



HAL
open science

Plants: A natural solution to enhance raw milk cheese preservation?

Coralie Dupas, Benjamin Métoyer, Halima El Hatmi, Isabelle Adt, Samir Mahgoub, Emilie E. Dumas

► To cite this version:

Coralie Dupas, Benjamin Métoyer, Halima El Hatmi, Isabelle Adt, Samir Mahgoub, et al.. Plants: A natural solution to enhance raw milk cheese preservation?. Food Research International, Elsevier, 2020, 130, pp.108883. 10.1016/j.foodres.2019.108883 . hal-02442493

HAL Id: hal-02442493

<https://hal-univ-lyon1.archives-ouvertes.fr/hal-02442493>

Submitted on 21 Jul 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial | 4.0 International License

1 **Plants: a natural solution to enhance raw milk cheese**
2 **preservation?**
3

4 Coralie Dupas^a, Benjamin Métoyer^a, Halima El Hatmi^b, Isabelle Adt^a, Samir A. Mahgoub^c and Emilie
5 Dumas^{*a}

6
7 ^a Univ Lyon, Université Claude Bernard Lyon 1, ISARA Lyon, BioDyMIA - Equipe Mixte d'Accueil
8 n°3733, rue Henri de Boissieu, F-01000 Bourg en Bresse, France

9 ^b Institut des Régions Arides (IRA), Km 22.5, route du Djorf, 4119 Medenine, Tunisia.

10 ^c Department of Agricultural Microbiology, Faculty of Agriculture, Zagazig University, 44511, Egypt
11

12 (* Corresponding author)

13
14 E-mail addresses of the authors:

15 coralie.dupas-farrugia@univ-lyon1.fr, benjamin.metoyer@univ-lyon1.fr, elhatmihalima@yahoo.fr,
16 isabelle.adt@univ-lyon1.fr, mahgoub.samir@gmail.com, emilie.dumas@univ-lyon1.fr,
17

18 Declarations of interest: none
19

20 **Abstract**

21

22 Plants have been traditionally used for centuries in cheese manufacturing, either for their aromatic
23 properties or as technological auxiliaries (e.g. milk-clotting enzyme preparations, cheese wrappers).

24 Some of these plants are known to have antimicrobial and / or antioxidant properties and could also
25 act as natural preservatives for raw milk and derived dairy products.

26 This review examined the traditional uses of plants in dairy processing, and then focuses on known
27 antimicrobial and antioxidant properties of their extracts (e.g. maceration, decoction, essential oil).

28 Known effects of these plants on technological flora (starter cultures and microorganisms implicated
29 in cheese ripening) were also summarized, and the potential for plant extracts used in combination
30 with hurdle technologies was explored. Then, legal restriction and bioactivity variations from a culture
31 media to a food matrix was reviewed: non-toxic bioactive molecules found in plants, extract
32 preparation modes suitable with foodgrade processing restrictions, the role of the food matrix as a
33 hindrance to the efficiency of bioactive compounds, and a review of food legislation. Finally, some
34 commercial plant extracts for milk preservation were discussed.

35

36 **Keywords:** raw milk; cheese; plants; plant extracts; natural preservatives

37

| | |
|----|-------------------------------------------------------------------------------------------------|
| 38 | 1. Introduction |
| 39 | 2. Traditional uses of plants for dairy processing |
| 40 | 2.1. Addition of plants in milk, before cheese making |
| 41 | 2.2. Use of plant extracts for milk-clotting |
| 42 | 2.3. Addition of plants on cheese, after coagulation |
| 43 | |
| 44 | 3. Biopreservation of milk and cheeses with plants |
| 45 | 3.1. Dairy products with addition of essential oils |
| 46 | 3.2. Dairy products with addition of plant extract other than essential oil |
| 47 | 3.3. Dairy products with raw plant additions |
| 48 | 3.4. Biological activities of plant extract used for milk-clotting |
| 49 | 3.5. Effect of plant extract on pro-technological flora |
| 50 | 3.6. Synergic effect and hurdle technology |
| 51 | |
| 52 | 4. From traditional plants uses to innovative products for food conservation enhancement |
| 53 | 4.1 Plant bioactive compounds families with potential use as food preservatives |
| 54 | 4.2 Sample preparations and extractive techniques suitable for the food industry |
| 55 | 4.3. Food legislation |
| 56 | 4.4. Commercial innovative systems with plant extracts |
| 57 | |
| 58 | 5. Conclusion |
| 59 | |
| 60 | |

61 **1. Introduction**

62 The Mediterranean dairy sector is characterized by high production volumes and product
63 diversification in all the Mediterranean countries. The Mediterranean countries comprise countries
64 located in and around the Mediterranean Sea, that is to say Southern Europe (Gibraltar, Spain, France,
65 Monaco, Italy, Malta, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, Greece,
66 Turkey), the Middle East (Syria, Cyprus, Lebanon, Israel, Palestine) and North Africa (Egypt, Libya,
67 Tunisia, Algeria, Morocco). Mediterranean dairy products supply essential nutrients such as high
68 biological value proteins, vitamins and minerals and are also attractive resources for the economic
69 livelihood of marginal areas in hot climate countries (Pulina et al., 2018). However, in these countries,
70 a warm climate and poor hygienic conditions, combined with inadequate refrigeration increase
71 biohazard of raw milk. This poses health safety concerns but also economic and ecological problems.
72 Indeed, during periods of milk overproduction (lactation period), prices can be lower and milk
73 collection centers can become saturated, and so a part of the production is lost. In addition, the short
74 shelf life of dairy product is an obstacle to distribution over long distances. Finally, in countries such
75 as Egypt, a deeply rooted popular belief considers raw milk cheese as a safer product than heat-treated
76 milk or pasteurized milk cheese. However, its consumption, especially by infants, can have dramatic
77 consequences (Ayad, Omran, & El-Soda, 2006; Hammad, Hassan, & Shimamoto, 2015; Ayad et al.,
78 2006).

79 In Europe, manufactured products made from raw milk are widespread and mainly located in the
80 Mediterranean countries. In these countries, there are many traditional products e.g. cheeses,
81 fermented milks, for which technological process prescribes the use of raw milk and very diverse
82 technological procedures transmitted across centuries (Boyazoglu & Morand-Fehr, 2001). This
83 diversification is officially recognized by the European Union through the attribution of the Protected
84 Designation of Origin (PDO) label. Moreover, the number of consumers of raw milk is increasing in
85 developed countries, as more people embrace the “organic” way of life and refuse to consume
86 processed or preserved foods (Nero & Carvalho, 2018).

87 Recent studies have reviewed the microbiological hazard of raw milk and derived products (Claeys et
88 al., 2013; Verraes et al., 2015). Milk contamination may be endogenous (e.g. *via* animal infection,

89 mastitis), or exogenous: the milk can be contaminated during milking *via* the udders and teats, but also
90 by the environment and the material, i.e. the milking machine, bucket, or milk storage tank, and finally
91 during the storage and transport. The major pathogenic bacteria found in raw milk cheese are *Listeria*
92 *monocytogenes*, verocytotoxin-producing *Escherichia coli*, *Staphylococcus aureus*, *Salmonella sp.* and
93 *Campylobacter sp.* (Boyazoglu & Morand-Fehr, 2001; Claeys et al., 2013; Hammad et al., 2015;
94 Pesavento, Calonico, Ducci, Magnanini, & Lo Nostro, 2014; Verraes et al., 2015). As there is no heat
95 treatment for raw milk cheese before production, these microorganisms are not killed during the
96 process and can also cause foodborne disease outbreaks (EFSA & ECDPC, 2016; Lahti et al., 2017).
97 However, small process modification during raw milk cheese production might have an effect on these
98 microorganisms (growth inhibition, destruction, or even growth promotion). For example,
99 fermentative bacteria (lactic acid bacteria) can inhibit or kill pathogenic bacteria in different ways,
100 through nutritional and space competition or metabolite production (e.g. lactic acid, bacteriocins).
101 Salting reduces the water activity, and inhibits some pathogenic bacteria growth. During ripening,
102 changes in physico-chemical conditions, such as pH increase, might be more favorable for the growth
103 of microorganisms including pathogenic ones. It is important to mention that the contamination on the
104 surface of a cheese can also occur during ripening. On top of that, adding ingredients like plants or
105 herbs could influence the evolution of the microorganisms in the cheese. Indeed, numerous countries
106 produce cheeses with leaves and plants for their organoleptic properties, or for decorative or
107 preservation purposes (Hayaloglu & Farkye, 2011).

108 The objective of this publication (Figure 1) is to review the traditional uses of plants for cheese
109 making and their associated antioxidant and/or antimicrobial properties. A summarize of the scientific
110 knowledge about the potential role of these plants for raw milk and cheese preservation is presented.
111 This review also provide information on innovative herbal/legume systems (commercial or not) that
112 have recently been developed for food/dairy products preservation or that could be used for such
113 purposes. The last part reviews legislation for the use of these systems.

114
115
116

2. Traditional uses of plants for dairy processing

2.1. Addition of plants in milk, before cheese making

Plants have been traditionally used in many types of cheeses for flavoring. While the most commonly encountered ones are fresh cheeses mixed with aromatic herbs, all cheese families can be flavored with plants (Table 1). They are thus mixed directly with the cheese curd at the beginning of ripening, to add a particular flavour that will be enhanced during ripening process. Commonly used herbs and spices and other flavors added to cheeses include red, black and green peppers, thyme, cloves, cumin, parsley, paprika, onion/garlic and other plants such as shallots, chives; and less commonly tarragon, oregano, mustard seed or bran, nettles, nutmeg, basil, and horseradish. Traditionally, the amount rarely exceeds 1% of the curd (Hayaloglu & Farkye, 2011). Other flavors may include nuts, smoke, soot/ashes, cider, beer, wine and wine byproducts, mushrooms, olives and olive oil, sundried tomatoes, cocoa, bell pepper, or black pepper (Sicard, 2018)

While the addition of natural extracts to cheese curd for cheese fortification, e.g. with the intention of improving the level of antioxidant in the consumer's blood, is presently more and more investigated for health product development (Marchiani, Bertolino, Ghirardello, McSweeney, & Zeppa, 2015; Rashidinejad, Birch, Sun-Waterhouse, & Everett, 2013), only a few studies concerning the role of extract additions in biopreservation processes are available. For example, the protective effects of a green tea extract against oxidation induced by light exposure were suggested (Huvaere et al., 2011).

Addition of black cumin oil to Domiati cheeses reduced the counts of the inoculated food borne pathogens during cold storage (Hassanien, Mahgoub, & El-Zahar, 2014; S. A. Mahgoub, Ramadan, & El-Zahar, 2013). Raw milk and its derivatives can also be preserved from pathogenic bacteria during cold storage by adding esterified legume proteins and 11S (glycinin) and 7S (β -conglycinin) soy globulin (S. Mahgoub, Osman, & Sitohy, 2011; A. Osman, Mahgoub, El-Masry, Al-Gaby, & Sitohy, 2014; A. O. Osman, Mahgoub, & Sitohy, 2013; M. Z. Sitohy, Mahgoub, & Osman, 2012). Moreover, extracts from plants used in these cheeses showed interesting bacteriostatic/bactericidal effects on target flora such as *Listeria monocytogenes in vitro*, or in other kinds of cheeses (see below).

144 However, these studies were often undertaken in culture media, thus neglecting the matrix effect that
145 could hinder the active molecules release from plants, and without considering the effects on the
146 positive endogenous raw milk flora. A better understanding of these aspects could be of particular
147 interest, because, as seen in table 1, (i) most of the cheese that are concerned are soft curd cheeses,
148 made with unpasteurized milk, with a short ripening time and considered as likely sources of
149 microbiological hazards and (ii) as these plants have been traditionnaly used in cheese-making,
150 sometimes for centuries, it seems that they are harmless to pro-technological microorganisms (figure
151 1).

152

153 **2.2 Use of plant extracts for milk-clotting**

154 Since ancient times, plant extracts have been added to milk to facilitate the coagulation step in
155 cheesemaking (Shah, Mir, & Paray, 2014). Cheeses made with vegetable coagulants instead of rennet
156 are suitable for specific diets (vegetarianism) or religious restrictions (Halal, Kosher). However,
157 nowadays, vegetable coagulant has often been replaced by animal rennet or microbial coagulant. In
158 France, during the Middle ages, the coagulation of some variants of Jonchée Niortaise cheese was
159 made using a thistle flower or artichoke extracts (Froc, 2007). The process has been preserved in
160 several Mediterranean countries: today, Spain and Portugal are the most important producers of
161 cheeses made with vegetable coagulant (Table 1).

162 *Cynara spp.* (in particular *C. cardunculus* var. *sylvestris*, also known as “wild cardoon”) is the most
163 used vegetal coagulant (Shah et al., 2014). Usually, the flowers are harvested in the summer, before
164 being air-dried. Despite an important variation of methods between cheesemakers, cardoon is added to
165 milk using two major techniques : i) flowers are mixed to milk (at nearly 30°C), during a few minutes,
166 and then milk is filtrated , ii) dry flowers are macerated in small amount of salted water and then the
167 filtrat is added to the milk (Macedo, Xavier Malcata, & Oliveira, 1993).

