods aim to determine the Minimum Inhibitory Concentration (MIC) as a measure of the anti-bacterial performance of EO. However, as there is no standardized method or definition for MIC, variations between the applied methodologies exist. Moreover, Minimum Bactericidal Concentration (MBC) or the bacteriostatic concentration is also stated in many research studies, both terms agreeing closely with the MIC (Burt, 2004).

To avoid confusion, for the purposes of the current review the following definitions (defined by EUCAST) will be adapted:

"**Minimal Inhibitory Concentration (MIC)** is the lowest concentration of an antimicrobial agent that completely inhibits the growth of the organism (EUCAST, 2000) whereas,

"**Minimum Bactericidal Concentration (MBC**) is the lowest concentration of a compound that under defined in vitro conditions reduces by 99.9% (3 log units) the number of organisms in a medium containing a defined inoculum of bacteria, within a defined period of time".

a) Antimicrobial Activity of Essential Oils and Active Compounds against Selected Pathogens - Literature Review

During the past decades, extensive documentation on the antimicrobial activity of different essential oils and their constituents against foodborne pathogens such as *Listeria monocytogenes, Escherichia coli, Salmonella spp., Staphylococcus aureus* has been carried out (**Table 3a, 3b, 4, 5, 6, 7 & 8**). Due to the use of many different microbiological methods for susceptibility testing and different definitions of antimicrobial activity, the comparability of studies on essential oils is often critical as variation in the method applied may result in variation in the expression of results (mg/ml, μg/ml, %v/v, %w/w, etc.). For ease of comparison, in the current review, all the results have been converted to %v/v. More specifically, several studies have been focused on the determination of antimicrobial activity of essential oils against foodborne pathogens. It is generally shown that Gram-positive bacteria are more sensitive to essential oils or antibacterial compounds than Gram-negative bacteria (**Table 3a, 3b**). This resistance is usually ascribed to the structure of the cellular walls of Gram-negative bacteria, mainly with regards to the presence of lipoproteins and lipopolysaccharides that form a barrier to restrict entry of hydrophobic compounds. Differences between the antimicrobial activity of different EOs can also be attributed to differences on their structure and polarity (Budiati et al., 2020, Takayama et al., 2016, Carolina et al., 2003).

Table 3a: MIC and MBC of different essential oils against selected foodborne pathogens

Essential oil or active substance	Strain Identification	MIC (% v/v)¥	MBC (% v/v)¥	Method Applied	Reference
Orange peel (Citrus sinensis)	*L. monocytogenes*	3.13	nd	Broth Dilution	Budiati et al., 2020
Lemon oil (Cymbopogon citratus)	*L. monocytogenes*	0.32	nd	Broth Dilution	Budiati et al., 2020
	Salmonella ATCC 14030	6.25	nd	Broth Method	Budiati et al. 2018
Lemon peel (Citrus lemon)	*Staphylococcus aureus*	2.5	nd	Micro-dilution	Otang and Afolaya, 2016
	Escherichia coli	2.5			
	Bacillus cereus	0.02			
Juniperus communis	*L. monocytogenes ATCC 19111*	0.5	2	Micro-dilution	Nikolic et al., 2019
	L. monocytogenes isolated from salmon (LMS)				
	L. monocytogenes from slaughterhouse water drainage tunnel (LMT)	0.5	1		
	L. monocytogenes from beef carcass (LMB)	1	4		
Tarragon	*E. coli ATCC 25922*	0.00008	0.00001	Broth Dilution	Akarca et al., 2019
	St. aureus ATCC 6538				
	S. typhimurium ATCC 14028	0.00004			
	L. monocytogenes ATCC 51774				
Salvia	*St. aureus ATCC 12600*	0.05120	nd	Micro-dilution	Bhavya et al., 2020
	L. monocytogenes ATCC 13932				
Mentha	*St. aureus ATCC 29213*	0.25	0.25	Micro-dilution	Chraibi et al (2017)
	B. cereus				
	E. coli ATCC 25922	0.5	1		
	S. typhi				
	Pseudomonas aeruginosa ATCC 27853	8	>8		
	Listeria monocytogenes	0.5	0.5	Micro-dilution	Bouyahya et al., 2017
	Listeria monocytogenes	15.3	nd	Micro-dilution	Teixeira et al. 2012
Lavandula mairei	*L. monocytogenes CECT 4032*	0.008	0.01	Macro-dilution	A. El Hamdaoui et al., 2018
	S. aureus CECT 976	0.012	0.012		

¥ For ease of comparison different MIC and MBC units (i.e., ppm, mg ml−1, µl l−1 and µg ml−1) have been converted to % (v/v) values

Table 3b: MIC and MBC of different essential oils against selected foodborne pathogens

Essential oil or active substance	Strain Identification	MIC (% v/v)[¥]	MBC (% v/v)[¥]	Method Applied	Reference
Date (Phoenix dactylifera L.)	*B. cereus ATCC 11778*	1.56	3.13	Broth Dilution	El Arem et al., 2013
	St. aureus ATCC 25923	0.78	1.56		
	L. monocytogenes ATCC 19115	0.09	0.19		
	E. coli ATCC 35218	12.50	25		
Sesame seeds (Sesamum indicum)	*Bacillus subtilis*	0.092	nd	Streak method	Sandeep et al., 2014
	E. coli	0.095	nd		
Oleuropein (olive leaves)	*P. aeruginosa*	0,10	nd	Micro-dilution	Djenane et al., 2012
	St aureus	0.05	nd		
	S. enterica	0.1	nd		
Hesperidin (orange byproduct)	*Aeromonas hydrophila ATCC 7966*	3125	12500	Broth micro-dilution	Abuelsaad et al., 2013
	B.subtilus	45	nd	Agar diffusion	Abass et al., 2014
	E. coli	75	nd		
	S. typhi	175	nd		
	St. aureus	175	nd		
Garlic	*St.aureus*	0.00016	0.00064	Tube-dilution	Elsom et al., 2000
	E/.coli	0.0032	0.0032		
	Salmonella	1 - 1.25	1.3 - 1.5	Broth Dilution	Belguith et al., 2010
	L. monocytogenes CECT 4032	0.01	nd	Tube Dilution	Somrani et al., 2020
	L. monocytogenes	0.4	>0.8	Micro-dilution	S. Pedrós-Garrido et al., 2020
	S. enterica ATCC 25957	0.2	nd	Broth Dilution	H. Al-Talib et al., 2015
	E. coli ATCC 43889	0.1	nd		
	St. aureus	0.8	nd	Agar Dilution	S. Sethi et al., 2013

Fennel seeds (Foeniculum vulgare)	*L. monocytogenes*	15.3	nd	Broth Dilution	Sayed Ahmad et al., 2017
	St. aureus	0.13	0.13		
Corriander (EO)	*L. monocytogenes*	<0.01	nd	Broth Dilution	Delaquis et al., 2004
	E. coli 25922	0.2	0.2	Broth Dilution	Casetti etal., 2012
	St. aureus ATCC 25923	0.2	1.6	Broth Dilution	Silva et al., 2011
	Salmonella ATCC 13311	0.4	0.8	Broth Dilution	Silva etal., 2012
Red pepper	*L. monocytogenes*	0.40	nd	Micro-dilution	Omolo et al., 2014
	E.coli	0.06	nd		

¥ For ease of comparison different MIC and MBC units (i.e., ppm, mg ml−1, µl l−1 and µg ml−1) have been converted to % (v/v) values

Table 4: MIC and MBC values (%v/v) of the active compound ´Carvacrol´ against different pathogenic microorganisms