168 With this method, milk-clotting is the result of the action of cardosins and cyprosins, a kind of aspartic
169 proteases also known as phytepsins (EC 3.4.23.40), that have a high specificity towards κ -casein
170 (Vairo Cavalli, Lufrano, Colombo, & Priolo, 2013). The use of serine and cysteine proteases from

171 plants for milk clotting has also been reported (Shah et al., 2014). Current uses in cheese making
172 include caprifig extracts in Ficu and Cacioricotta (Faccia et al., 2012).

173

174 **2.3. Addition of plants on cheese, after coagulation**

175 While some cheeses are traditionally rolled into crushed herbs or spices such as garlic, pepper, sage,
176 chives, rosemary, the whole plant is sometimes used directly on the cheese surface for flavouring
177 and/or aesthetic purposes (Table 1). Among French cheeses, thyme or rosemary sprigs or even
178 glasswort (Galette du Paludier) can be encountered. Wood, leaves have long been used in cheese
179 processing and packaging around the globe. Aromatic effect most often appeared as a side-effect of
180 that packaging process while the initial intention was cheese preservation (Froc, 2007). Chestnut,
181 gentian, avizzo, or vine leaves, for example, were (or are still) used as cheese interleaves (Cantin,
182 Gaudin, & Leser, 2013), as moisture absorbers or for cheese wrapping. In France, Banon goat cheese
183 is ripened wrapped in chestnut leaves (Décret du 23 juillet 2003 relatif à l'appellation d'origine
184 contrôlée « Banon », 2003) which brings specific flavours thanks to anaerobic fermentation and to the
185 tannin-rich rot-proof leaves. These traditionnal uses participate in the taste of the final product
186 (Collectif, 1998; Froc, 2007; Sicard, 2018), which directly suggests molecule migrations from the
187 organic matter to the cheese surface and/or curd. In the U.K., the Cornish Yarg is wrapped in nettle or
188 wild garlic leaves to form an mouldy edible rind. In Italy, Pecorino is sometimes covered with a fresh
189 walnut leaf, Ubriaco with a fig leaf and Seirass with hay for decorative purposes (Sicard, 2018).
190 Little is known concerning possible migration of molecules, such as phenolic compounds from the leaf
191 to the cheese, and concerning their potent action as natural preservatives during cheese storage and
192 ripening. Terpenes arising from the surface of mint leave springling, during the manufacture of the
193 cheese, were detected in Halloumi cheese curd (Papademas & Robinson, 2001). Their role as
194 flavouring molecules is reported, but while the role of mint as a preservative in this cheese is
195 traditionally claimed, as the cheese is entirely covered in folded mint leaves during the ripening period
196 (Sicard, 2018), it has never been scientifically investigated.

197

198 **3. Biopreservation of milk and cheeses with plants**

199 Numerous plants traditionally added in dairy products have been studied for their anti-oxydant and
200 anti-microbial effects. This part summarizes findings on the plants whose efficiency as been
201 demonstrated (Table 2).

202

203 **3.1. Dairy products with addition of essential oils**

204 As the demand for natural preservatives increases, essential oil addition in cheese was particularly
205 explored (Table 2). For example, *E. coli* O157:H7 and *L. monocytogenes* growth were inhibited in feta
206 cheese by adding essential oil of thyme (at a dose of 0.1 mL/100 g) (Govaris, Botsoglou, Sergelidis, &
207 Chatzopoulou, 2011) or oregano (0.1 or 0.2 mL/100 g) (Govaris et al., 2011). Antimicrobial activity of
208 these 2 essential oil was also demonstrated in fresh goat cheese (Zantar et al., 2014). Original
209 approaches, such as the use of antimicrobial sachets containing rosemary and thyme oils, designed to
210 enhance the shelf-life of shredded mozzarella, were also reported (Han, Patel, Kim, & Min, 2014).

211 The recent review of Khorshidian et al. (Khorshidian, Yousefi, Khanniri, & Mortazavian, 2018) on
212 preservation of cheese with essential oils can be consulted for further information.

213

214 **3.2. Dairy products with addition of plant extract other than essential oil**

215 In spite of the proven antibacterial effect of essential oil for cheese preservation, several factors limit
216 their application: intense flavour and potential interactions with food components may be an hindrance
217 to their efficiency. Other concerns include their price (Calo, Crandall, O'Bryan, & Ricke, 2015;
218 Hyldgaard, Mygind, & Meyer, 2012; Perricone, Arace, Corbo, Sinigaglia, & Bevilacqua, 2015), and
219 their potential toxicity at high doses despite their GRAS status. For these reasons, recent studies on
220 dairy product preservation have focused on the effects of plant extracts other than essential oil (Table
221 2). Rosemary extract was thus successfully used as an antioxidant for the lipid preservation of cow
222 milk enriched with fish oil (Qiu, Jacobsen, & Sørensen, 2018). Rosemary extract also inhibited the
223 growth of *L.monocytogenes* (4×10^5 CFU.mL⁻¹) incubated at 37°C for 24 hours in cheddar base media
224 at a concentration of 750 µg.mL⁻¹ (Tayel, Hussein, Sorour, & El-Tras, 2015). Rosemary alcoholic

225 extracts enhanced the oxidative stability of butter at temperatures of 60 and 110°C, when added at
226 concentrations such as 400 mg of phenolic compounds per kg of butter (Santos, Shetty, & da Silva
227 Miglioranza, 2014). A clove extract (625 µg.mL⁻¹) inhibited a population of *L.monocytogenes* (4x10⁵
228 CFU.mL⁻¹) incubated at 37°C for 24 hours in cheddar based media (Tayel et al., 2015). In the same
229 study, an oregano extract (950 µg.mL⁻¹) yielded similar results.

230 Other extracts of plants used in cheesemaking have shown antimicrobial properties against foodborne
231 pathogens, like *Thymus vulgaris* (Thymus) (Kozłowska, Laudy, Przybył, Ziarno, & Majewska, 2015;
232 Mostafa et al., 2018), *Olea europea* (oliv tree) (Ahmed, Rabii, Garbaj, & Abolghait, 2014; Aouidi,
233 2012; Botsoglou, Govaris, Ambrosiadis, Fletouris, & Papageorgiou, 2014; Sudjana et al., 2009) or
234 *Urtica doica* (nettle) (Aksu & Kaya, 2004; Alp & Aksu, 2010; Alp Erbay, Dağtekin, Türe, Yeşilsu, &
235 Torres-Giner, 2017), but to our knowledge, these extracts have not been tested in dairy products. On
236 the other hand, an extract from a plant belonging to the genus *Thymus*, *Thymus mastichina*, was able
237 to inhibit the development of spoilage microorganism on the cheese surface (F. Carvalho et al., 2018).
238 Also, an extract of oil mill wastewater from olives, rich in phenolic compounds, was tested to
239 enhance the preservation of “Fior di latte” cheese. The phenols retarded the growth of the spoilage
240 bacteria *Pseudomonas fluorescens* and *Enterobacteriaceae*, resulting in a cheese longer shelf life
241 (Roila et al., 2019).

242 The use of plant extracts, as preservatives can also be a source of innovative products by creating new
243 tastes as a side effect. Low fat Kalari (Indian hard and dry cheese) was sprayed with 0%, 2.5% and
244 5.0% pine needles extract (*Cedrus deodara*) and aerobically packaged in low-density polyethylene
245 pouches. This resulted in lower thiobarbituric acid reactive substances, free fatty acid (% oleic acid)
246 values, and lower total plate, counts of psychrophilic bacteria, yeast and mould (Mahajan, Bhat, &
247 Kumar, 2016). Addition of *Inula britannica* flower extract during cheddar-type cheese making
248 increased antioxidant properties (Lee, Jeewanthi, Park, & Paik, 2016). Clove (*Syzygium aromaticum*)
249 extract increased the stability of cheese against lipid oxidation (Shan, Cai, Brooks, & Corke, 2011)
250 and was also efficient against *L. monocytogenes*, *S. aureus*, and *Salmonella enterica* in cheese at room
251 temperature (Shan et al., 2011). Finally, fresh ovine Greek cheese was supplemented with saffron,

252 resulting in a significant decrease of the total aerobic bacteria counts, with an antibacterial activity
253 against coliform and enterococci groups (Aktypis et al., 2018).

254 Another possibility is to use plant proteins as alternative food preservatives (Nielsen, 1985). Active
255 peptides were produced from plant seeds such as peas (Aluko, 2008) soy bean (Chen, Yang, Suetsuna,
256 & Chao, 2004; Wu & Ding, 2002), rice, sunflower and wheat (Guang & Phillips, 2009). These active
257 peptides were found to be good sources of antimicrobial, antioxidants and functional agents.

258 Several classes of plant proteins and their fractions with antibacterial and/or antifungal properties have
259 been isolated, characterized and applied as antimicrobial agents in food systems (A. Osman et al.,
260 2014, Ali Osman, Abbas, Mahgoub, & Sitohy, 2016; M. Sitohy, Doheim, & Badr, 2007, Sitohy,
261 Mahgoub, Osman, El-Masry, & Al-Gaby, 2014; Osman, El-Araby, & Taha, 2016). The minimum
262 inhibitory concentrations (MICs) of 7S and 11S globulins isolated from cowpea seeds ranged between
263 10 to 200 $\mu\text{g}\cdot\text{mL}^{-1}$ against *L. monocytogenes*, *Listeria ivanovii*, *S. aureus*, *Streptococcus pyogenes*,
264 *Klebsiella pneumonia*, *Pseudomonas aeruginosa*, *E. coli* and *Salmonella sp.* Supplementing 11S
265 globulin at both concentrations 50 and 100 $\mu\text{g}/\text{g}$ to minced meat showed considerable decreases in
266 viable bacterial count, psychrotrophs and coliforms (Abdel-Shafi, Al-Mohammadi, Osman, Enan,
267 Abdel-Hameid, & Sitohy, 2019). Therefore, further studies are needed to use antimicrobial natural
268 peptides as food preservatives.

269

270 **3.3. Dairy products with raw plant additions**

271 Studies concerning the potential of whole leaves and dried herbs for cheese preservation are scarce.
272 The commercial potential of cheese covered with lard and dehydrated rosemary leaves was explored
273 (Marinho, Bersot, Nogueira, Colman, & Schnitzler, 2015) for their antioxidant effects. To date, the
274 only study exploring health-related effects of a leaf-wrapped cheese concerned the Banon cheese. The
275 Banon cheese curd was investigated for antiproliferative activity against the HL-60 human
276 promyelocytic leukemia cell line, but no significant effect was observed, while other investigated goat
277 cheeses revealed more interesting profiles (Yasuda et al., 2012).

278 Carochó et al. (Carochó et al., 2016) compared the effect of the incorporation of decoctions and
279 dehydrated basil in Serra da Estrela cheese. Basil leaves provided antioxidant activity to the cheeses,

280 reduced the moisture and preserved the unsaturated fatty acids and proteins; while the basil decoction
281 showed an antimicrobial effect against eight bacterial and eight fungi strains in culture media. These
282 bioactivities were not studied in cheese, though. Josipovick (Josipović et al., 2015) added fresh or
283 dried parsley, dill, pepper, garlic and rosemary to cottage cheese. This plant addition did not reduce
284 the concentration of foodborne pathogens, contrary to the plant extract. Soft cheese supplemented with
285 either 1% garlic or 1% clove powders showed no improvement in antimicrobial effects against
286 *L. monocytogenes* after one or two weeks at 37°C and at 4°C (Leuschner & Ielsch, 2003).

287 The effect of *Matricaria recutita* L. (chamomile) on cheese preservation was tested by adding a
288 chamomile powder or a decoction (Caleja et al., 2015). Both additions similarly improved the
289 antioxidant activity of plain cottage cheese without modifying the nutritional characteristics or fatty
290 acids profiles. After 14 days of storage, only the control cheese showed visual microbial degradation.
291 The bioactivity of the chamomile decoction was tested in cultured media showing antimicrobial
292 activities against 16 bacterial and fungi strains (which can be attributed to the presence of phenolic
293 compounds).

294 Another strategy is to directly incorporate plants to the cattle's diet. A rosemary leaves distillate was
295 introduced in the diet of the Murciano-Granadina goats and the resulting effects on the phenolic
296 profile of the milk was investigated. While neither yield nor quality were impaired, flavonoids and
297 phenol diterpenes could be detected in relevant quantities in the goat milk (Jordán, Moñino, Martínez,
298 Lafuente, & Sotomayor, 2010). However, the same kind of experiment performed with thyme leaves
299 distillate resulted in a slightly impaired clotting ability, and the addition of thyme leaves did not show
300 any inhibition of the mesophilic aerobic flora and enterobacteria growth between the control and the
301 cheeses made from such milk (Boutoial et al., 2013).

302

303 **3.4. Biological activities of plant extract used for milk-clotting**

304 As previously described, some plant extracts, such as *Cynara cardunculus* var *sylvestris* flower
305 extracts, may be used for milk clotting. (Ben Amira et al., 2017). Besides this application, some
306 studies have shown the antioxidant and antimicrobial effect of different organs of the *C. cardunculus*

307 species, due to phenolic compounds with bioactive properties. The three main *C. cardunculus* taxa are
308 the domestic cardoon (*C. cardunculus* var. *altilis* DC), the globe artichoke (*C. cardunculus* var.
309 *scolymus* L.) and the wild cardoon (*C. cardunculus* var. *Sylvestris* (Lamk) Fiori).
310 Falleh et al. (Falleh et al., 2008) compared extracts from domestic cardoon leaves, flowers and seeds.
311 The phenolics/flavonoids contents of leaves and seeds were similar (approximately 14 mg GAE g⁻¹
312 DW) and 2 times higher than those in flowers. Seed extracts displayed the highest DPPH[•] followed by
313 leaves, and flowers; IC₅₀ values were 23, 53 and 118 µg.mL⁻¹ respectively. In contrast, leave extract
314 showed the highest capacity to quench superoxide compared to seeds and flowers, IC₅₀ values were 1.
315 6 and 9 µg.mL⁻¹ respectively. Only an extract from leaves was tested for antimicrobial activity,
316 showing growth inhibition of *S. aureus* and *E. coli*. Kukić et al. (Kukić et al., 2008) also showed the
317 antioxidant and antimicrobial effects of cardoon leave extracts. Besides their strong antioxidant
318 activity, the cardoon inflorescences showed antibacterial activity against Gram-positive strains, the
319 lowest MIC being observed for *L. monocytogenes* (Dias et al., 2018). However, this antimicrobial
320 effect was not found in food media when comparing Ewes' cheese produced with plant coagulant from
321 cardoon *C. cardunculus* (21 g.100 L⁻¹) and cheese produced with a calf rennet (Galán, Cabezas, &
322 Fernández-Salguero, 2012). Throughout the ripening of the cheeses, no significant differences in
323 microbial counts were observed between the ones made with these two types of coagulant. It can also
324 be noted that Silva et al. (Silva, Pihlanto, & Malcata, 2006) studied ovine and caprine cheeselike
325 systems manufactured with proteases from *C. cardunculus* and showed that it is a source of peptides
326 with antioxidant activities.

327

328 **3.5. Effect of plant extract on pro-technological flora**

329 One drawback of using plant extracts as preservatives is that cheese is a fermented product containing
330 a living flora, and thus such preservatives have an action on the pathogenic flora while sparing
331 microorganisms implicated in milk coagulation and ripening.

332 *Thymus vulgaris* essential oil affected *S. aureus*, *L. monocytogenes* growth (1.3 log CFU.mL⁻¹
333 reduction at 10°C for 24h), but also the mesophilic starter co-culture in cheese-mimicking models

334 (cheese-based broth and in a semi-solid (*coalho*) cheese) (R. J. de Carvalho et al., 2015). Some
335 essential oils met this criterion successfully, though : a rosemary essential oil (215mg.L⁻¹ in sheep milk
336 cheese) inhibited *Clostridium ssp.* during the 5 month ripening period while not reducing the
337 population of lactic acid bacteria (Moro, Librán, Berruga, Carmona, & Zalacain, 2015). *Cuminum*
338 *cuminum* essential oil (0, 7.5, 15 and 30 µL.100mL⁻¹ in cow milk) used in synergy with *Lactobacillus*
339 *acidophilus* strains also inhibited *S. aureus* in Iranian white brined cheese (Sadeghi, Akhondzadeh
340 Basti, Noori, Khanjari, & Partovi, 2013). Oregano essential oil (200 mg.L⁻¹ in cow milk) impeded the
341 growth of enterobacteria in a traditionnal Argentinean cheese while not affecting starters (Marcial et
342 al., 2016). Thyme or sage essential oils added at doses of 1500 mg.kg⁻¹ to Fior di Latte cheese
343 inhibited *Pseudomonas spp.* and coliforms stored at 10°C for 6 days while not reducing the population
344 of lactic acid bacteria (Gammariello, Di Giulio, Conte, & Del Nobile, 2008). Grape seed extract of
345 *Vitis vinifera* showed important anti- *L. monocytogenes* effects (Rhodes, Mitchell, Wilson, & Melton,
346 2006), while the addition of grape seed extract of *Vitis vinifera* did not affect yoghurts *Lactobacilli*
347 count (Chouchouli et al., 2013). Galindo et al. (Galindo-Cuspinera, Westhoff, & Rankin, 2003) studied
348 the antimicrobial properties of a commercial Annato extract against pathogenic, lactic acid and
349 spoilage microorganisms. Indeed, Annato is an orange-red condiment and food coloring extracted
350 from the achiote tree (*Bixa orellana*), and added to obtain the color of numerous cheeses e.g. Cheddar,
351 Mimolette, Edam and Livarot. The effect was very variable between studied strains. An inhibitory
352 effect on pathogenic *Bacillus cereus*, *Clostridium perfringens*, and *S. aureus*, with MICs values of
353 0.08, 0.31, and 0.16% (vol/vol) was respectively observed. Higher concentrations of Annato (0.63%,
354 vol/vol) were needed to inhibit the growth of pro-technological *Streptococcus thermophilus*,
355 *Lactobacillus casei* subsp. *casei* and *Lactococcus lactis*. However, at this concentration, the growth of
356 *L. monocytogenes* and *Enterococcus durans* were not inhibited (MICs: 1.25 and 2.5%, vol/vol,
357 respectively). No activity was detected against *Lactobacillus plantarum*, *Bifidobacterium bifidum*,
358 yeasts, or selected Gram-negative bacteria.

359

360 **3.6. Synergic effect and hurdle technology**

361 To enhance the effects of plant extracts, combinations with other preservation technologies have been
362 studied. For example, supercritical fluid thyme extracts containing carvacrol (190.44–609.57 $\mu\text{g}\cdot\text{mL}^{-1}$)
363 reduced $\text{CFU}\cdot\text{g}^{-1}$ *L. monocytogenes* by 1.68 log in cheeses when combined with a high pressure
364 treatment (Bleoancă et al., 2016). The addition of 3% of cayenne or of 9% of dry green pepper extract
365 (obtained from a maceration in 70% ethanol) to Kareish cheese during manufacture reduced the *S.*
366 *aureus* population from 10^8 $\text{CFU}\cdot\text{g}^{-1}$ to undetectable levels within two days of storage at 4°C (Wahba,
367 Ahmed, & Ebraheim, 2010).

368

369 **4. From traditional plants uses to innovative products for food conservation** 370 **enhancement**

371 Tradition provides interesting semi-empiric knowledge, and is particularly helpful in the choice of
372 plants to use for bio-guided essays. Nevertheless, scientific investigations are required to achieve
373 innovative preservation solutions. Compound identification and characterization, extraction process
374 optimization and tests for undesirable effects are needed. The specificities of the food industry in
375 terms of stability and toxicity, for example, must be investigated. Also, these solutions must comply
376 with current food legislation or provide sufficient evidence to modify it.

377 In this part, an overview of plant compound families with a potential as food preservative, foodgrade
378 extraction techniques and the food legislation constraints, is presented.

379

380 **4.1 Plant bioactive compounds families with potential use as food** 381 **preservatives**

382 Most of the compounds from plants that are of interest in biopreservation solutions are secondary
383 metabolites with various functions in plant survival, among which is the antimicrobial activity. Plant
384 metabolite content varies according to the taxa, the organ, the stage of growth and development, the

385 season, and the stress conditions, for example. Metabolites are classified into different categories
386 depending on the chemical structure and the main ones are presented in Table 3.

387 The most abundant literature concerns phenolic compounds. They have important roles fighting plant
388 pathogens and ultraviolet radiations, and so can be good candidates for antimicrobial and antioxidant
389 activities. They are compounds with one or more hydroxyl groups attached to a phenyl moiety. Based
390 on their chemical structure, they can be divided into flavonoids and non-flavonoïds phenolics. Other
391 secondary metabolites with reported antibacterial and/or antioxydant properties consist of waxes, fatty
392 acids, alkaloids, terpenoids, glycosides and phytosterols (Da Silva, Rocha-Santos, & Duarte, 2016,
393 Mogoşanu, Grumezescu, Bejenaru, & Bejenaru, 2017; Hugo & Hugo, 2015). It is generally accepted
394 that such compounds are more efficient against Gram-positive than Gram-negative bacteria (Pisoschi
395 et al., 2018; Hintz, Matthews, & Di, 2015).

396 Antimicrobial peptide also represents a promising tool for enhancing the shelf-life of food (Johnson et
397 al., 2017). Generally, their mode of action towards pathogens consists in electrostatic interaction,
398 membrane permeabilizing and then disruption (Rai, Pandit, Gaikwad, & Kövics, 2016). Important
399 structural diversification of antimicrobial peptides from plants and their associated antibacterial
400 activity provide lots of potential natural compounds for food preservation (Salas, Badillo-Corona,
401 Ramírez-Sotelo, & Oliver-Salvador, 2015).

402 However, an extract showing an antimicrobial effect in a culture medium will not necessarily have an
403 effect in a food media, because of the structure's complexity (Calo et al., 2015; Hyldgaard et al., 2012;
404 Perricone et al., 2015). For example, antimicrobial effect could be lowered due to solubilization of
405 hydrophobic active molecules in lipidic phases, whereas microorganisms are present in aqueous
406 phases. Proteins may also interact with phenolic compounds (Calo et al., 2015; Hyldgaard et al., 2012;
407 Perricone et al., 2015). Finally, during the different steps of cheese production, a_w , pH, microflora
408 composition, temperature and nutrient composition will change, having an influence on the biological
409 activity of plant extracts in food. Therefore, a fine understanding of the chemical nature of plant
410 extracts, of food matrix characteristics and possible interactions with dairy food components of
411 extracted molecules is a prerequisite.

412

413 **4.2 Sample preparations and extractive techniques suitable for the food** 414 **industry**

415 Different techniques exist to extract compounds from plants and several parameters, such as
416 temperature, pressure and solvent composition might be set. In this part, common extractive
417 techniques are discussed with a differentiation between extraction for essential oil and other extraction
418 (mainly solid-liquid extraction).

419 Prior to extraction, several sample preparations are used. Generally, dried samples are preferred to
420 fresh samples because of metabolites deterioration during storage. However, cases were reported for
421 *Moringa oleifera* leaves for which no significant differences with total phenolic contents were
422 observed between dry and fresh samples whereas dried samples contain more flavonoids (Vongsak et
423 al., 2013).

424 The contact surface between the organic material and the solvent highly impacts the extraction yield
425 and so, a powdered sample is preferred to a grinded one. This preparation leads to small and
426 homogenized organic particles. It was shown that particle sizes smaller than 0.5 mm are ideal for an
427 efficient extraction (Thermo scientific, 2013). The most common method is maceration, for which no
428 apparatus is needed. This method uses small amounts of solvent and is inexpensive. The main
429 disadvantage is a moderate yield.

430 Soxhlet extraction is a continuous extractive technique for which no successive extractions are needed
431 to fully drain the secondary metabolites from the organic material, it is also very simple and cheap
432 (Luque de Castro & García-Ayuso, 1998). Disadvantages of this technique are a long extraction time
433 and a high risk of thermal decomposition since solvent temperatures are up to their boiling point
434 during the extraction (Wang & Weller, 2006).

435 Introduced in the 90s, pressurized liquid extraction is characterized by high temperature (from 50 to
436 200 °C) and high pressure (from 500 to 3000 psi), mainly to keep the solvent liquid, resulting in high
437 performance (yield, quantities of solvent, duration) (Azmir et al., 2013). A high temperature disturbs
438 weak interactions (Van der Waals, hydrogen bond and dipolar interaction) and decreases solvent
439 viscosity. High pressure increases contact between solvent and matrices. Some limitations for the

440 technique include its cost and the degradation of thermo sensible compounds (Mustafa & Turner,
441 2011).

442 Enzyme-assisted extraction is a recently developed technique that might be considered sustainable
443 since it uses mainly water. Applied temperatures are generally below 90°C, and less solvent is needed.
444 It consists in the use of selected enzymes (e.g. cellulase, pectinase, hemicellulose) to disrupt cellular
445 integrity and/or hydrolysis metabolites bound to the membrane. The efficiency of this technique
446 depends strongly on the cell-wall architecture, and so it seems attractive for sea-weed whose cell walls
447 and cuticles are chemically and structurally more complex and heterogeneous than those of land plants
448 (Wijesinghe & Jeon, 2012). This technique has successful applications on commercial compounds
449 such as the extraction of carotenoids from marigold flowers (Barzana et al., 2002), the simultaneous
450 extraction of glucovanillin from green vanilla pods and the transformation into vanillin (Ruiz-Terán,
451 Perez-Amador, & López-Munguia, 2001) and lycopene extraction from tomatoes peel (Dehghan-
452 Shoar, Hardacre, Meerdink, & Brennan, 2011). Numerous commercial compounds extracted using
453 enzyme-assisted extraction are listed in recent reviews (Mustafa & Turner, 2011; Puri, Sharma, &
454 Barrow, 2012; Wijesinghe & Jeon, 2012).