Essential oil or active substance	Strain Identification	MIC (% v/v)[¥]	MBC (% v/v)[¥]	Method Applied	Reference
Carvacrol	*L. monocytogenes 10403S*	0.025	0.05	Micro-dilution	Churklam et al., 2019
	L. monocytogenes DMST17303				
	L. monocytogenes CM2-BM–HF–Black				
	L. monocytogenes CM8-ISO–HF–Blac				
	L. monocytogenes CM9-ISO–HF–Black				
	L. monocytogenes CM11-ISO–HF–Black				
	L. monocytogenes CM12-ISO–HF–Black				
	L. monocytogenes CM13-ISO–HF–Black				
	L. monocytogenes CM15-ISO–HF–Black				
	L. monocytogenes CECT 4032	0.01	nd	Tube-dilution	Somrani et al., 2020
	Salmonella SP 11	0.03	nd	Micro-dilution	Gomez-Garcia et al. 2019
	Salmonella SP 28	0.06			
	Salmonella CECT 443	0.03			
	Salmonella CECT 700				
	Salmonella CECT 915				
	Salmonella CECT 4300				
	S. Enteritidis SE86	0.0331	nd	Micro-dilution	Both Engel et.al., 2017
	S. Typhimurium isolated from pork feces				
	S. Newport				
	S. Saint Paul isolated from meat				
	Escherichia coli 60	0.03	nd	microdilution	Gomez-Garcia et al., 2019
	Escherichia coli 61	0.03	nd		
	Escherichia coli 67	0.06	nd		
	Escherichia coli 96	0.015	nd		
	Escherichia coli 107	0.06	nd		
	Escherichia coli 115	0.03	nd		
	E. coli O157:H7 (ATCC 35150)	0.25	nd	microdilution	Yuan et al., 2019
	Staphylococcus aureus 4668/03	0.0662	nd	Micro-dilution	Both Engel et.al., 2017
	Staphylococcus aureus S6	0.0662	nd		
	Staphylococcus aureus S8	0.0662	nd		
	Staphylococcus aureus ATCC 2998	0.0662	nd		
	Staphylococcus aureus isolated from meat	0.2	0.4	Micro-dilution	Gochev&Girova, 2009

Table 5: MIC and MBC values (%v/v) of ´Oregano essential oil´ against different pathogenic microorganisms

Essential oil or active substance	Strain Identification	MIC (% v/v)[¥]	MBC (% v/v)[¥]	Method Applied	Reference
Oregano oil	*L. monocytogenes ATCC 13932*	0.000052	nd	Micro-dilution	Hulánková and Bořilová, 2011
	L. monocytogenes ATCC 13932				
	L. monocytogenes ATCC 7644	0.000125	nd	Tube-dilution	Azeredo et.al., 2011
	L. monocytogenes ATCC 7644	0.0025	nd	Micro-dilution	Barbosa et al., 2020
	L. monocytogenesATCC 19112				
	L. monocytogenes ATCC 19117				
	S. Typhimurium	0.04	0.04	Micro-dilution	Mogan et al, 2020
	Salmonella SP 11	0.06	nd	Micro-dilution	Gomez-Garcia et al. 2019
	Salmonella SP 28	0.12			
	Salmonella CECT 443	0.06			
	Salmonella CECT 700	0.06			
	Salmonella CECT 915	0.06			
	Salmonella CECT 4300	0.06			
	Salmonella ATCC 13076	0.0005	nd	Micro-dilution	Hulánková&Bořilová, 2011
	Salmonella entericakasenyi	0.001	nd	Micro-dilution	Rossi et al. 2019
	Salmonella enterica Veneziana	0.0005			
	Salmonela enterica Derby	0.0002			
	Salmonella enterica Thomson	0.0005			
	Salmonella enterica Napoli	0.0005			
	Escherichia coli 60	0.06	nd	Micro-dilution	Gomez-Garcia et al., 2019
	Escherichia coli 61	0.03	nd		
	Escherichia coli 67	0.06	nd		
	Escherichia coli 96	0.03	nd		
	Escherichia coli 107	0.12	nd		
	Escherichia coli 115	0.03	nd		
	Escherichia coli O157:H7 ATCC 700728	0.000051	nd	Micro-dilution	Hulánková&Bořilová, 2011
	Staphylococcus aureus ATCC 25923	0.05%	nd		
	Staphylococcus aureus isolated from meat	0.05	0.05	Micro-dilution	Gochev&Girova, 2009

Table 6: MIC and MBC values (%v/v) of ´Cinnamon essential oil´ against different pathogenic microorganisms

Essential oil or active substance	Strain Identification	MIC (% v/v)¥	MBC (% v/v)¥	Method Applied	Reference
Cinnamon oil (*C. cassia*, EOC)	*L. monocytogenes train- FSL*	0.078	0.078	Micro-dilution	Paudel et al., 2019
	L. monocytogenes N1-017, LMI				
	L. monocytogenes strain- FSL J2-064, LMII				
	L. monocytogenes strain- FSL N3-165, LMIII				
	Salmonella entericakasenyi	0.0002	nd	Micro-dilution	Rossi et al. 2019
	Salmonella enterica Veneziana	0.0001			
	Salmonela enterica Derby	0.0001			
	Salmonella enterica Thomson	0.000125			
	Salmonella enterica Napoli	0.0001			
	S. Typhimurium T123	0.1	0.2	Micro-dilution	Al-Nabulsi et al., 2020
	S. Aberdeen T069,				
	S. Cubana T109				
	S. Paratyphi A T193				
	SalI (Salmonella enterica)	0.039	0.078	Micro-dilution	Paudel et al. 2019
	SalII (Salmonella enetrica subspecies enterica serovar Newport)				
	SalIII (Salmonella choleraesuis subsp. Choleraesuis)				

Table 7: MIC and MBC values (%v/v) of ´Rosemary essential oil´ against different pathogenic microorganisms

Essential oil or active substance	Strain Identification	MIC (% v/v)¥	MBC (% v/v)¥	Method Applied	Reference
Rosemary oil	*L. monocytogenes*	3.13	nd	Broth Dilution	Budiati et al., 2020
	L. monocytogenes ATCC 7644	0.002	nd	Tube-dilution	Azeredo et.al., 2011
	L. monocytogenes ATCC 7644	0.0005	nd	Micro-dilution	Barbosa et al., 2020
	L. monocytogenes ATCC 19112				
	L. monocytogenes ATCC 19117				
	Salmonella entericakasenyi	>0.004	nd	Micro-dilution	Rossi et al. 2019
	Salmonella enterica Veneziana				
	Salmonela enterica Derby				
	Salmonella enterica Thomson				
	Salmonella enterica Napoli				
	Escherichia coli ATCC 8739	0.30	0.50	Microdilution	Jiang et.al., 2011
	Staphylococcus aureus MRSA 53	0.03	0.1	Micro-dilution	Jiang et.al., 2011

Table 8: MIC and MBC values (%v/v) of ´Thyme essential oil & Thymol´ against different pathogenic microorganisms

Essential oil (EO) or active substance (AS)	Application	Strain Identification	MIC % (v/v)	MBC %(v/v)	Method Applied	Reference
Thyme	EO	*E. coli ATCC 25922*	4.0	4.0	Agar Dilution	Moghimi et al., 2016
		Staphylococcus aureus isolated from meat	0.1	0.2	Micro-dilution	Gochev&Girova, 2010
		E. coli O157:H7 (NCCP 11090)	0.01	0.03	Microbroth diltion	Sadekuzzaman et al., 2018
		S. Typhimurium T123	0.1	0.2	Micro-dilution	Al-Nabulsi et al., 2020
		S. Aberdeen T069,				
		S. Cubana T109				
		S. Paratyphi A T193				
		S. ser Enteritidis ATCC13076	0.03	0.07	Microbroth dilution	Sadekuzzaman et al., 2018
		L.monocytogenes ATCC19113	0.06	0.12	Microbroth diltion	Sadekuzzaman et al., 2018
Thymol	AS	*Salmonella* SP 11	0.03	nd	Micro-dilution	Gomez-Garcia et al. 2019
		Salmonella SP 28				
		Salmonella CECT 443				
		Salmonella CECT 700				
		Salmonella CECT 915				
		Salmonella CECT 4300				
		S. Enteritidis SE86	0.0331	nd	Micro-dilution	Both Engel et.al., 2017
		S. Typhimurium isolated from pork feces				
		S. Newport				
		S. Saint Paul isolated from meat				
		Staphylococcus aureus 4668/03	0.0662	nd	Micro-dilution	Both Engel et.al., 2017
		Staphylococcus aureus S6	0.0662	nd	Micro-dilution	
		Staphylococcus aureus S8	0.0662	nd	Micro-dilution	
		Staphylococcus aureus ATCC 2998	0.0662	nd	Micro-dilution	
		Staphylococcus aureus isolated from meat	0.2	0.4	Micro-dilution	Gochev&Girova, 2009
		Escherichia coli 60	0.12	nd	Broth microdilution	Gomez-Garcia et al., 2019
		Escherichia coli 61	0.06	nd		
		Escherichia coli 67	0.06	nd		
		Escherichia coli 96	0.06	nd		
		Escherichia coli 107	0.12	nd		
		Escherichia coli 115	0.06	nd		
		E. coli O157:H7 (ATCC 35150)	0.063	nd	microdilution	Yuan et al., 2019

However, other experimental factors such as the choice of bacterial strains and their sensitivity, volume of inoculum, incubation time, and temperature may also be related to the variation in the antimicrobial activity presented among studies.