455 Essential oils are composed of volatile and lipophilic compounds, which are mainly lightly
456 hydroxylated terpenoid and low molecular weight aromatic compounds. They can be obtained by
457 different means, among which hydrodistillation, steam distillation, maceration in apolar solvent and
458 supercritical extraction (Tyśkiewicz, Gieysztor, Konkol, Szałas, & Rój, 2018). Hydrosols, which are
459 aqueous products of hydrodistillation (also known as floral waters), might be considered too, since
460 they usually are food grade products, and some (cumin, clove, garlic, mustard, oregano, rosemary,
461 sage and thyme hydrosols) exhibited antimicrobial activities against food relevant strains (D'Amato,
462 Serio, López, & Paparella, 2018). Hydrodistillation using a Clevenger apparatus is a common method
463 for essential oil extraction because it is cheap and easy to use, but some of its disadvantages are a low
464 yield, losses of volatile compounds, and long extraction times. Moreover, the degradation of
465 unsaturated compounds, partial hydrolysis and deterioration due to heat-sensitive compounds might
466 occur (Puri et al., 2012). Nevertheless, recent innovations improving yield and decreasing the

467 extraction time have been reported. These were hydrodistillation coupled with ultrasonic extraction
468 and ohmic hydrodistillation. During ohmic hydrodistillation, an alternative current is passed through
469 the round bottom flask to generate heat within the medium (Gavahian, Farahnaky, Shavezipur, &
470 Sastry, 2016).

471 Most expensive, the supercritical fluids extraction (SFE) can be performed at temperatures around 313
472 K thereby preserving original oil composition and properties. SFE is mostly performed with carbon
473 dioxide (CO₂) because it has low critical pressure (73.8 bar) and temperature (31.1°C). In addition, it
474 is relatively non-toxic, nonflammable, and relatively cheap (Sodeifian, Sajadian, & Saadati Ardestani,
475 2016, Ivanovic, Mistic, Zizovic, & Ristic, 2012), nevertheless other solvents (or co-solvent), including
476 water, may be used (Da Silva et al., 2016). SFE is valuable for the food industry especially for
477 products such as de-caffeinated or de-alcoholized beverages, zero-fat potato chips, and others
478 (Brunner, 2005).

479 The application of ultrasound during the extraction (UAE) process is widely used to increase yield and
480 to decrease duration. Under some conditions, the ultrasonic capillary effect increases the depth and the
481 velocity of the penetration of the extraction solvents into canals and pores. Moreover, during the UAE,
482 disruptions of biological membranes may occur, therefore facilitating the release of extractable
483 compounds. Comparing the extraction rate of chlorophylls between the UAE and maceration process,
484 a linear increase is obtained at the beginning of the UAE, corresponding to a direct solubilization of
485 chlorophylls (ref "à ajouter partie ultrasons"). Fragmentation of friable solids resulting from ultrasonic
486 cavitation has been identified by several authors. In addition, particle size may decrease during the
487 application of ultrasound therefore increasing the surface exchange. Fragmentation can be due to inter-
488 particle collisions, and from shockwaves created from collapsing cavitation bubbles in the liquid. The
489 ultrasonic capillary effect (UCE) refers to the increase in the depth and velocity of the penetration of
490 the liquid into canals and pores under some of the conditions of ultrasonication (Dai & Mumper, 2010,
491 Vilku, Mawson, Simons, & Bates, 2008). Ultrasound-assisted extraction is cheap and might be
492 applied to a small and large scale of plants.

493

494 **4.3. Food legislation**

495 Raw milk can be contaminated by various important pathogenic bacteria leading to safety risks for
496 consumers. High level of hygienic conditions during milking are required to minimize microbial risk.
497 Unfortunately, such conditions are not sufficient to guarantee safety for consumers (Willis et al.,
498 2018). Not only taste, but also tradition, cultural norms, socio-economic status, health perception and
499 risks contribute to the acceptance of raw milk products by consumers. Preferences for raw- *versus*
500 pasteurized-milk products vary between countries, with trends emerging, such as the preference for
501 raw-milk products in Southern Europe and for pasteurized-milk products in Northern Europe (Nero &
502 Carvalho, 2018). These different consumption cultures impact legislations all around the world. For
503 example, it is illegal to sell raw milk as food in Australia, Canada and in some States of the United
504 States of America (USA) (Baars, 2019), while raw milk sale is authorized in the European Union,
505 although some differences in law interpretation between country members should be noted. In some
506 areas, like England or some American States , raw milk can be sold but only directly from the
507 producer to the consumer (Baars, 2019, Willis et al., 2018). In Mediterrean countries like Tunisia or
508 Egypt, raw milk consumption is a tradition and food regulations are generally harmonized with EU
509 food regulation (CE) N°178/2002. Although some countries allow raw milk sales, to date, heat
510 treatment (pasteurization or sterilization) is highly recommended by governments, regulatory
511 authorities and/or public health practitioners in order to reduce the risk of foodborne illness
512 (Muehlhoff & FAO, 2013, Codex Alimentarius Commission, 2011).

513 Similarly to raw milk, raw-milk derived products are considered as “risky foods.” Heat treatment
514 applied to milk (pasteurization or sterilization) leads to an alteration of cheese properties (i. e. typical
515 aromas, texture, flavors). In developed countries, cheeses are manufactured with pasteurized milk, and
516 raw-milk cheese diffusion is limited, even in Europe, despite a derogative directive (92/46) of the EEC
517 (Licitra, Caccamo, & Lortal, 2019). However, traditional and artisan raw-milk cheeses are produced
518 worldwide and have an important economic role, and also a social and a cultural role. As plants are
519 already traditionally used in cheese production methods for their aromatic properties, or in other food

520 products, plant additions in raw-milk in order to enhance the safety of cheeses respect the existing
521 legislation (Food an Drug Administration - Food Ingredients & Packaging, 2019; Regulation EC
522 N°1334/2008, 2008).

523 **4.4. Commercial innovative systems with plant extracts**

524 Many edible plants are known for their antimicrobial and / or antioxidant potential. Nevertheless, only
525 a few of them are actually marketed for their properties as food preservatives. This part presents some
526 promising plant / plant extracts with a potential commercial application or already commercialized.
527 Legume extracts, especially from the the Fabaceae family (e.g. cowpeas, soybean, peas) contain
528 polyphenols or proteins known for their antimicrobial activity against foodborne pathogens like
529 *L. monocytogenes* or *Salmonella* spp. (Pina-Pérez & Ferrús Pérez, 2018, Sitohy, Mahgoub, & Osman,
530 2012) or antioxidant properties (Jayathilake et al., 2018). For example, esterified proteins from
531 soybean and chickpea enhance raw buffalo milk conservation, even at room temperature (Osman,
532 Mahgoub, El-Masry, Al-Gaby, & Sitohy, 2014, (M. Sitohy, Mahgoub, & Osman, 2011). Nevertheless,
533 there are no preservatives based on legume extracts currently on the market.

534 In some Asians coutries, all bamboo parts (e.g. shoot skin, seeds, leaves) are largely used for industrial
535 and domestic uses (notably as a traditional source of food). Furthermore, bamboo has been used in
536 medicine since ancient times (Nirmala, Bisht, Bajwa, & Santosh, 2018). Studies revealed that bamboo
537 contains various bioactive compounds especially antioxidant which can be beneficial to the
538 consumer's health. Furthermore, the bamboo species *Phyllostachys pubescens* is known for it is
539 antimicrobial activity against *Staphylococcus aureus* (Tanaka, Kim, Oda, Shimizu, & Kondo, 2011), and
540 bamboo vinegar can be used to developped edible coating for pork chops conservation (Zhang, He,
541 Kang, & Li, 2018). Bamboo properties are now exploited by the Take X society (Japan). Takex
542 Fresh™ is a bamboo extract based food additive (alcohol formulation) that can be used instead of
543 sodium hypochlorite (100 ppm) to wash foods like vegetables or fish in order to improve their storage
544 life.

545 BioVia™ YM 10 (Danisco, Denmark) contains, notably, green tea extract, and mustard essential oil;
546 it has been developed to control food spoilage through yeast and mold. Freshglow Co (USA) sells
547 sheets of paper that have been infused with plant extract like Fenugreek and claims that these sheets
548 can enhance fruit and vegetable conservation time at home from 2 to 4 folds.

549 Rosemary extracts for food preservation are commercially available, with, for example, the Santiox®
550 (Santis, Morocco), a natural discolored and deodorized extract from rosemary leaves containing 15%
551 carnosic acid, 1 to 4% carnosol and 1 to 6% rosmarinic acid which claims antioxidant efficiency with
552 applications for milk and dairy products. Another commercial product : Guardox™ RA (Hunday, Belgium)
553 is a rosemary extract that is rich in rosmarinic acid, with minimal odor and bitterness which
554 was developed to delay lipid oxidation or rancidity on a wide range of products (e.g. cookies, soft
555 drinks, cooked meat, ready to eat meals).

556 Hydroxytyrosol is a major constituent of olives that possesses antimicrobial and antioxidant activities
557 (Robles-Almazan et al., 2018) without genotoxic effects (Kirkland, Edwards, Woehrle, & Beilstein,
558 2015). It is currently commercialized by CREAGRI, Inc.® (USA) in Hidrox®. The antimicrobial and
559 antioxidant properties of Hidrox® for food preservation is supported by literature (Soni, Burdock,
560 Christian, Bitler, & Crea, 2006). In the same way, Citrox® (New Zealand) is a citrus extract based
561 product that is on the market for the food industry. It has been demonstrated that Citrox® can affect
562 foodborne bacteria growth in dairy based products (Tsiraki et al., 2018), (Tsiraki & Savvaidis, 2016).

563 **5. Conclusion**

564 Numerous plants are traditionally used in cheese making, for their flavouring properties as well as for
565 their technological properties (e.g. milk clotting, packaging). Some of those plants contain peptides
566 and/or secondary metabolites that exhibit antimicrobial properties against foodborne pathogens. In
567 Mediterranean countries, dairy products, mainly raw milk, play an important role in the local
568 economic sector, and in the diet of local consumers. However, the contamination level of raw milk
569 with pathogenic strains might be enhanced by the lack of refrigeration or adequate transformation
570 equipments. Thus, delaying microbial contamination of raw milk with plants traditionally associated

571 with dairy products might be part of the solution. Such solutions can be developed in all the
572 Mediterranean countries while respecting regulations and economic considerations. Also, scientific
573 studies must prove the antimicrobial effect against pathogenic and spoilage microorganisms, while
574 preserving the technological flora implicated in milk clotting and ripening.

575

576 **Acknowledgements**

577 Funding: This work was supported by the Project AROMATIC, funded through the ARIMNet2_2017,
578 Joint Call by the following funding agencies: ANR (France), ISERA (Tunisie) and ASRT (Egypt).
579 ARIMNet2 (ERA-NET) has received funding from the European Union's Seventh Framework
580 Programme for research, technological development and demonstration under grant agreement no.
581 618127.

582

583 **References**

- 584 Ahmed, A. M., Rabii, N. S., Garbaj, A. M., & Abolghait, S. K. (2014). Antibacterial effect of olive
585 (*Olea europaea* L.) leaves extract in raw peeled undeveined shrimp (*Penaeus semisulcatus*).
586 *International Journal of Veterinary Science and Medicine*, 2(1), 53–56.
587 <https://doi.org/10.1016/j.ijvsm.2014.04.002>
- 588 Aksu, M. I., & Kaya, M. (2004). Effect of usage *Urtica dioica* L. on microbiological properties of
589 sucuk, a Turkish dry-fermented sausage. *Food Control*, 15(8), 591–595.
590 <https://doi.org/10.1016/j.foodcont.2003.09.006>
- 591 Aktypis, A., Christodoulou, E. D., Manolopoulou, E., Georgala, A., Daferera, D., & Polysiou, M.
592 (2018). Fresh ovine cheese supplemented with saffron (*Crocus sativus* L.): Impact on
593 microbiological, physicochemical, antioxidant, color and sensory characteristics during
594 storage. *Small Ruminant Research*, 167, 32–38.
595 <https://doi.org/10.1016/j.smallrumres.2018.07.016>
- 596 Alp, E., & Aksu, M. İ. (2010). Effects of water extract of *Urtica dioica* L. and modified atmosphere
597 packaging on the shelf life of ground beef. *Meat Science*, 86(2), 468–473.
598 <https://doi.org/10.1016/j.meatsci.2010.05.036>
- 599 Alp Erbay, E., Dağtekin, B. B. (Gözü), Türe, M., Yeşilsu, A. F., & Torres-Giner, S. (2017). Quality
600 improvement of rainbow trout fillets by whey protein isolate coatings containing electrospun
601 poly(ε-caprolactone) nanofibers with *Urtica dioica* L. extract during storage. *LWT - Food*
602 *Science and Technology*, 78, 340–351. <https://doi.org/10.1016/j.lwt.2017.01.002>
- 603 Aluko, R. E. (2008). *Determination of Nutritional and Bioactive Properties of Peptides in Enzymatic*
604 *Pea, Chickpea, and Mung Bean Protein Hydrolysates*. 91(10), 947–956.
- 605 Aouidi, F. (2012). *Etude et valorisation des feuilles d'Olivier Olea europaea dans l'industrie Agro-*
606 *Alimentaire* (Université de Carthage). Retrieved from
607 https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwidyI_E8Y_dAhUMzhoKHTXaBI8QFjAAegQIBxAC&url=https%3A%2F%2Fwww.imbe.fr%2F
608 <https://www.imbe.fr>

609 IMG%2Fpdf%2Fre-
610 38_2012_aouidi_these_version_soutenance.pdf%3F932%2F1696e160fbaaf69aaf4d32d8211b
611 77fd483c397e&usg=AOvVaw0LvM9ISz0lYgK-uWcjw6Uy