Essential oils of cinnamon, oregano, thyme and rosemary are found to exhibit promising antimicrobial effects against foodborne pathogens (**Table 5, 6, 7, 8**), that can be attributed to the presence of their principle bioactive constituents, such as carvacrol (**Table 4**) and thymol (**Table 8**). As such it has been suggested that the MICs of oregano EOs can be set as the benchmark for other Eos (Thielmann et al., 2019).

However well EOs perform in antibacterial assays in vitro, it has generally been found that a greater concentration of EO is needed to achieve the same effect in foods (Burt 2004). The later forced researchers to focus on the antimicrobial effects of encapsulated essential oils.

b) Antimicrobial Activity of Essential Oils and Active Compounds against Selected Pathogens- *In-Vitro* Screening of natural extracts

The **I*n-Vitro* screening of the MIC** values of selected antimicrobials was determined against number of indicator (spoilage and pathogenic) organisms, such as E. coli O157:H7, *Salmonella* spp., *L. monocytogenes, S. aureus*. From the stock solution of each antimicrobial, nine principal dilutions (i.e. fractional dilutions from 1 to 0.2) were prepared in TSB and 300 µl of each dilution was added into the wells of the first row of a microplate. The remaining wells were filled with 150 µl of TSB. Two-fold dilutions follow, from the 1st to the 4th row, transferring 150 µl from one well to the next, across the same column. Culture suspension (50 µl) was added to each well, containing 10^5CFU/ml of the target strain. Negative control wells contained only TSB. Microplates were incubated in Bioscreen C at the optimum temperature (from 25 to 37 °C) and incubation period per indicator organism. OD600 nm measurements were recorded every 30 min and MIC was determined as the minimum concentration of the antimicrobial solution at which no increase in OD was observed. For **MBC determination**, aliquots of 100 µl culture suspension (CFU/ml) were added into each microplate well, except for the negative control wells, which contain only TSB. Microplates were incubated under static conditions at optimum conditions per microorganism. The wells of a separate microplate weree filled with various concentrations of each antimicrobial according to fractional and twofold dilutions. Dilutions of the antimicrobial took place in TSB or in dH2O: ethanol mixture at ratio 70:30. An aliquot of 200 µl antimicrobial from each concentration was transferred to the respective well of the microplate with the culture. The antimicrobial solution was left in contact with cells for 5 min at 25°C. Then, cells were transferred to Eppendorf tubes with 300 µl of neutralizing broth (Dey-Engley neutralizing broth, Fluka Analytical) and incubated at 25°C for 30 s. Finally, 400 µl TSB were added to each well and the treated microplate was incubated at the optimum conditions per organism. Control wells were not be subjected to the antimicrobial treatments. After incubation, turbidity (OD) of TSB was be

measured at A =600 nm. MBC was determined as the antimicrobial concentration for which no regrowth is observed. Tables 9, 10 and 11 show the in vitro screening of MIC & MBC values of selected essential oils against foodborne pathogens.

Table 9: MIC and MBC values (%v/v) of extracts against different pathogenic microorganisms, tested by partners UCO and UIZ

Partner	Essential oil or active substance	Strain Identification	MIC (% w/v)¥	MBC (% w/v)¥
UCO (Spain)	*Thymus vulgaris* (thyme)	*Salmonella* Enteritidis ATCC13076	0.0625	nd
	Cymbopogon martinii (palm rose)	*Salmonella* Enteritidis ATCC13077	0.125	nd
	Cymbopogon citratus (lemongrass)	*Salmonella* Enteritidis ATCC13078	0.25	nd
	Ocimum gratissimum (african basil)	*Salmonella* Enteritidis ATCC13079	1	nd
UIZ (Morocco)	Thymus satureioides-E.O.-	*L. monocytogenes* CECT 4032	0.032	0.032
		L. innocua CECT 4031	0.032	0.032
		S. aureus CECT 976	0.04	0.125
		B. subtilis DSM 6633	0.25	0.25
		P. aeruginosa CECT 118	1	>1
		P. vulgaris CECT 484	>1	>1
	Thymus satureioides-Eth.Ext.-	*L. monocytogenes* CECT 4032	0.5	1
		L. innocua CECT 4031	0.5	>1
		S. aureus CECT 976	>1	>1
		B. subtilis DSM 6633	>1	>1
		P. aeruginosa CECT 118	>1	>1
		P. vulgaris CECT 484	0.5	0.5

Table 10: MIC and MBC values (%v/v) of extracts against different pathogenic microorganisms, tested by partner IPB

Partner	Essential oil or active substance	Strain Identification	MIC (% w/v)¥	MBC (% w/v)¥
IPB (Portugal)	Rosemary	*L. monocytogenes WDCM 00019*	2	nd
	Lemon balm	*L. monocytogenes WDCM 00019*	> 2	nd
	Basil	*L. monocytogenes WDCM 00019*	> 2	nd
	Tarragon	*L. monocytogenes WDCM 00019*	> 2	nd
	Salvia	*L. monocytogenes WDCM 00019*	2	nd
	Mentha spicata	*L. monocytogenes WDCM 00019*	> 2	nd
	Rosemary	*L. monocytogenes WDCM 00019*	1	nd
	Lemon balm	*L. monocytogenes WDCM 00019*	> 2	nd
	Basil	*L. monocytogenes WDCM 00019*	> 2	nd
	Tarragon	*L. monocytogenes WDCM 00019*	> 2	nd
	Salvia	*L. monocytogenes WDCM 00019*	1	nd
	Mentha spicata	*L. monocytogenes WDCM 00019*	1	nd
	Rosemary	*L. monocytogenes WDCM 00019*	2	nd
	Lemon balm	*L. monocytogenes WDCM 00019*	> 2	nd
	Basil	*L. monocytogenes WDCM 00019*	0.5	nd
	Tarragon	*L. monocytogenes WDCM 00019*	1	nd
	Salvia	*L. monocytogenes WDCM 00019*	0.125	nd
	Mentha spicata	*L. monocytogenes WDCM 00019*	1	nd
	Rosemary	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	2	nd
	Lemon balm	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Basil	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Tarragon	*Salmonella enterica subsp. Enterica serotype Typhimurium*	> 2	nd

		ATCC 43971		
	Salvia	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Mentha spicata	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Rosemary	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	2	nd
	Lemon balm	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Basil	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Tarragon	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Salvia	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Mentha spicata	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Rosemary	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Lemon balm	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Basil	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Tarragon	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Salvia	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Mentha spicata	*Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971*	> 2	nd
	Rosemary	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Lemon balm	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Basil	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Tarragon	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Salvia	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Mentha spicata	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Rosemary	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Lemon balm	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Basil	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Tarragon	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Salvia	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Mentha spicata	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Rosemary	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Lemon balm	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Basil	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Tarragon	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Salvia	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd
	Mentha spicata	*S. aureus WDCM 00032 (=ATCC 6538)*	> 2	nd

Specifically, Partner **UCO (Spain)** determined the MIC of thyme, palm rose, lemongrass and African basil essential oils against *Salmonella* Enteritidis ATCC3076. Partner **UIZ (Morocco)** tested the antimicrobial activity (MIC & MBC values) of thyme essential oil and thyme in hydroalcoholic extraction against *L. monocytogenes, L. innocua, S. aureus*, *B. subtilis*, *Pseudomonas aeruginosa* and *P. vulgaris*. Partner **IPB (Portugal)** determined activity (MIC values) of rosemary, lemon balm, basil, tarragon, salvia and *Mentha spicata* essential oils against *L. monocytogenes WDCM 00019, Salmonella enterica subsp. Enterica serotype Typhimurium ATCC 43971 and S. aureus WDCM 00032 (=ATCC 6538)*.

Table 11: MIC and MBC values (%v/v) of extracts against different pathogenic microorganisms, tested by AUA

Partner	Essential oil or active substance	Strain Identification	MIC (% w/v)[¥]	MBC (% w/v)[¥]
AUA (Greece)	Carvacrol	*L. monocytogenes C5 (4b, surface isolate from dairy farm enviroment)*	0.04	0.08
		Salmonella enterica subsp. enterica (ex Kauffmann and Edwards) Le Minor and Poppof serovar Typhimurium 4/74	0.06	0.05
		Escherichia coli O157:H7 NCTC 12079	0.08	0.15
		Staphylococcus aureus subsp. aureus Rosenbach ATCC 6538	0.035	0.08
	Cinnamon oil (*C. cassia,* EOC)	*L. monocytogenes C5 (4b, surface isolate from dairy farm enviroment)*	0.115	0.3
		Salmonella enterica subsp. enterica (ex Kauffmann and Edwards) Le Minor and Poppof serovar Typhimurium 4/74	0.225	0.225
	Oregano oil	*L. monocytogenes C5 (4b, surface isolate from dairy farm enviroment)*	0.13	0.37
		L. monocytogenes 6179 (1/2a)	0.21	0.45
		Salmonella enterica subsp. enterica (ex Kauffmann and Edwards) Le Minor and Poppof serovar Typhimurium 4/74	0.15	0.225
		Salmonella enterica subsp. enterica serovar Agona 23	0.3	0.3
		Escherichia coli O157:H7 NCTC 12079	0.115	0.3
		Escherichia coli O157:H7 NCTC 13127	0.3	0.3
		Staphylococcus aureus subsp. aureus Rosenbach ATCC 6538	0.15	0.26
		Staphylococcus aureus NCBF 1499	0.15	0.3
	Rosemary oil	*L. monocytogenes C5 (4b, surface isolate from dairy farm enviroment)*	0.9	2.35
		L. monocytogenes 6179 (1/2a)	0.9	3.5
		Salmonella enterica subsp. enterica (ex Kauffmann and Edwards) Le Minor and Poppof serovar Typhimurium 4/74	0.6	1.2
		Salmonella enterica subsp. enterica serovar Agona 23	0.6	1.2
		Escherichia coli O157:H7 NCTC 12079	0.9	0.9
		Escherichia coli O157:H7 NCTC 13127	0.45	2.05
		Staphylococcus aureus subsp. aureus Rosenbach ATCC 6538	1.2	3.5
		Staphylococcus aureus NCBF 1499	1.2	1.2
	Orange peel (*Citrus sinensis*)	*L. monocytogenes C5 (4b, surface isolate from dairy farm enviroment)*	0.6	4.25
		L. monocytogenes 6179 (1/2a)	0.9	3.5
		Salmonella enterica subsp. enterica (ex Kauffmann and Edwards) Le Minor and Poppof serovar Typhimurium 4/74	0.9	1.475
		Salmonella enterica subsp. enterica serovar Agona 23	0.9	3.5
		Escherichia coli O157:H7 NCTC 12079	1.2	1.475
		Escherichia coli O157:H7 NCTC 13127	0.45	1.2
		Staphylococcus aureus subsp. aureus Rosenbach ATCC 6538	1.2	2.125
		Staphylococcus aureus NCBF 1499	1.2	4.2
	Lemon oil (*Cymbopogon citratus*)	*L. monocytogenes C5 (4b, surface isolate from dairy farm enviroment)*	1.475	4.2
		L. monocytogenes 6179 (1/2a)	0.9	5
		Salmonella enterica subsp. enterica (ex Kauffmann and Edwards) Le Minor and Poppof serovar Typhimurium 4/74	1.2	5
		Salmonella enterica subsp. enterica serovar Agona 23	1.2	>5
		Escherichia coli O157:H7 NCTC 12079	1.65	>5
		Escherichia coli O157:H7 NCTC 13127	0.9	5
		Staphylococcus aureus subsp. aureus Rosenbach ATCC 6538	3	4.25
		Staphylococcus aureus NCBF 1499	3.5	3.5
	Aloe vera oil	*L. monocytogenes C5 (4b, surface isolate from dairy farm enviroment)*	0.525	1.05
		Salmonella enterica subsp. enterica (ex Kauffmann and Edwards) Le Minor and Poppof serovar Typhimurium 4/74	1.05	1.2
		Escherichia coli O157:H7 NCTC 12079	2.1	2.1
		Staphylococcus aureus subsp. aureus Rosenbach ATCC 6538	2.1	4.2

Finally, partner AUA (Greece) tested the antimicrobial activity (MIC & MBC values) of the essential oils of Cinnamon, Oregano, Rosemary, Orange peel, Lemon, and aloe vera as well as the active compound of Carvacrol against 2 strains of *L. monocytogenes, Escherichia coli O157:H7, Salmonella enterica subsp. Enterica and St. aureus.* Task 4.2 has been completed by IPB, UCO and AUA. Based on the screening results from both the *in-vitro* testing and literature review, the aforementioned partners selected the natural extracts (or essential oils), according to region (Table 12). The extracts currently studied by UIZ and ISBST/UMA – and listed in Table 12 – are subject to confirmation when in-vitro testing is completed by April 2021. The in-situ antimicrobial capacity of the extracts or essential oils shown in Table 23 will be assessed in the target artisanal foods.

Table 12: Natural extracts selected to be assessed in the target artisanal foods (*: to be confirmed)

Country	Extracts	Type	To be tested in
IPB	Lemon balm	Extraction in water	Alheira sausage
	Bixa orellana	Extraction in oil	Alheira sausage
	Spearmint	Hydroalcoholic extraction	Goat milk cheese
	Salvia	Hydroalcoholic extraction	Goat milk cheese
UCO	Thyme	Extraction in water	Goat milk cheese
	Thyme	Extraction in water	Salchichón sausage
	Palm rose	Extraction in water	Salchichón sausage
	Lemongrass	Extraction in water	Salchichón sausage
	African basil	Extraction in water	Salchichón sausage
AUA	Oregano essential oil	Pure essential oil	Katiki
	Oregano essential oil	Encapsulated in liposomes	Katiki
	Oregano essential oil	Encapsulated in β-cyclodextrins	Katiki
	Rosemary essential oil	Pure essential oil	Noumboulo sausage
	Rosemary essential oil	Encapsulated in liposomes	Noumboulo sausage
	Rosemary essential oil	Encapsulated in β-cyclodextrins	Noumboulo sausage
UIZ*	Thyme	Hydroalcoholic Extraction	Jben cheese
	Oregano	Essential oil	Jben cheese
	Rosemary	Hydroalcoholic Extraction	Merguez sausage
	Oregano	Essential oil	Merguez sausage
ISBST/UMA*	Lemon peel	Extraction in hydroethanolic solution	Leben milk
	Date	Extraction in hydroacetone solution	Leben milk
	Sesame seeds	Extraction in hydroethanolic solution	Leben milk
	Hesperidin	Extraction in hydroethanolic solution	Leben milk
	Fennel seeds	Extraction in hydroethanolic solution	Dry merguez sausage
	Mint	Extraction in hydroethanolic solution	Dry merguez sausage
	Red pepper	Extraction in hydroethanolic solution	Dry merguez sausage
	Coriander	Extraction in hydroethanolic solution	Dry merguez sausage
	Oleuropein	Extraction in hydromethanolic solution	Dry merguez sausage
	Garlic	Extraction in water	Kaddid sheep meat
	Mint	Pure essential oil / extraction in methanolic solution	Kaddid sheep meat

References

Al-Nabulsi, A. A., Osaili, T. M., Olaimat, A. N., Almasri, W. E., Ayyash, M., Al-Holy, M. A., Jaradat, Z. W., Obaid, R. S., & Holley, R. A. (2020). Inactivation of Salmonella spp. in tahini using plant essential oil extracts. *Food Microbiology*, *86*(September 2019), 103338. https://doi.org/10.1016/j.fm.2019.103338

Bakkali, F., Averbeck, S., Averbeck, D., & Idaomar, M. (2008). Biological effects of essential oils – A review. Food and Chemical Toxicology, 46, 446–475.