612 Ayad, E. H. E., Omran, N., & El-Soda, M. (2006). Characterisation of lactic acid bacteria isolated
613 from artisanal Egyptian Ras cheese. *Le Lait*, 86(4), 317–331.
614 <https://doi.org/10.1051/lait:2006007>

615 Azmir, J., Zaidul, I. S. M., Rahman, M. M., Sharif, K. M., Mohamed, A., Sahena, F., Omar, A. K. M.
616 (2013). Techniques for extraction of bioactive compounds from plant materials: A review.
617 *Journal of Food Engineering*, 117(4), 426–436.
618 <https://doi.org/10.1016/j.jfoodeng.2013.01.014>

619 Baars, T. (2019). Regulations and Production of Raw Milk. In *Raw Milk* (pp. 65–89).
620 <https://doi.org/10.1016/B978-0-12-810530-6.00004-3>

621 Barzana, E., Rubio, D., Santamaria, R. I., Garcia-Correa, O., Garcia, F., Ridaura Sanz, V. E., &
622 López-Munguía, A. (2002). Enzyme-Mediated Solvent Extraction of Carotenoids from
623 Marigold Flower (*Tzagetes erecta*). *Journal of Agricultural and Food Chemistry*, 50(16),
624 4491–4496. <https://doi.org/10.1021/jf025550q>

625 Basile, A., Sorbo, S., Giordano, S., Ricciardi, L., Ferrara, S., Montesano, D., Ferrara, L. (2000).
626 Antibacterial and allelopathic activity of extract from *Castanea sativa* leaves. *Fitoterapia*, 71,
627 S110–S116. [https://doi.org/10.1016/S0367-326X\(00\)00185-4](https://doi.org/10.1016/S0367-326X(00)00185-4)

628 Ben Amira, A., Bauwens, J., De Pauw, E., Besbes, S., Attia, H., Francis, F., & Blecker, C. (2017).
629 Identification of proteins from wild cardoon flowers (*Cynara cardunculus* L.) by a proteomic
630 approach. *Journal of Chemical Biology*, 10(1), 25–33. [https://doi.org/10.1007/s12154-016-](https://doi.org/10.1007/s12154-016-0161-9)
631 [0161-9](https://doi.org/10.1007/s12154-016-0161-9)

632 Bleoancă, I., Saje, K., Mihalcea, L., Oniciuc, E.-A., Smole-Mozina, S., Nicolau, A. I., & Borda, D.
633 (2016). Contribution of high pressure and thyme extract to control *Listeria monocytogenes* in

634 fresh cheese - A hurdle approach. *Innovative Food Science & Emerging Technologies*, 38, 7–
635 14. <https://doi.org/10.1016/j.ifset.2016.09.002>

636 Borges, A., Ferreira, C., Saavedra, M. J., & Simões, M. (2013). Antibacterial Activity and Mode of
637 Action of Ferulic and Gallic Acids Against Pathogenic Bacteria. *Microbial Drug Resistance*,
638 19(4), 256–265. <https://doi.org/10.1089/mdr.2012.0244>

639 Botsoglou, E., Govaris, A., Ambrosiadis, I., Fletouris, D., & Papageorgiou, G. (2014). Effect of olive
640 leaf (*Olea europea* L.) extracts on protein and lipid oxidation in cooked pork meat patties
641 enriched with *n*-3 fatty acids: Olive leaf extracts and oxidation of pork patties. *Journal of the*
642 *Science of Food and Agriculture*, 94(2), 227–234. <https://doi.org/10.1002/jsfa.6236>

643 Boutoial, K., García, V., Rovira, S., Ferrandini, E., Abdelkhalek, O., & López, M. B. (2013). Effect of
644 feeding goats with distilled and non-distilled thyme leaves (*Thymus zygis* subsp. *gracilis*) on
645 milk and cheese properties. *Journal of Dairy Research*, 80(04), 448–456.
646 <https://doi.org/10.1017/S0022029913000459>

647 Boyazoglu, J., & Morand-Fehr, P. (2001). Mediterranean dairy sheep and goat products and their
648 quality. *Small Ruminant Research*, 40(1), 1–11. <https://doi.org/10.1016/S0921->
649 4488(00)00203-0

650 Brunner, G. (2005). Supercritical fluids: technology and application to food processing. *Journal of*
651 *Food Engineering*, 67(1–2), 21–33. <https://doi.org/10.1016/j.jfoodeng.2004.05.060>

652 Bukvicki, D., Giweli, A., Stojkovic, D., Vujisic, L., Tesevic, V., Nikolic, M., Marin, P. D. (2018).
653 Short communication: Cheese supplemented with *Thymus algeriensis* oil, a potential natural
654 food preservative. *Journal of Dairy Science*, 101(5), 3859–3865.
655 <https://doi.org/10.3168/jds.2017-13714>

656 Caleja, C., Barros, L., Antonio, A. L., Ciric, A., Barreira, J. C. M., Sokovic, M., Ferreira, I. C. F. R.
657 (2015). Development of a functional dairy food: Exploring bioactive and preservation effects
658 of chamomile (*Matricaria recutita* L.). *Journal of Functional Foods*, 16, 114–124.
659 <https://doi.org/10.1016/j.jff.2015.04.033>

- 660 Calo, J. R., Crandall, P. G., O'Bryan, C. A., & Ricke, S. C. (2015). Essential oils as antimicrobials in
661 food systems – A review. *Food Control*, 54, 111–119.
662 <https://doi.org/10.1016/j.foodcont.2014.12.040>
- 663 Cantin, M.-A., Gaudin, C., & Leser, N. (2013). *Guide de l'amateur de fromages*. Paris: A. Michel.
- 664 Carocho, M., Barros, L., Barreira, J. C. M., Calhella, R. C., Soković, M., Fernández-Ruiz, V.,
665 Ferreira, I. C. F. R. (2016). Basil as functional and preserving ingredient in “Serra da Estrela”
666 cheese. *Food Chemistry*, 207, 51–59. <https://doi.org/10.1016/j.foodchem.2016.03.085>
- 667 Carvalho, F., Rodrigues, A., Gomes, D. M. G. S., Ferreira, F. M. L., Dias, S. P., Pereira, C. J. D., &
668 Henriques, M. H. F. (2018). Chapter 7 - Improvement of Ripened Cheese Quality and Safety
669 With *Thymus mastichina* L. Bioactive Extracts. In A. M. Holban & A. M. Grumezescu (Eds.),
670 *Advances in Biotechnology for Food Industry* (pp. 197–211). <https://doi.org/10.1016/B978-0->
671 12-811443-8.00007-4
- 672 Chanwitheesuk, A., Teerawutgulrag, A., Kilburn, J. D., & Rakariyatham, N. (2007). Antimicrobial
673 gallic acid from *Caesalpinia mimosoides* Lamk. *Food Chemistry*, 100(3), 1044–1048.
674 <https://doi.org/10.1016/j.foodchem.2005.11.008>
- 675 Chen, J.-R., Yang, S.-C., Suetsuna, K., & Chao, J. C.-J. (2004). Soybean protein-derived hydrolysate
676 affects blood pressure in spontaneously hypertensive rats. *Journal of Food Biochemistry*,
677 28(1), 61–73. <https://doi.org/10.1111/j.1745-4514.2004.tb00055.x>
- 678 Chouchouli, V., Kalogeropoulos, N., Konteles, S. J., Karvela, E., Makris, D. P., & Karathanos, V. T.
679 (2013). Fortification of yoghurts with grape (*Vitis vinifera*) seed extracts. *LWT - Food Science*
680 *and Technology*, 53(2), 522–529. <https://doi.org/10.1016/j.lwt.2013.03.008>
- 681 Claeys, W. L., Cardoen, S., Daube, G., De Block, J., Dewettinck, K., Dierick, K., Herman, L. (2013).
682 Raw or heated cow milk consumption: Review of risks and benefits. *Food Control*, 31(1),
683 251–262. <https://doi.org/10.1016/j.foodcont.2012.09.035>
- 684 Collectif. (1998). *L'inventaire du patrimoine culinaire de la France. Auvergne. Produits de terroir et*
685 *recettes traditionnelles*. Albin Michel.

686 Da Silva, R. P. F. F., Rocha-Santos, T. A. P., & Duarte, A. C. (2016). Supercritical fluid extraction of
687 bioactive compounds. *TrAC Trends in Analytical Chemistry*, 76, 40–51.
688 <https://doi.org/10.1016/j.trac.2015.11.013>

689 Dai, J., & Mumper, R. J. (2010). Plant Phenolics: Extraction, Analysis and Their Antioxidant and
690 Anticancer Properties. *Molecules*, 15(10), 7313–7352.
691 <https://doi.org/10.3390/molecules15107313>

692 D’Amato, S., Serio, A., López, C. C., & Paparella, A. (2018). Hydrosols: Biological activity and
693 potential as antimicrobials for food applications. *Food Control*, 86, 126–137.
694 <https://doi.org/10.1016/j.foodcont.2017.10.030>

695 Dashtdar, M., Dashtdar, M. R., Dashtdar, B., shirazi, M. khabaz, & Khan, S. A. (2013). In-Vitro, Anti-
696 Bacterial Activities of Aqueous Extracts of *Acacia catechu* (L.F.) Willd, *Castanea sativa*,
697 *Ephedra sinica* stapf and *Shilajita mumiyo* Against Gram Positive and Gram Negative
698 Bacteria. *Journal of Pharmacopuncture*, 16(2), 15–22.
699 <https://doi.org/10.3831/KPI.2013.16.014>

700 de Carvalho, R. J., de Souza, G. T., Honório, V. G., de Sousa, J. P., da Conceição, M. L., Maganani,
701 M., & de Souza, E. L. (2015). Comparative inhibitory effects of *Thymus vulgaris* L. essential
702 oil against *Staphylococcus aureus*, *Listeria monocytogenes* and mesophilic starter co-culture
703 in cheese-mimicking models. *Food Microbiology*, 52, 59–65.
704 <https://doi.org/10.1016/j.fm.2015.07.003>

705 *Décret du 23 juillet 2003 relatif à l'appellation d'origine contrôlée « Banon »*. Pub. L. No.
706 AGRP0300859D, § 33, 12688 (2003).

707 Dehghan-Shoar, Z., Hardacre, A. K., Meerdink, G., & Brennan, C. S. (2011). Lycopene extraction
708 from extruded products containing tomato skin: Lycopene extraction from extruded products.
709 *International Journal of Food Science & Technology*, 46(2), 365–371.
710 <https://doi.org/10.1111/j.1365-2621.2010.02491.x>

711 Diniz-Silva, H. T., Sousa, J. B. de, Guedes, J. da S., Queiroga, R. de C. R. do E., Madruga, M. S.,
712 Tavares, J. F., Magnani, M. (2019). A synergistic mixture of *Origanum vulgare* L. and
713 *Rosmarinus officinalis* L. essential oils to preserve overall quality and control *Escherichia coli*
714 O157:H7 in fresh cheese during storage. *LWT*, *112*, 107781.
715 <https://doi.org/10.1016/j.lwt.2019.01.039>

716 EFSA, & ECDPC. (2016). The European Union summary report on trends and sources of zoonoses,
717 zoonotic agents and food-borne outbreaks in 2015. *EFSA Journal*, *14*(12).
718 <https://doi.org/10.2903/j.efsa.2016.4634>

719 Ehsani, A., & Mahmoudi, R. (2012). Phytochemical Properties and Hygienic Effects of *Allium*
720 *ascalonicum* and *Pimpinella anisum* Essential Oils in Iranian White Brined Cheese. *Journal of*
721 *Essential Oil Bearing Plants*, *15*(6), 1013–1020.
722 <https://doi.org/10.1080/0972060X.2012.10662606>

723 El-Azzouny, M. M., El-Demerdash, A. S., Seadawy, H. G., & Abou-Khadra, S. H. (2018).
724 Antimicrobial Effect of Garlic (*Allium sativum*) and Thyme (*Zataria multiflora* Boiss)
725 Extracts on Some Food Borne Pathogens and Their Effect on Virulence Gene Expression.
726 *Cellular and Molecular Biology (Noisy-Le-Grand, France)*, *64*(10), 79–86.