Bouyahya, A., Lagrouh, F., El Omari, N., Bourais, I., El Jemli, M., Marmouzi, I., Salhi, N., Faouzi, M. E. A., Belmehdi, O., Dakka, N., & Bakri, Y. (2020). Essential oils of Mentha viridis rich phenolic compounds show important antioxidant, antidiabetic, dermatoprotective, antidermatophyte and antibacterial properties. *Biocatalysis and Agricultural Biotechnology*, *23*(December 2019), 101471. https://doi.org/10.1016/j.bcab.2019.101471

Braca, A., Siciliano, T., D'Arrigo, M., & Germanò, M. P. (2008). Chemical composition and antimicrobial activity of Momordica charantia seed essential oil. *Fitoterapia*, *79*(2), 123–125. https://doi.org/10.1016/j.fitote.2007.11.002

Budiati, T., Suryaningsih, W., Umaroh, S., Poerwanto, B., Bakri, A., & Kurniawati, E. (2018). Antimicrobial activity of essential oil from Indonesian medicinal plants against food-borne pathogens. *IOP Conference Series: Earth and Environmental Science*, *207*(1). https://doi.org/10.1088/1755-1315/207/1/012036

Budiati, T., Wibisono, Y., Pambayun, R. A., Fahrezy, M. F., Ariyani, R., Kurniawati, E., Suryaningsih, W., Yudiastuti, S. O. N., & Bakri, A. (2020). Inhibition of Listeria monocytogenes by natural antimicrobial. *IOP Conference Series: Earth and Environmental Science*, *411*(1). https://doi.org/10.1088/1755-1315/411/1/012042

Bukvički, D., Stojković, D., Soković, M., Vannini, L., Montanari, C., Pejin, B., Savić, A., Veljić, M., Grujić, S., & Marin, P. D. (2014). Satureja horvatii essential oil: In vitro antimicrobial and antiradical properties and in situ control of Listeria monocytogenes in pork meat. *Meat Science*, *96*(3), 1355–1360. https://doi.org/10.1016/j.meatsci.2013.11.024

Burt, S. (2004). *Essential oils : their antibacterial properties and potential applications in foods — a review*. *94*, 223–253. https://doi.org/10.1016/j.ijfoodmicro.2004.03.022

Chaves, T. P., Pinheiro, R. E. E., Melo, E. S., Soares, M. J. dos S., Souza, J. S. N., Andrade, T. B. de, Lemos, T. L. G. de, & Coutinho, H. D. M. (2018). Essential oil of Eucalyptus camaldulensis Dehn potentiates β-lactam activity against Staphylococcus aureus and Escherichia coli resistant strains. *Industrial Crops and Products*, *112*(June 2017), 70–74. https://doi.org/10.1016/j.indcrop.2017.10.048

Chen, P., Ference, C., Sun, X., Lin, Y., Tan, L., & Zhong, T. (2020). Antimicrobial Efficacy of Liposome-Encapsulated Citral and Its Effect on the Shelf Life of Shatangju Mandarin. *Journal of Food Protection*, *83*(8), 1315–1322. https://doi.org/10.4315/JFP-20-115

Churklam, W., Chaturongakul, S., Ngamwongsatit, B., & Aunpad, R. (2020). The mechanisms of action of carvacrol and its synergism with nisin against Listeria monocytogenes on sliced bologna sausage. *Food Control*, *108*(September 2019), 106864. https://doi.org/10.1016/j.foodcont.2019.106864

Coma, V. (2008). Bioactive packaging technologies for extended shelf life of meat-based products. Meat Science, 78, 90–103.Davidson & Naidu, 2000.

Davidson, P. M. (1997). Chemical preservatives and natural antimicrobial compounds. In M. P. Doyle, L. R. Beuchat, & T. J. Montville (Eds.), Food microbiology fundamentals and frontiers (pp. 520–556). New York: ASM Press.

De Azeredo, G. A., Stamford, T. L. M., Nunes, P. C., Gomes Neto, N. J., De Oliveira, M. E. G., & De Souza, E. L. (2011). Combined application of essential oils from Origanum vulgare L. and Rosmarinus officinalis L. to inhibit bacteria and autochthonous microflora associated with minimally processed vegetables. *Food Research International*, *44*(5), 1541–1548. https://doi.org/10.1016/j.foodres.2011.04.012

de Medeiros Barbosa, I., da Cruz Almeida, É. T., Gomes, A. C. A., & de Souza, E. L. (2020). Evidence on the induction of viable but non-culturable state in Listeria monocytogenes by Origanum vulgare L. and Rosmarinus officinalis L. essential oils in a meat-based broth. *Innovative Food Science and Emerging Technologies*, *62*(December 2019), 102351. https://doi.org/10.1016/j.ifset.2020.102351

Donsì, F., & Ferrari, G. (2016). Essential oil nanoemulsions as antimicrobial agents in food. *Journal of Biotechnology*, *233*, 106–120. https://doi.org/10.1016/j.jbiotec.2016.07.005

Ehsani, A., Rezaeiyan, A., Hashemi, M., Aminzare, M., Jannat, B., & Afshari, A. (2019). Antibacterial activity and sensory properties of Heracleum persicum essential oil, nisin, and Lactobacillus acidophilus against Listeria monocytogenes in cheese. *Veterinary World*, *12*(1), 90–96. https://doi.org/10.14202/vetworld.2019.90-96

Emami, S., Azadmard-Damirchi, S., Peighambardoust, S. H., Valizadeh, H., & Hesari, J. (2016). Liposomes as carrier vehicles for functional compounds in food sector. *Journal of Experimental Nanoscience*, *11*(9), 737–759. https://doi.org/10.1080/17458080.2016.1148273

Engel, J. B., Heckler, C., Tondo, E. C., Daroit, D. J., & da Silva Malheiros, P. (2017). Antimicrobial activity of free and liposome-encapsulated thymol and carvacrol against Salmonella and Staphylococcus aureus adhered to stainless steel. *International Journal of Food Microbiology*, *252*(April), 18–23. https://doi.org/10.1016/j.ijfoodmicro.2017.04.003

Fetsch, A., & Johler, S. (2018). Staphylococcus aureus as a Foodborne Pathogen. *Current Clinical Microbiology Reports*, *5*(2), 88–96. https://doi.org/10.1007/s40588-018-0094-x

Ghasemi Pirbalouti, A., Hashemi, M., & Ghahfarokhi, F. T. (2013). Essential oil and chemical compositions of wild and cultivated Thymus daenensis Celak and Thymus vulgaris L. *Industrial Crops and Products*, *48*, 43–48. https://doi.org/10.1016/j.indcrop.2013.04.004

Gochev, V. K., & Girova, T. D. (2009). Antimicrobial activity of various essential oils against spoilage and pathogenic microorganisms isolated from meat products. *Biotechnology and Biotechnological Equipment*, *23*, 900–904. https://doi.org/10.1080/13102818.2009.10818568

Gómez-García, M., Sol, C., De Nova, P. J. G., Puyalto, M., Mesas, L., Puente, H., Mencía-Ares, Ó., Miranda, R., Argüello, H., Rubio, P., & Carvajal, A. (2019). Antimicrobial activity of a selection of organic acids, their salts and essential oils against swine enteropathogenic bacteria. *Porcine Health Management*, *5*(1), 1–8. https://doi.org/10.1186/s40813-019-0139-4

Guandalini Cunha, B., Duque, C., Sampaio Caiaffa, K., Massunari, L., Araguê Catanoze, I., dos Santos, D. M., de Oliveira, S. H. P., & Guiotti, A. M. (2020). Cytotoxicity and antimicrobial effects of citronella oil (Cymbopogon nardus) and commercial mouthwashes on S. aureus and C. albicans biofilms in prosthetic materials. *Archives of Oral Biology*, *109*(September 2019). https://doi.org/10.1016/j.archoralbio.2019.104577

Habeeb, F., Shakir, E., Bradbury, F., Cameron, P., Taravati, M. R., Drummond, A. J., Gray, A. I., & Ferro, V. A. (2007). Screening methods used to determine the anti-microbial properties of Aloe vera inner gel. *Methods*, *42*(4), 315–320. https://doi.org/10.1016/j.ymeth.2007.03.004

Hassanshahian, M., Bayat, Z., Saeidi, S., & Shiri, Y. (2014). Antimicrobial activity of Trachyspermum ammi essential oil against human bacterial. *International Journal of Advanced Biological and Biomedical Research*, *2*(1), 18–24. https://doi.org/10.1051/0004-6361/200911869

Hulánková, R., & Bořilová, G. (2011). In vitro combined effect of oregano essential oil and caprylic acid against salmonella serovars, escherichia coli O157:H7, staphylococcus aureus and listeria monocytogenes. *Acta Veterinaria Brno*, *80*(4), 343–348. https://doi.org/10.2754/avb201180040343

Hyldgaard, M., Mygind, T., & Meyer, R. L. (2012). Essential oils in food preservation: Mode of action, synergies, and interactions with food matrix components. *Frontiers in Microbiology*, *3*(JAN), 1–24. https://doi.org/10.3389/fmicb.2012.00012

Jiang, Y., Wu, N., Fu, Y. J., Wang, W., Luo, M., Zhao, C. J., Zu, Y. G., & Liu, X. L. (2011). Chemical composition and antimicrobial activity of the essential oil of Rosemary. *Environmental Toxicology and Pharmacology*, *32*(1), 63–68. https://doi.org/10.1016/j.etap.2011.03.011

Kang, J., Jin, W., Wang, J., Sun, Y., Wu, X., & Liu, L. (2019). Antibacterial and anti-biofilm activities of peppermint essential oil against Staphylococcus aureus. *Lwt*, *101*(August 2018), 639–645. https://doi.org/10.1016/j.lwt.2018.11.093

Khorshidian, N., Yousefi, M., Khanniri, E., & Mortazavian, A. M. (2018). Potential application of essential oils as antimicrobial preservatives in cheese. *Innovative Food Science and Emerging Technologies*, *45*(March 2017), 62–72. https://doi.org/10.1016/j.ifset.2017.09.020

Knobloch, K., Pauli, A., Iberl, B., Weigand, H., & Weis, N. (1989). Antibacterial and antifungal properties of essential oil components. *Journal of Essential Oil Research*, *1*(3), 119–128. https://doi.org/10.1080/10412905.1989.9697767

Mallmann, C. A., Brugnari, T., Abreu Filho, B. A. de, Mikcha, J. M. G., & Machinski, M. (2017). Curcuma longa L. essential oil composition, antioxidant effect, and effect on Fusarium verticillioides and fumonisin production. *Food Control*, *73*, 806–813. https://doi.org/10.1016/j.foodcont.2016.09.032

Manzan, A. C. C. M., Toniolo, F. S., Bredow, E., & Povh, N. P. (2003). Extraction of Essential Oil and Pigments from Curcuma longa [L.] by Steam Distillation and Extraction with Volatile Solvents. *Journal of Agricultural and Food Chemistry*, *51*(23), 6802–6807. https://doi.org/10.1021/jf030161x

McClements, D. J. (2012). Nanoemulsions versus microemulsions: Terminology, differences, and similarities. *Soft Matter*, *8*(6), 1719–1729. https://doi.org/10.1039/c2sm06903b

Moghimi, R., Ghaderi, L., Rafati, H., Aliahmadi, A., & Mcclements, D. J. (2016). Superior antibacterial activity of nanoemulsion of Thymus daenensis essential oil against E. coli. *Food Chemistry*, *194*, 410–415. https://doi.org/10.1016/j.foodchem.2015.07.139

Mohan, A., & Purohit, A. S. (2020). Anti-Salmonella activity of pyruvic and succinic acid in combination with oregano essential oil. *Food Control*, *110*(October 2019), 106960. https://doi.org/10.1016/j.foodcont.2019.106960

Nazzaro, F., Fratianni, F., De Martino, L., Coppola, R., & De Feo, V. (2013). Effect of essential oils on pathogenic bacteria. *Pharmaceuticals*, *6*(12), 1451–1474. https://doi.org/10.3390/ph6121451

Nikolic, B., Vasilijevic, B., & Mitic-Culafic, D. (2019). Antilisterial effect of juniper (Juniperus communis) and its mixed application with winter savory (Satureja montana) in beef protection. *IOP Conference Series: Earth and Environmental Science*, *333*(1). https://doi.org/10.1088/1755-1315/333/1/012019

Paparella, A., Taccogna, L., Aguzzi, I., Chaves-López, C., Serio, A., Marsilio, F., & Suzzi, G. (2008). Flow cytometric assessment of the antimicrobial activity of essential oils against Listeria monocytogenes. *Food Control*, *19*(12), 1174–1182. https://doi.org/10.1016/j.foodcont.2008.01.002

Paudel, S. K., Bhargava, K., & Kotturi, H. (2019). Antimicrobial activity of cinnamon oil nanoemulsion against Listeria monocytogenes and Salmonella spp. on melons. *Lwt*, *111*(October 2018), 682–687. https://doi.org/10.1016/j.lwt.2019.05.087

Ricke, S. C., Kundinger, M. M., Miller, D. R., & Keeton, J. T. (2002). Alternatives to Antibiotics : Chemical and Physical Antimicrobial Interventions and Foodborne Pathogen Response. *Poultry Science*, *84*(4), 667–675. https://doi.org/10.1093/ps/84.4.667

Rossi, C., Chaves-López, C., Možina, S. S., Di Mattia, C., Scuota, S., Luzzi, I., Jenič, T., Paparella, A., & Serio, A. (2019). Salmonella enterica adhesion: Effect of Cinnamomum zeylanicum essential oil on lettuce. *Lwt*, *111*(February), 16–22. https://doi.org/10.1016/j.lwt.2019.05.026

Sadekuzzaman, M., Mizan, M. F. R., Kim, H. S., Yang, S., & Ha, S. Do. (2018). Activity of thyme and tea tree essential oils against selected foodborne pathogens in biofilms on abiotic surfaces. *LWT - Food Science and Technology*, *89*(April 2017), 134–139. https://doi.org/10.1016/j.lwt.2017.10.042

Sagalowicz, L., & Leser, M. E. (2010). Delivery systems for liquid food products. *Current Opinion in Colloid and Interface Science*, *15*(1–2), 61–72. https://doi.org/10.1016/j.cocis.2009.12.003

Shahrezaee, M., Soleimanian-Zad, S., Soltanizadeh, N., & Akbari-Alavijeh, S. (2018). Use of Aloe vera gel powder to enhance the shelf life of chicken nugget during refrigeration storage. *Lwt*, *95*(September 2017), 380–386. https://doi.org/10.1016/j.lwt.2018.04.066

Smid, E. J., & Gorris, L. G. M. (1999). Natural antimicrobials for food preservation. In M. S.Rahman (Ed.), Handbook of food preservation (pp. 285–308). New York:Marcel Dekker Inc.

Somrani, M., Inglés, M. C., Debbabi, H., Abidi, F., & Palop, A. (2020). Garlic, onion, and cinnamon essential oil anti-biofilms' effect against listeria monocytogenes. *Foods*, *9*(5), 1–12. https://doi.org/10.3390/foods9050567

Stanley, M. C., Ifeanyi, O. E., & Eziokwu, O. G. (2014). *Original Research Article Antimicrobial effects of Aloe vera on some human pathogens*. *3*(3), 1022–1028.

Swamy, M. K., Akhtar, M. S., & Sinniah, U. R. (2016). Antimicrobial properties of plant essential oils against human pathogens and their mode of action: An updated review. *Evidence-Based Complementary and Alternative Medicine*, *2016*. https://doi.org/10.1155/2016/3012462

Tanhaeian, A., Sekhavati, M. H., & Moghaddam, M. (2020). Antimicrobial activity of some plant essential oils and an antimicrobial-peptide against some clinically isolated pathogens. *Chemical and Biological Technologies in Agriculture*, *7*(1), 1–11. https://doi.org/10.1186/s40538-020-00181-9

Tassou, C. C., Lambropoulou, K., & Nychas, G.-J. E. (2004). Effect of prestorage treatments and storage conditions on the survival of Salmonella enteritidis PT4 and *Listeria monocytogenes* on fresh marine and freshwater aquaculture fish. Journal of Food Protection, 67,193–198.