727 Faccia, M., Picariello, G., Trani, A., Loizzo, P., Gambacorta, G., Lamacchia, C., & Di Luccia, A.
728 (2012). Proteolysis of Cacioricotta cheese made from goat milk coagulated with caprifig
729 (*Ficus carica sylvestris*) or calf rennet. *European Food Research and Technology*, *234*(3),
730 527–533. <https://doi.org/10.1007/s00217-012-1668-0>

731 Falleh, H., Ksouri, R., Chaieb, K., Karray-Bouraoui, N., Trabelsi, N., Boulaaba, M., & Abdelly, C.
732 (2008). Phenolic composition of *Cynara cardunculus* L. organs, and their biological activities.
733 *Comptes Rendus Biologies*, *331*(5), 372–379. <https://doi.org/10.1016/j.crv.2008.02.008>

734 Filip, V. (2003). Resveratrol and its antioxidant and antimicrobial effectiveness. *Food Chemistry*,
735 *83*(4), 585–593. [https://doi.org/10.1016/S0308-8146\(03\)00157-2](https://doi.org/10.1016/S0308-8146(03)00157-2)

736 *Food an Drug Administration - Food Ingredients & Packaging.*

- 737 Froc, J. (2007). *Balade au pays des fromages: Les traditions fromagères en France*. Versailles: Quae.
- 738 Galán, E., Cabezas, L., & Fernández-Salguero, J. (2012). Proteolysis, microbiology and sensory
739 properties of ewes' milk cheese produced with plant coagulant from cardoon *Cynara*
740 *cardunculus*, calf rennet or a mixture thereof. *International Dairy Journal*, 25(2), 92–96.
741 <https://doi.org/10.1016/j.idairyj.2012.02.001>
- 742 Galindo-Cuspinera, V., Westhoff, D. C., & Rankin, S. A. (2003). Antimicrobial properties of
743 commercial annatto extracts against selected pathogenic, lactic acid, and spoilage
744 microorganisms. *Journal of Food Protection*, 66(6), 1074–1078.
- 745 Gammariello, D., Di Giulio, S., Conte, A., & Del Nobile, M. A. (2008). Effects of Natural Compounds
746 on Microbial Safety and Sensory Quality of Fior di Latte Cheese, a Typical Italian Cheese.
747 *Journal of Dairy Science*, 91(11), 4138–4146. <https://doi.org/10.3168/jds.2008-1146>
- 748 Gavahian, M., Farahnaky, A., Shavezipur, M., & Sastry, S. (2016). Ethanol concentration of
749 fermented broth by ohmic-assisted hydrodistillation. *Innovative Food Science & Emerging*
750 *Technologies*, 35, 45–51. <https://doi.org/10.1016/j.ifset.2016.04.001>
- 751 Govaris, A., Botsoglou, E., Sergelidis, D., & Chatzopoulou, P. S. (2011). Antibacterial activity of
752 oregano and thyme essential oils against *Listeria monocytogenes* and *Escherichia coli*
753 O157:H7 in feta cheese packaged under modified atmosphere. *LWT - Food Science and*
754 *Technology*, 44(4), 1240–1244. <https://doi.org/10.1016/j.lwt.2010.09.022>
- 755 Guang, C., & Phillips, R. D. (2009). Plant Food-Derived Angiotensin I Converting Enzyme Inhibitory
756 Peptides. *Journal of Agricultural and Food Chemistry*, 57(12), 5113–5120.
757 <https://doi.org/10.1021/jf900494d>
- 758 Guarda, A., Rubilar, J. F., Miltz, J., & Galotto, M. J. (2011). The antimicrobial activity of
759 microencapsulated thymol and carvacrol. *International Journal of Food Microbiology*, 146(2),
760 144–150. <https://doi.org/10.1016/j.ijfoodmicro.2011.02.011>

761 Hammad, A. M., Hassan, H. A., & Shimamoto, T. (2015). Prevalence, antibiotic resistance and
762 virulence of *Enterococcus spp.* in Egyptian fresh raw milk cheese. *Food Control*, 50, 815–
763 820. <https://doi.org/10.1016/j.foodcont.2014.10.020>

764 Han, J. H., Patel, D., Kim, J. E., & Min, S. C. (2014). Retardation of *Listeria Monocytogenes* Growth
765 in Mozzarella Cheese Using Antimicrobial Sachets Containing Rosemary Oil and Thyme Oil:
766 Antimicrobial sachets of essential oil. *Journal of Food Science*, 79(11), E2272–E2278.
767 <https://doi.org/10.1111/1750-3841.12659>

768 Hassanien, M. F. R., Mahgoub, S. A., & El-Zahar, K. M. (2014). Soft cheese supplemented with black
769 cumin oil: Impact on food borne pathogens and quality during storage. *Saudi Journal of*
770 *Biological Sciences*, 21(3), 280–288. <https://doi.org/10.1016/j.sjbs.2013.10.005>

771 Hayaloglu, A. A., & Farkye, N. Y. (2011). Cheese | Cheese with Added Herbs, Spices and
772 Condiments. In *Encyclopedia of Dairy Sciences* (pp. 783–789). [https://doi.org/10.1016/B978-](https://doi.org/10.1016/B978-0-12-374407-4.00507-0)
773 [0-12-374407-4.00507-0](https://doi.org/10.1016/B978-0-12-374407-4.00507-0)

774 Hintz, T., Matthews, K. K., & Di, R. (2015). The Use of Plant Antimicrobial Compounds for Food
775 Preservation. *BioMed Research International*, 2015, 1–12.
776 <https://doi.org/10.1155/2015/246264>

777 Hufford, C. D., Jia, Y., Croom, E. M., Muhammed, I., Okunade, A. L., Clark, A. M., & Rogers, R. D.
778 (1993). Antimicrobial Compounds from *Petalostemum purpureum*. *Journal of Natural*
779 *Products*, 56(11), 1878–1889. <https://doi.org/10.1021/np50101a003>

780 Hugo, C. J., & Hugo, A. (2015). Current trends in natural preservatives for fresh sausage products.
781 *Trends in Food Science & Technology*, 45(1), 12–23.
782 <https://doi.org/10.1016/j.tifs.2015.05.003>

783 Huvaere, K., Nielsen, J. H., Bakman, M., Hammershøj, M., Skibsted, L. H., Sørensen, J., Dalsgaard,
784 T. K. (2011). Antioxidant Properties of Green Tea Extract Protect Reduced Fat Soft Cheese
785 against Oxidation Induced by Light Exposure. *Journal of Agricultural and Food Chemistry*,
786 59(16), 8718–8723. <https://doi.org/10.1021/jf201139e>

787 Hyldgaard, M., Mygind, T., & Meyer, R. L. (2012). Essential Oils in Food Preservation: Mode of
788 Action, Synergies, and Interactions with Food Matrix Components. *Frontiers in Microbiology*,
789 3. <https://doi.org/10.3389/fmicb.2012.00012>

790 Ivanovic, J., Mistic, D., Zizovic, I., & Ristic, M. (2012). In vitro control of multiplication of some
791 food-associated bacteria by thyme, rosemary and sage isolates. *Food Control*, 25(1), 110–116.
792 <https://doi.org/10.1016/j.foodcont.2011.10.019>

793 Jayathilake, C., Visvanathan, R., Deen, A., Bangamuwage, R., Jayawardana, B. C., Nammi, S., &
794 Liyanage, R. (2018). Cowpea: an overview on its nutritional facts and health benefits:
795 Nutritional and health properties of cowpea. *Journal of the Science of Food and Agriculture*,
796 98(13), 4793–4806. <https://doi.org/10.1002/jsfa.9074>

797 Johnson, E. M., Jung, Dr. Y.-G., Jin, Dr. Y.-Y., Jayabalan, Dr. R., Yang, Dr. S. H., & Suh, J. W.
798 (2017). Bacteriocins as food preservatives: Challenges and emerging horizons. *Critical*
799 *Reviews in Food Science and Nutrition*, 1–25.
800 <https://doi.org/10.1080/10408398.2017.1340870>

801 Jordán, M. J., Moñino, M. I., Martínez, C., Lafuente, A., & Sotomayor, J. A. (2010). Introduction of
802 Distillate Rosemary Leaves into the Diet of the Murciano-Granadina Goat: Transfer of
803 Polyphenolic Compounds to Goats' Milk and the Plasma of Suckling Goat Kids. *Journal of*
804 *Agricultural and Food Chemistry*, 58(14), 8265–8270. <https://doi.org/10.1021/jf100921z>

805 Josipović, R., Knežević, Z. M., Frece, J., Markov, K., Kazazić, S., & Mrvčić, J. (2015). Improved
806 Properties and Microbiological Safety of Novel Cottage Cheese Containing Spices. *Food*
807 *Technology and Biotechnology*, 53(4), 454–462. <https://doi.org/10.17113/ftb.53.04.15.4029>

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

- 811 Kirkland, D., Edwards, J., Woehrl, T., & Beilstein, P. (2015). Investigations into the genotoxic
812 potential of olive extracts. *Mutation Research/Genetic Toxicology and Environmental*
813 *Mutagenesis*, 777, 17–28. <https://doi.org/10.1016/j.mrgentox.2014.10.012>
- 814 Kozłowska, M., Laudy, A. E., Przybył, J., Ziarno, M., & Majewska, E. (2015). Chemical composition
815 and antibacterial activity of some medicinal plants from Lamiaceae family. *Acta Poloniae*
816 *Pharmaceutica*, 72(4), 757–767.
- 817 Kukić, J., Popović, V., Petrović, S., Mucaji, P., Ćirić, A., Stojković, D., & Soković, M. (2008).
818 Antioxidant and antimicrobial activity of *Cynara cardunculus* extracts. *Food Chemistry*,
819 *107*(2), 861–868. <https://doi.org/10.1016/j.foodchem.2007.09.005>
- 820 Lahti, E., Rehn, M., Ockborn, G., Hansson, I., Ågren, J., Engvall, E. O., & Jernberg, C. (2017).
821 Outbreak of Campylobacteriosis Following a Dairy Farm Visit: Confirmation by Genotyping.
822 *Foodborne Pathogens and Disease*, 14(6), 326–332. <https://doi.org/10.1089/fpd.2016.2257>
- 823 Lee, J.-H., Kim, Y.-G., Shi Yong Ryu, Cho, M. H., & Lee, J. (2014). Resveratrol Oligomers Inhibit
824 Biofilm Formation of *Escherichia coli* O157:H7 and *Pseudomonas aeruginosa*. *Journal of*
825 *Natural Products*, 77(1), 168–172. <https://doi.org/10.1021/np400756g>
- 826 Lee, N.-K., Jeewanthi, R. K. C., Park, E.-H., & Paik, H.-D. (2016). Short communication:
827 Physicochemical and antioxidant properties of Cheddar-type cheese fortified with *Inula*
828 *britannica* extract. *Journal of Dairy Science*, 99(1), 83–88. [https://doi.org/10.3168/jds.2015-](https://doi.org/10.3168/jds.2015-9935)
829 9935
- 830 Leuschner, R. G. K., & Ielsch, V. (2003). Antimicrobial effects of garlic, clove and red hot chilli on
831 *Listeria monocytogenes* in broth model systems and soft cheese. *International Journal of*
832 *Food Sciences and Nutrition*, 54(2), 127–133. <https://doi.org/10.1080/0963748031000084070>
- 833 Licitra, G., Caccamo, M., & Lortal, S. (2019). Artisanal Products Made With Raw Milk. In *Raw Milk*
834 (pp. 175–221). <https://doi.org/10.1016/B978-0-12-810530-6.00009-2>

835 Lopez-Solanilla, E., Gonzalez-Zorn, B., Novella, S., Vazquez-Boland, J., & Rodriguez-Palenzuela, P.
836 (2003). Susceptibility of *Listeria monocytogenes* to antimicrobial peptides. *FEMS*
837 *Microbiology Letters*, 226(1), 101–105. [https://doi.org/10.1016/S0378-1097\(03\)00579-2](https://doi.org/10.1016/S0378-1097(03)00579-2)

838 Lou, Z., Wang, H., Zhu, S., Ma, C., & Wang, Z. (2011). Antibacterial Activity and Mechanism of
839 Action of Chlorogenic Acid. *Journal of Food Science*, 76(6), M398–M403.
840 <https://doi.org/10.1111/j.1750-3841.2011.02213.x>

841 Luque de Castro, M. D., & García-Ayuso, L. E. (1998). Soxhlet extraction of solid materials: an
842 outdated technique with a promising innovative future. *Analytica Chimica Acta*, 369(1–2), 1–
843 10. [https://doi.org/10.1016/S0003-2670\(98\)00233-5](https://doi.org/10.1016/S0003-2670(98)00233-5)

844 Macedo, A. C., Xavier Malcata, F., & Oliveira, J. C. (1993). The Technology, Chemistry, and
845 Microbiology of Serra Cheese: A Review. *Journal of Dairy Science*, 76(6), 1725–1739.
846 [https://doi.org/10.3168/jds.S0022-0302\(93\)77505-0](https://doi.org/10.3168/jds.S0022-0302(93)77505-0)

847 Mahajan, D., Bhat, Z. F., & Kumar, S. (2016). Pine needles (*Cedrus deodara* (Roxb.) Loud.) extract as
848 a novel preservative in cheese. *Food Packaging and Shelf Life*, 7, 20–25.
849 <https://doi.org/10.1016/j.fpsl.2016.01.001>

850 Mahgoub, S. A., Ramadan, M. F., & El-Zahar, K. M. (2013). Cold Pressed *Nigella sativa* Oil Inhibits
851 the Growth of Foodborne Pathogens and Improves the Quality of Domiati Cheese: Black
852 Cumin Oil Inhibit the Growth of Foodborne Pathogens in Domiati Cheese. *Journal of Food*
853 *Safety*, 33(4), 470–480. <https://doi.org/10.1111/jfs.12078>

854 Mahgoub, S., Osman, A., & Sitohy, M. (2011). Inhibition of Growth of Pathogenic Bacteria in Raw
855 Milk by Legume Protein Esters. *Journal of Food Protection*, 74(9), 1475–1481.
856 <https://doi.org/10.4315/0362-028X.JFP-11-065>

857 Marchiani, R., Bertolino, M., Ghirardello, D., McSweeney, P. L. H., & Zeppa, G. (2015).
858 Physicochemical and nutritional qualities of grape pomace powder-fortified semi-hard
859 cheeses. *Journal of Food Science and Technology*. <https://doi.org/10.1007/s13197-015-2105-8>

- 860 Marcial, G. E., Gerez, C. L., de Kairuz, M. N., Araoz, V. C., Schuff, C., & de Valdez, G. F. (2016).
861 Influence of oregano essential oil on traditional Argentinean cheese elaboration: Effect on
862 lactic starter cultures. *Revista Argentina de Microbiología*, 48(3), 229–235.
863 <https://doi.org/10.1016/j.ram.2016.04.006>
- 864 Marinho, M. T., Bersot, L. dos S., Nogueira, A., Colman, T. A. D., & Schnitzler, E. (2015).
865 Antioxidant effect of dehydrated rosemary leaves in ripened semi-hard cheese: A study using
866 coupled TG–DSC–FTIR (EGA). *LWT - Food Science and Technology*, 63(2), 1023–1028.
867 <https://doi.org/10.1016/j.lwt.2015.03.108>
- 868 Mogoşanu, G. D., Grumezescu, A. M., Bejenaru, C., & Bejenaru, L. E. (2017). Natural products used
869 for food preservation. In *Food Preservation* (pp. 365–411). [https://doi.org/10.1016/B978-0-](https://doi.org/10.1016/B978-0-12-804303-5.00011-0)
870 [12-804303-5.00011-0](https://doi.org/10.1016/B978-0-12-804303-5.00011-0)
- 871 Moro, A., Librán, C. M., Berruga, M. I., Carmona, M., & Zalacain, A. (2015). Dairy matrix effect on
872 the transference of rosemary (*Rosmarinus officinalis*) essential oil compounds during cheese
873 making. *Journal of the Science of Food and Agriculture*, 95(7), 1507–1513.
874 <https://doi.org/10.1002/jsfa.6853>
- 875 Mostafa, A. A., Al-Askar, A. A., Almaary, K. S., Dawoud, T. M., Sholkamy, E. N., & Bakri, M. M.
876 (2018). Antimicrobial activity of some plant extracts against bacterial strains causing food
877 poisoning diseases. *Saudi Journal of Biological Sciences*, 25(2), 361–366.
878 <https://doi.org/10.1016/j.sjbs.2017.02.004>
- 879 Muehlhoff, E., & FAO (Eds.). (2013). *Milk and dairy products in human nutrition*. Rome: FAO.
- 880 Mustafa, A., & Turner, C. (2011). Pressurized liquid extraction as a green approach in food and herbal
881 plants extraction: A review. *Analytica Chimica Acta*, 703(1), 8–18.
882 <https://doi.org/10.1016/j.aca.2011.07.018>
- 883 Nero, A. L., & Carvalho, A. F. de. (2018). *Raw milk: balance between hazards and benefits* (1st ed.,
884 Vols. 1–1). Academic Press.

- 885 Nirmala, C., Bisht, M. S., Bajwa, H. K., & Santosh, O. (2018). Bamboo: A rich source of natural
886 antioxidants and its applications in the food and pharmaceutical industry. *Trends in Food*
887 *Science & Technology*, 77, 91–99. <https://doi.org/10.1016/j.tifs.2018.05.003>
- 888 Olasupo, N. A., Fitzgerald, D. J., Gasson, M. J., & Narbad, A. (2003). Activity of natural
889 antimicrobial compounds against *Escherichia coli* and *Salmonella enterica* serovar
890 *Typhimurium*. *Letters in Applied Microbiology*, 37(6), 448–451.
891 <https://doi.org/10.1046/j.1472-765X.2003.01427.x>
- 892 Osman, A., Mahgoub, S., El-Masry, R., Al-Gaby, A., & Sitohy, M. (2014). Extending the
893 Technological Validity of Raw Buffalo Milk at Room Temperature by Esterified Legume
894 Proteins: Extending the Technological Validity of Raw Milk. *Journal of Food Processing and*
895 *Preservation*, 38(1), 223–231. <https://doi.org/10.1111/j.1745-4549.2012.00768.x>
- 896 Osman, A. O., Mahgoub, S. A., & Sitohy, M. Z. (2013). Preservative action of 11S (glycinin) and 7S
897 (β -conglycinin) soy globulin on bovine raw milk stored either at 4 or 25 °C. *Journal of Dairy*
898 *Research*, 80(02), 174–183. <https://doi.org/10.1017/S0022029913000095>
- 899 Osman, Ali, Abbas, E., Mahgoub, S., & Sitohy, M. (2016). Inhibition of *Penicillium digitatum* in vitro
900 and in postharvest orange fruit by a soy protein fraction containing mainly β -conglycinin.
901 *Journal of General Plant Pathology*, 82(6), 293–301. [https://doi.org/10.1007/s10327-016-](https://doi.org/10.1007/s10327-016-0686-3)
902 0686-3
- 903 Papademas, P., & Robinson, R. K. (2001). The sensory characteristics of different types of halloumi
904 cheese as perceived by tasters of different ages. *International Journal of Dairy Technology*,
905 54(3), 94–99. <https://doi.org/10.1046/j.1364-727x.2001.00013.x>
- 906 Park, C., Cho, J.-Y., Hwang, B.-M., Hwang, I.-S., Kim, M.-R., Woo, E.-R., & Lee, D.-G. (2010).
907 Styraxjaponoside A and B, Antifungal Lignan Glycosides Isolated from *Styrax japonica* S. et
908 Z. *Biomolecules and Therapeutics*, 18(4), 420–425.
909 <https://doi.org/10.4062/biomolther.2010.18.4.420>

- 910 Pavlović, D. R., Veljković, M., Stojanović, N. M., Gočmanac-Ignjatović, M., Mihailov-Krstev, T.,
911 Branković, S., Radenković, M. (2017). Influence of different wild-garlic (*Allium ursinum*)
912 extracts on the gastrointestinal system: spasmolytic, antimicrobial and antioxidant properties.
913 *Journal of Pharmacy and Pharmacology*, 69(9), 1208–1218.
914 <https://doi.org/10.1111/jphp.12746>
- 915 Perricone, M., Arace, E., Corbo, M. R., Sinigaglia, M., & Bevilacqua, A. (2015). Bioactivity of
916 essential oils: a review on their interaction with food components. *Food Microbiology*, 6, 76.
917 <https://doi.org/10.3389/fmicb.2015.00076>
- 918 Pesavento, G., Calonico, C., Ducci, B., Magnanini, A., & Lo Nostro, A. (2014). Prevalence and
919 antibiotic resistance of *Enterococcus spp.* isolated from retail cheese, ready-to-eat salads, ham,
920 and raw meat. *Food Microbiology*, 41, 1–7. <https://doi.org/10.1016/j.fm.2014.01.008>
- 921 Pina-Pérez, M. C., & Ferrús Pérez, M. A. (2018). Antimicrobial potential of legume extracts against
922 foodborne pathogens: A review. *Trends in Food Science & Technology*, 72, 114–124.
923 <https://doi.org/10.1016/j.tifs.2017.12.007>
- 924 Pisoschi, A. M., Pop, A., Georgescu, C., Turcuș, V., Olah, N. K., & Mathe, E. (2018). An overview of
925 natural antimicrobials role in food. *European Journal of Medicinal Chemistry*, 143, 922–935.
926 <https://doi.org/10.1016/j.ejmech.2017.11.095>
- 927 Pranting, M., Loov, C., Burman, R., Goransson, U., & Andersson, D. I. (2010). The cyclotide
928 cycloviolacin O2 from *Viola odorata* has potent bactericidal activity against Gram-negative
929 bacteria. *Journal of Antimicrobial Chemotherapy*, 65(9), 1964–1971.
930 <https://doi.org/10.1093/jac/dkq220>
- 931 Pulina, G., Milán, M. J., Lavín, M. P., Theodoridis, A., Morin, E., Capote, J., Caja, G. (2018). Invited
932 review: Current production trends, farm structures, and economics of the dairy sheep and goat
933 sectors. *Journal of Dairy Science*, 101(8), 6715–6729. <https://doi.org/10.3168/jds.2017-14015>
- 934 Puri, M., Sharma, D., & Barrow, C. J. (2012). Enzyme-assisted extraction of bioactives from plants.
935 *Trends in Biotechnology*, 30(1), 37–44. <https://doi.org/10.1016/j.tibtech.2011.06.014>

- 936 Qiu, X., Jacobsen, C., & Sørensen, A.-D. M. (2018). The effect of rosemary (*Rosmarinus officinalis*
937 L.) extract on the oxidative stability of lipids in cow and soy milk enriched with fish oil. *Food*
938 *Chemistry*, 263, 119–126. <https://doi.org/10.1016/j.foodchem.2018.04.106>
- 939 Quave, C. L., Lyles, J. T., Kavanaugh, J. S., Nelson, K., Parlet, C. P., Crosby, H. A., Horswill, A. R.
940 (2015). *Castanea sativa* (European Chestnut) Leaf Extracts Rich in Ursene and Oleanene
941 Derivatives Block *Staphylococcus aureus* Virulence and Pathogenesis without Detectable
942 Resistance. *PLoS ONE*, 10(8). <https://doi.org/10.1371/journal.pone.0136486>
- 943 Rai, M., Pandit, R., Gaikwad, S., & Kövics, G. (2016). Antimicrobial peptides as natural bio-
944 preservative to enhance the shelf-life of food. *Journal of Food Science and Technology*, 53(9),
945 3381–3394. <https://doi.org/10.1007/s13197-016-2318-5>
- 946 Rashidinejad, A., Birch, E. J., Sun-Waterhouse, D., & Everett, D. W. (2013). Effects of catechin on
947 the phenolic content and antioxidant properties of low-fat cheese. *International Journal of*
948 *Food Science & Technology*, 48(12), 2448–2455. <https://doi.org/10.1111/ijfs.12234>
- 949 *Regulation (EC) N°1334/2008.*
- 950 Rhodes, P. L., Mitchell, J. W., Wilson, M. W., & Melton, L. D. (2006). Antilisterial activity of grape
951 juice and grape extracts derived from *Vitis vinifera* variety Ribier. *International Journal of*
952 *Food Microbiology*, 107(3), 281–286. <https://doi.org/10.1016/j.ijfoodmicro.2005.10.022>
- 953 Robles-Almazan, M., Pulido-Moran, M., Moreno-Fernandez, J., Ramirez-Tortosa, C., Rodriguez-
954 Garcia, C., Quiles, J. L., & Ramirez-Tortosa, Mc. (2018). Hydroxytyrosol: Bioavailability,
955 toxicity, and clinical applications. *Food Research International*, 105, 654–667.
956 <https://doi.org/10.1016/j.foodres.2017.11.053>
- 957 Roila, R., Valiani, A., Ranucci, D., Ortenzi, R., Servili, M., Veneziani, G., & Branciarri, R. (2019).
958 Antimicrobial efficacy of a polyphenolic extract from olive oil by-product against “Fior di
959 latte” cheese spoilage bacteria. *International Journal of Food Microbiology*, 295, 49–53.
960 <https://doi.org/10.1016/j.ijfoodmicro.2019.02.013>

- 961 Ruiz-Terán, F., Perez-Amador, I., & López-Munguia, A. (2001). Enzymatic Extraction and
962 Transformation of Glucovanillin to Vanillin from Vanilla Green Pods. *Journal of Agricultural*
963 *and Food Chemistry*, 49(11), 5207–5209. <https://doi.org/10.1021/jf010723h>
- 964 Rukachaisirikul, T., Innok, P., Aroonrerk, N., Boonamnuaylap, W., Limrangsun, S., Boonyon, C.,
965 Suksamrarn, A. (2007). Antibacterial Pterocarpanes from *Erythrina subumbrans*. *Journal of*
966 *Ethnopharmacology*, 110(1), 171–175. <https://doi.org/10.1016/j.jep.2006.09.022>
- 967 Sadeghi, E., Akhondzadeh Basti, A., Noori, N., Khanjari, A., & Partovi, R. (2013). Effect of *Cuminum*
968 *cuminum* L. essential oil and *Lactobacillus acidophilus* (a probiotic) on *Staphylococcus*
969 *aureus* during the manufacture, ripening and storage of white brined cheese: effect of essential
970 oil and probiotic on *S. aureus*. *Journal of Food Processing and Preservation*, 37(5), 449–455.
971 <https://doi.org/10.1111/j.1745-4549.2011.00664.x>
- 972 Salas, C. E., Badillo-Corona, J. A., Ramírez-Sotelo, G., & Oliver-Salvador, C. (2015). Biologically
973 Active and Antimicrobial Peptides from Plants. *BioMed Research International*, 2015, 1–11.
974 <https://doi.org/10.1155/2015/102129>
- 975 Santos, R. D., Shetty, K., & da Silva Miglioranza, L. H. (2014). Oxidative stability of butter with
976 added phenolics from Lamiaceae herbs and *in vitro* evaluation of potential cytotoxicity of
977 rosemary (*Rosmarinus officinalis* L.) extract. *International Journal of Food Science &*
978 *Technology*, 49(3), 768–775. <https://doi.org/10.1111/ijfs.12364>
- 979 Shah, M. A., Mir, S. A., & Paray, M. A. (2014). Plant proteases as milk-clotting enzymes in
980 cheesemaking: a review. *Dairy Science & Technology*, 94(1), 5–16.
981 <https://doi.org/10.1007/s13594-013-0144-3>
- 982 Shan, B., Cai, Y.-Z., Brooks, J. D., & Corke, H. (2011). Potential Application of Spice and Herb
983 Extracts as Natural Preservatives in Cheese. *Journal of Medicinal Food*, 14(3), 284–290.
984 <https://doi.org/10.1089/jmf.2010.0009>
- 985 Sicard, T. (2018). *L'atlas pratique des fromages: origines, terroirs, accords*.