Yuan, W., Teo, C. H. M., & Yuk, H. G. (2019). Combined antibacterial activities of essential oil compounds against Escherichia coli O157:H7 and their application potential on fresh-cut lettuce. *Food Control*, *96*(September 2018), 112–118. https://doi.org/10.1016/j.foodcont.2018.09.005.

Annexes

MIC and MBC values of plant-based extracts or essential oils pre-selected by partners IPB, UCO, AUA, UIZ and ISBST/UMA

Partner	Essential oil or active substance	Strain Identification	MIC (% w/v)[¥]	MBC (% w/v)[¥]	Method Applied	Reference
IPB	Rosemary	*L. monocytogenes WDCM 00019*	2	nd	Micro-dilution	Own experiments
IPB	Lemon balm	*L. monocytogenes WDCM 00019*	> 2	nd	Micro-dilution	Own experiments
IPB	Basil	*L. monocytogenes WDCM 00019*	> 2	nd	Micro-dilution	Own experiments
IPB	Tarragon	*L. monocytogenes WDCM 00019*	> 2	nd	Micro-dilution	Own experiments
IPB	Salvia	*L. monocytogenes WDCM 00019*	2	nd	Micro-dilution	Own experiments
IPB	Mentha spicata	*L. monocytogenes WDCM 00019*	> 2	nd	Micro-dilution	Own experiments
IPB	Rosemary	*L. monocytogenes WDCM 00019*	1	nd	Micro-dilution	Own experiments
IPB	Lemon balm	*L. monocytogenes WDCM 00019*	> 2	nd	Micro-dilution	Own experiments
IPB	Basil	*L. monocytogenes WDCM 00019*	> 2	nd	Micro-dilution	Own experiments
IPB	Tarragon	*L. monocytogenes WDCM 00019*	> 2	nd	Micro-dilution	Own experiments
IPB	Salvia	*L. monocytogenes WDCM 00019*	1	nd	Micro-dilution	Own experiments
IPB	Mentha spicata	*L. monocytogenes WDCM 00019*	1	nd	Micro-dilution	Own experiments
IPB	Rosemary	*L. monocytogenes WDCM 00019*	2	nd	Micro-dilution	Own experiments
IPB	Lemon balm	*L. monocytogenes WDCM 00019*	> 2	nd	Micro-dilution	Own experiments
IPB	Basil	*L. monocytogenes WDCM 00019*	0.5	nd	Micro-dilution	Own experiments
IPB	Tarragon	*L. monocytogenes WDCM 00019*	1	nd	Micro-dilution	Own experiments
IPB	Salvia	*L. monocytogenes WDCM 00019*	0.125	nd	Micro-dilution	Own experiments
IPB	Mentha spicata	*L. monocytogenes WDCM 00019*	1	nd	Micro-dilution	Own experiments
IPB	Rosemary	*Salmonella enterica subsp. Enterica*	2	nd	Micro-dilution	Own experiments
IPB	Lemon balm	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Basil	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Tarragon	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Salvia	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Mentha spicata	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Rosemary	*Salmonella enterica subsp. Enterica*	2	nd	Micro-dilution	Own experiments
IPB	Lemon balm	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Basil	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Tarragon	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Salvia	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Mentha spicata	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Rosemary	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Lemon balm	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Basil	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Tarragon	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Salvia	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Mentha spicata	*Salmonella enterica subsp. Enterica*	> 2	nd	Micro-dilution	Own experiments
IPB	Rosemary	*S. aureus WDCM 00032 (=ATCC 65*	> 2	nd	Micro-dilution	Own experiments
IPB	Lemon balm	*S. aureus WDCM 00032 (=ATCC 65*	> 2	nd	Micro-dilution	Own experiments
IPB	Basil	*S. aureus WDCM 00032 (=ATCC 65*	> 2	nd	Micro-dilution	Own experiments
IPB	Tarragon	*S. aureus WDCM 00032 (=ATCC 65*	> 2	nd	Micro-dilution	Own experiments
IPB	Salvia	*S. aureus WDCM 00032 (=ATCC 65*	> 2	nd	Micro-dilution	Own experiments

Partner	Essential oil or active substance	Strain Identification	MIC (% v/v)[¥]	MBC (% v/v)[¥]	Method Applied	Reference
UCO	*Thymus vulgaris* (thyme)	*Salmonella* Enteritidis ATCC13076	0.0625	nd	Micro-dilution	Own experiments
UCO	*Cymbopogon martinii* (palm rose)	*Salmonella* Enteritidis ATCC13077	0.125	nd	Micro-dilution	Own experiments
UCO	*Cymbopogon citratus* (lemongrass)	*Salmonella* Enteritidis ATCC13078	0.25	nd	Micro-dilution	Own experiments
UCO	*Ocimum gratissimum* (african basil)	*Salmonella* Enteritidis ATCC13079	1	nd	Micro-dilution	Own experiments
UCO	*Thymus vulgaris* (thyme)	*Staphylococcus aureus* ATCC6538	0.3013	nd	Micro-dilution	Zhang (2019)
UCO	*Thymus vulgaris* (thyme)	*Staphylococcus aureus* ATCC25923	0.062	0.062	Micro-dilution	Veloso (2019)
UCO	*Thymus vulgaris* (thyme)	*Staphylococcus aureus* STA32	0.25	nd	Micro-dilution	Pellegrini (2018)
UCO	*Thymus vulgaris* (thyme)	*Staphylococcus aureus* STA47	0.125	nd	Micro-dilution	Pellegrini (2018)
UCO	*Thymus vulgaris* (thyme)	*Staphylococcus aureus* STA39	0.125	nd	Micro-dilution	Pellegrini (2018)

Partner	Essential oil or active substance	Strain Identification	MIC (% v/v)[¥]	MBC (% v/v)[¥]	Method Applied	Reference
AUA	Carvacrol	*L. monocytogenes 10403S*	0.025	0.05	Micro-dilution	Churklam et al., 2019
		L. monocytogenes DMST17303				
		L. monocytogenes CM2-BM–HF–Black				
		L. monocytogenes CM8-ISO–HF–Blac				
		L. monocytogenes CM9-ISO–HF–Black				
		L. monocytogenes CM11-ISO–HF–Black				
		L. monocytogenes CM12-ISO–HF–Black				
		L. monocytogenes CM13-ISO–HF–Black				
		L. monocytogenes CM15-ISO–HF–Black				
		L. monocytogenes CECT 4032	0.01	nd	Tube Dilution	Somrani et al., 2020
AUA	Cinnamon oil nanoemulsion	*L. monocytogenes train- FSL*	0.078	0.078	Micro-dilution	Paudel et al., 2019
		L. monocytogenes N1-017, LMI				
		L. monocytogenes strain- FSL J2-064, LMII				
		L. monocytogenes strain- FSL N3-165, LMIII				
AUA	Galangal (*Alpinia galanga*)	*L. monocytogenes*	2.6	nd	Broth Dilution	Budiati et al., 2020
AUA	Garlic	*L. monocytogenes CECT 4032*	0.01	nd	Tube Dilution	Somrani et al., 2020
AUA	Ginger (*Zingiber officinale*)	*L. monocytogenes*	1.56	nd	Broth Dilution	Budiati et al., 2020
AUA	Heracleum persicum	*L. monocytogenes PTCC1165*	0.00025	0.00025	Micro-dilution	Eshani et al., 2019
AUA	*Juniperus communis*	*L. monocytogenes ATCC 19111*	0.5	2	Micro-dilution	Nikolic et al., 2019
		L. monocytogenes isolated from salmon (LMS)				
		L.monocytogenes from slaughterhouse water drainage tunnel (LMT)		1		
		L.monocytogenes from beef carcass (LMB)	1	4		
AUA	Lemongrass (*Cymbopogon citratus*)	*L. monocytogenes*	0.32	nd	Broth Dilution	Budiati et al., 2020
AUA	*Mentha viridis*	*L. monocytogenes4b CECT 4032*	0.25	0.25	Micro-dilution	Bouyahya et.al., 2020
AUA	Onion	*L. monocytogenes CECT 4032*	0.0025	nd	Tube Dilution	Somrani et al., 2020
AUA	Orange peel (*Citrus sinensis*)	*L. monocytogenes*	3.13	nd	Broth Dilution	Budiati et al., 2020
AUA	*Oreganum vulgaris*	*L. monocytogenes ATCC 13932*	0.000052	nd	Micro-dilution	Hulánková and Bořilová, 2011
		L. monocytogenes ATCC 13932				
		L. monocytogenes ATCC 7644	0.000125	nd	Tube Dilution	Azeredo et.al., 2011
		L. monocytogenes ATCC 7644	0.0025	nd	Micro-dilution	Barbosa et al., 2020
		L. monocytogenesATCC 19112				
		L. monocytogenes ATCC 19117				
AUA	*Rosmarinus officinalis L.*	*L. monocytogenes*	3.13	nd	Broth Dilution	Budiati et al., 2020
		L. monocytogenes ATCC 7644	0.002	nd	Tube Dilution	Azeredo et.al., 2011
		L. monocytogenes ATCC 7644	0.0005	nd	Micro-dilution	Barbosa et al., 2020
		L. monocytogenes ATCC 19112				
		L. monocytogenes ATCC 19117				
AUA	*Satureja montana*	*L. monocytogenes ATCC 19111*	0.5	1	Micro-dilution	Nikolic et al., 2019
		L. monocytogenes isolated from salmon (LMS)	1			
		L.monocytogenes from slaughterhouse water drainage tunnel (LMT)				
		L.monocytogenes from beef carcass (LMB)				
AUA	Turmeric (*Curcuma longa*)	*L. monocytogenes*	12.5	nd	Broth Dilution	Budiati et al., 2020

Partner	Essential oil or active substance	Strain Identification	MIC (% v/v)¥	MBC (% v/v)¥	Method Applied	Reference
UIZ	**Thymus satureioides-E.O.-**	L. monocytogenes CECT 4032	0.032	0.032	Micro-dilution	Own experiments
		L. innocua CECT 4031	0.032	0.032	Micro-dilution	
		S. aureus CECT 976	0.04	0.125	Micro-dilution	
		B. subtilis DSM 6633	0.25	0.25	Micro-dilution	
		P. aeruginosa CECT 118	1	>1	Micro-dilution	
		P. vulgaris CECT 484	>1	>1	Micro-dilution	
	Thymus satureioides-Eth.Ext.-	L. monocytogenes CECT 4032	0.5	1	Micro-dilution	Own experiments
		L. innocua CECT 4031	0.5	>1	Micro-dilution	
		S. aureus CECT 976	>1	>1	Micro-dilution	
		B. subtilis DSM 6633	>1	>1	Micro-dilution	
		P. aeruginosa CECT 118	>1	>1	Micro-dilution	
		P. vulgaris CECT 484	0.5	0.5	Micro-dilution	
	Thyme	L. monocytogenes NCTC 11994	0.05	0.05	Broth Dilution	H. Mith et al., 2014
		S. typhimurium ATCC 14028	0.1	0.1	Broth Dilution	
		E. coli ATCC 35150	0.05	0.1	Broth Dilution	
		S. aureus ATCC 25923	0.78	1.56	Broth Dilution	M. Carvalho et al., 2018
	Oreganum compactum	S. aureus MBLA	0.125	0.125	Micro-dilution	Bouyahya et al (2017)
		S. aureus CECT 976	0.25	0.25	Micro-dilution	
		S. aureus CECT 994	0.125	0.125	Micro-dilution	
		P. aeruginosa IH	2	2	Micro-dilution	
		L. monocytogenes CECT 4032	0.5	0.5	Micro-dilution	
		E. coli K12	0.25	0.25	Micro-dilution	
	Rosmarinus officinalis	S. aureus CECT 239	1.5	>3	Tube Dilution	Ait-Ouazzou et al (2011)
		L. monocytogenes EGD-e	0.5	1	Tube Dilution	
		L. monocytogenes CECT 935	3	>3	Tube Dilution	
		S. enteritidis CECT 4155	1.5	>3	Tube Dilution	
		E. coli O157:H7 CECT 4267	>3	>3	Tube Dilution	
		P. aeruginosa CECT 110	>3	>3	Tube Dilution	
	Mentha	S. aureus ATCC 29213	0.25	0.25	Micro-dilution	Chraibi et al (2017)
		B. cereus	0.25	0.25	Micro-dilution	
		E. coli ATCC 25922	0.5	1	Micro-dilution	
		S. typhi	0.5	1	Micro-dilution	
		P. aeruginosa ATCC 27853	8	>8	Micro-dilution	
	Garlic	L. monocytogenes CECT 4032	0.01	nd	Tube Dilution	Somrani et al., 2020
		L. monocytogenes	0.4	>0.8	Micro-dilution	S. Pedrós-Garrido et al., 2020
		S. enterica ATCC 25957	0.2	nd	Broth Dilution	H. Al-Talib et al., 2015
		E. coli ATCC 43889	0.1	nd		
		S. aureus	0.8	nd	Agar Dilution	S. Sethi et al., 2013
	Lavandula mairei	L. monocytogenes CECT 4032	0.008	0.01	Macro-dilution	A. El Hamdaoui et al., 2018
		Salmonella	nd	nd		
		E. coli	nd	nd		
		S. aureus CECT 976	0.012	0.012		

Partner	Essential oil or active substance	Strain Identification	MIC (% v/v)¥	MBC (% v/v)¥	Method Applied	Reference
ISBST/UMA	Lemon peel (*Citrus lemon*)	*Staphylococcus aureus*	2.5	nd	Micro-dilution	Otang and Afolaya, 2016
		Escherichia coli	2.5	nd		
		Bacillus cereus	0.02	nd		
ISBST/UMA	*Date (Phoenix dactylifera L.)*	*Bacillus cereus ATCC 11778*	1.56	3.13	Broth Dilution	El Arem et al., 2013
		Staphylococcus aureus ATCC 25923	0.78	1.56		
		Listeria monocytogenes ATCC 19115	0.09	0.19		
		Escherichia coli ATCC 35218	12.50	25		
ISBST/UMA	*Sesame seeds (Sesamum indicum)*	*Bacillus subtilis*	0.092	nd	Streak method	Sandeep et al., 2014
		Escherichia coli	0.095	nd		
ISBST/UMA	Oleuropein (olive leaves)	*Pseudomonas aeruginosa*	0,10	nd	Micro-dilution	Djenane et al., 2012
		Staphylococcus aureus	0.05	nd		
		Salmonella enterica	0.1	nd		
ISBST/UMA	Hesperidin (orange byproduct)	*Aeromonas hydrophila ATCC 7966*	3125	12500	Broth micro-dilution	Abuelsaad et al., 2013
		Bacillus subtilus	45	nd	Agar diffusion	Abass et al., 2014
		Escherchia coli	75	nd		
		Salmonella typhi	175	nd		
		Staphylococcus aureus	175	nd		
ISBST/UMA	Garlic	*Staphylococcus aureus*	0.00016	0.00064	Tube-dilution	Elsom et al., 2000
		Escherichia coli	0.0032	0.0032		
		Salmonella	1 - 1.25	1.3 - 1.5	Broth Dilution	Belguith et al., 2010
ISBST/UMA	Mint	*Listeria monocytogenes*	0.5	0.5	Micro-dilution	Bouyahya et al., 2017
	Fennel seeds (*Foeniculum vulgare*)	*Escherchia coli*	0.13	0.13	Broth Dilution	Sayed Ahmad et al., 2017
		Staphylococcus Aureus	0.13	0.13		
	Mint (*Mentha spicata*)	*Listeria monocytogenes*	15.3		Micro-dilution	Teixeira et *al.* 2012
ISBST/UMA	Corriander (EO)	*Listeria monocytogenes*	<0.01	nd	Broth Dilution	Delaquis et al., 2004
		Escherichia coli 25922	0.2	0.2		Casetti et al., 2012
		Staphylococcus Aureus ATCC 25923	0.2	1.6		Silva et al., 2011
		Salmonella ATCC 13311	0.4	0.8		Silva et al., 2012
ISBST/UMA	Red pepper	*Listeria monocytogenes*	0.40	-	Micro-dilution	Omolo et al., 2014
		Escherichia coli	0.06	-		