- 986 Silva, S. V., Pihlanto, A., & Malcata, F. X. (2006). Bioactive Peptides in Ovine and Caprine
987 Cheeselike Systems Prepared with Proteases from *Cynara cardunculus*. *Journal of Dairy*
988 *Science*, 89(9), 3336–3344. [https://doi.org/10.3168/jds.S0022-0302\(06\)72370-0](https://doi.org/10.3168/jds.S0022-0302(06)72370-0)
- 989 Sitohy, M., Doheim, M., & Badr, H. (2007). Isolation and characterization of a lectin with antifungal
990 activity from *Egyptian Pisum sativum* seeds. *Food Chemistry*, 104(3), 971–979.
991 <https://doi.org/10.1016/j.foodchem.2007.01.026>
- 992 Sitohy, M., Mahgoub, S., & Osman, A. (2011). Controlling psychrotrophic bacteria in raw buffalo
993 milk preserved at 4 °C with esterified legume proteins. *LWT - Food Science and Technology*,
994 44(8), 1697–1702. <https://doi.org/10.1016/j.lwt.2011.03.008>
- 995 Sitohy, M. Z., Mahgoub, S. A., & Osman, A. O. (2012). In vitro and in situ antimicrobial action and
996 mechanism of glycinin and its basic subunit. *International Journal of Food Microbiology*,
997 154(1–2), 19–29. <https://doi.org/10.1016/j.ijfoodmicro.2011.12.004>
- 998 Snoussi, M., Trabelsi, N., Dehmeni, A., Benzekri, R., Bouslama, L., Hajlaoui, B., Papetti, A. (2016).
999 Phytochemical analysis, antimicrobial and antioxidant activities of *Allium roseum* var.
1000 *odoratissimum* (Desf.) Coss extracts. *Industrial Crops and Products*, 89, 533–542.
1001 <https://doi.org/10.1016/j.indcrop.2016.05.048>
- 1002 Sodeifian, G., Sajadian, S. A., & Saadati Ardestani, N. (2016). Optimization of essential oil extraction
1003 from *Launaea acanthodes* Boiss: Utilization of supercritical carbon dioxide and cosolvent. *The*
1004 *Journal of Supercritical Fluids*, 116, 46–56. <https://doi.org/10.1016/j.supflu.2016.05.015>
- 1005 Soni, M. G., Burdock, G. A., Christian, M. S., Bitler, C. M., & Crea, R. (2006). Safety assessment of
1006 aqueous olive pulp extract as an antioxidant or antimicrobial agent in foods. *Food and*
1007 *Chemical Toxicology*, 44(7), 903–915. <https://doi.org/10.1016/j.fct.2006.01.008>
- 1008 Stojanović, S., Sprinz, H., & Brede, O. (2001). Efficiency and Mechanism of the Antioxidant Action
1009 of trans-Resveratrol and Its Analogues in the Radical Liposome Oxidation. *Archives of*
1010 *Biochemistry and Biophysics*, 391(1), 79–89. <https://doi.org/10.1006/abbi.2001.2388>

- 1011 Sudjana, A. N., D’Orazio, C., Ryan, V., Rasool, N., Ng, J., Islam, N., Hammer, K. A. (2009).
1012 Antimicrobial activity of commercial *Olea europaea* (olive) leaf extract. *International Journal*
1013 *of Antimicrobial Agents*, 33(5), 461–463. <https://doi.org/10.1016/j.ijantimicag.2008.10.026>
- 1014 Taguri, T., Tanaka, T., & Kouno, I. (2004). Antimicrobial Activity of 10 Different Plant Polyphenols
1015 against Bacteria Causing Food-Borne Disease. *Biological & Pharmaceutical Bulletin*, 27(12),
1016 1965–1969. <https://doi.org/10.1248/bpb.27.1965>
- 1017 Tanaka, A., Kim, H. J., Oda, S., Shimizu, K., & Kondo, R. (2011). Antibacterial activity of moso
1018 bamboo shoot skin (*Phyllostachys pubescens*) against *Staphylococcus aureus*. *Journal of*
1019 *Wood Science*, 57(6), 542–544. <https://doi.org/10.1007/s10086-011-1207-9>
- 1020 Tayel, A. A., Hussein, H., Sorour, N. M., & El-Tras, W. F. (2015). Foodborne Pathogens Prevention
1021 and Sensory Attributes Enhancement in Processed Cheese via Flavoring with Plant Extracts:
1022 Cheese protection using plant extracts. *Journal of Food Science*, 80(12), M2886–M2891.
1023 <https://doi.org/10.1111/1750-3841.13138>
- 1024 Thermo scientific. (2013). *Methods Optimization in Accelerated Solvent Extraction* (pp. 1–4).
- 1025 Tsiraki, M. I., & Savvaidis, I. N. (2016). The effects of citrus extract (Citrox ©) on the naturally
1026 occurring microflora and inoculated pathogens, *Bacillus cereus* and *Salmonella enterica* , in a
1027 model food system and the traditional Greek yogurt-based salad Tzatziki. *Food Microbiology*,
1028 53, 150–155. <https://doi.org/10.1016/j.fm.2015.09.015>
- 1029 Tsiraki, M. I., Yehia, H. M., Elobeid, T., Osaili, T., Sakkas, H., & Savvaidis, I. N. (2018). Viability of
1030 and *Escherichia coli* O157:H7 and *Listeria monocytogenes* in a delicatessen appetizer (yogurt-
1031 based) salad as affected by citrus extract (Citrox ©) and storage temperature. *Food*
1032 *Microbiology*, 69, 11–17. <https://doi.org/10.1016/j.fm.2017.07.014>
- 1033 Tyśkiewicz, K., Gieysztor, R., Konkol, M., Szałas, J., & Rój, E. (2018). Essential Oils from Humulus
1034 Lupulus scCO₂ Extract by Hydrodistillation and Microwave-Assisted Hydrodistillation.
1035 *Molecules*, 23(11), 2866. <https://doi.org/10.3390/molecules23112866>

- 1036 Vairo Cavalli, S., Lufrano, D., Colombo, M. L., & Priolo, N. (2013). Properties and applications of
1037 phytepsins from thistle flowers. *Phytochemistry*, 92, 16–32.
1038 <https://doi.org/10.1016/j.phytochem.2013.04.013>
- 1039 Verraes, C., Vlaemyck, G., Van Weyenberg, S., De Zutter, L., Daube, G., Sindic, M., Herman, L.
1040 (2015). A review of the microbiological hazards of dairy products made from raw milk.
1041 *International Dairy Journal*, 50, 32–44. <https://doi.org/10.1016/j.idairyj.2015.05.011>
- 1042 Vilku, K., Mawson, R., Simons, L., & Bates, D. (2008). Applications and opportunities for
1043 ultrasound assisted extraction in the food industry — A review. *Innovative Food Science &*
1044 *Emerging Technologies*, 9(2), 161–169. <https://doi.org/10.1016/j.ifset.2007.04.014>
- 1045 Vongsak, B., Sithisarn, P., Mangmool, S., Thongpraditchote, S., Wongkrajang, Y., & Gritsanapan, W.
1046 (2013). Maximizing total phenolics, total flavonoids contents and antioxidant activity of
1047 Moringa oleifera leaf extract by the appropriate extraction method. *Industrial Crops and*
1048 *Products*, 44, 566–571. <https://doi.org/10.1016/j.indcrop.2012.09.021>
- 1049 Wahba, N. M., Ahmed, A. S., & Ebraheim, Z. Z. (2010). Antimicrobial Effects of Pepper, Parsley, and
1050 Dill and Their Roles in the Microbiological Quality Enhancement of Traditional Egyptian
1051 Kareish Cheese. *Foodborne Pathogens and Disease*, 7(4), 411–418.
1052 <https://doi.org/10.1089/fpd.2009.0412>
- 1053 Wang, L., & Weller, C. L. (2006). Recent advances in extraction of nutraceuticals from plants. *Trends*
1054 *in Food Science & Technology*, 17(6), 300–312. <https://doi.org/10.1016/j.tifs.2005.12.004>
- 1055 Wang, X., Yao, X., Zhu, Z., Tang, T., Dai, K., Sadovskaya, I., Jabbouri, S. (2009). Effect of berberine
1056 on *Staphylococcus epidermidis* biofilm formation. *International Journal of Antimicrobial*
1057 *Agents*, 34(1), 60–66. <https://doi.org/10.1016/j.ijantimicag.2008.10.033>
- 1058 Wijesinghe, W. A. J. P., & Jeon, Y.-J. (2012). Enzyme-assistant extraction (EAE) of bioactive
1059 components: A useful approach for recovery of industrially important metabolites from
1060 seaweeds: A review. *Fitoterapia*, 83(1), 6–12. <https://doi.org/10.1016/j.fitote.2011.10.016>

- 1061 Willis, C., Jørgensen, F., Aird, H., Elviss, N., Fox, A., Jenkins, C., McLauchlin, J. (2018). An
1062 assessment of the microbiological quality and safety of raw drinking milk on retail sale in
1063 England. *Journal of Applied Microbiology*, 124(2), 535–546.
1064 <https://doi.org/10.1111/jam.13660>
- 1065 Wu, J., & Ding, X. (2002). Characterization of inhibition and stability of soy-protein-derived
1066 angiotensin I-converting enzyme inhibitory peptides. *Food Research International*, 35(4),
1067 367–375. [https://doi.org/10.1016/S0963-9969\(01\)00131-4](https://doi.org/10.1016/S0963-9969(01)00131-4)
- 1068 Yasuda, S., Kuwata, H., Kawamoto, K., Shirakawa, J., Atobe, S., Hoshi, Y., Igoshi, K. (2012). Effect
1069 of highly lipolyzed goat cheese on HL-60 human leukemia cells: Antiproliferative activity and
1070 induction of apoptotic DNA damage. *Journal of Dairy Science*, 95(5), 2248–2260.
1071 <https://doi.org/10.3168/jds.2011-4153>
- 1072 Zantar, S., Yedri, F., Mrabet, R., Laglaoui, A., Bakkali, M., & Zerrouk, M. H. (2014). Effect of
1073 *Thymus vulgaris* and *Origanum compactum* essential oils on the shelf life of fresh goat cheese.
1074 *Journal of Essential Oil Research*, 26(2), 76–84.
1075 <https://doi.org/10.1080/10412905.2013.871673>
- 1076 Zarai, Z., Boujelbene, E., Ben Salem, N., Gargouri, Y., & Sayari, A. (2013). Antioxidant and
1077 antimicrobial activities of various solvent extracts, piperine and piperic acid from *Piper*
1078 *nigrum*. *LWT - Food Science and Technology*, 50(2), 634–641.
1079 <https://doi.org/10.1016/j.lwt.2012.07.036>
- 1080 Zhang, H., He, P., Kang, H., & Li, X. (2018). Antioxidant and antimicrobial effects of edible coating
1081 based on chitosan and bamboo vinegar in ready to cook pork chops. *LWT*, 93, 470–476.
1082 <https://doi.org/10.1016/j.lwt.2018.04.005>
- 1083

1084 **Figure caption**

1085

1086 **Figure 1: Potential of vegetal matter traditionally used in cheese processing and its pros and cons for raw milk cheese preservation**

1087

1088

1089

1090 **Table 1: Traditional cheese made with plant or plant extract (Sicard, 2018)**

| PLANT | CHEESE | ORIGIN | MILK PROCESSING | RIPENING |
|-----------------------------------------------|---------------------------------|-------------|-----------------|----------------|
| Addition of plants in cheese curd | | | | |
| Cow milk | | | | |
| <i>Allium sativum</i> (garlic) | Gaperon | France | raw, butter | 3 to 4 weeks |
| | Spinosien à l'ail | | raw | 8 months |
| | Boursin à l'ail, P'Ail | | pasteurized | none |
| <i>Allium schoenoprasum</i> L (chives) | Boursin | | pasteurized | none |
| <i>Allium ursinum</i> (wild/bear's garlic) | Tomme fermière à l'ail des ours | | raw | 2 months |
| | Tomme vaudoise à l'ail des ours | Switzerland | raw/thermized | 2 months |
| <i>Brassica nigra/Sinapis nigra</i> (Mustard) | Mustard seed Gouda | Netherlands | raw/pasteurized | 2 months |
| <i>Capsicum annuum</i> (paprika) | Mossa | France | pasteurized | none |
| <i>Cuminum cyminum</i> (cumin) | Altenburger Ziegenkäse | Deutschland | raw* | 4 weeks |
| | Cumin seed Gouda | Netherlands | raw/pasteurized | 2 months |
| | Munster au cumin | | raw/pasteurized | 2-3 months |
| | Tomme vaudoise au cumin | | raw/thermized | 2 months |
| <i>Piper nigrum</i> (pepper) | Boursin au poivre, Mossa | France | pasteurized | none |
| | Gaperon | | raw, butter | 3 to 4 weeks |
| | Holunderkas | | pasteurized | 3 weeks |
| <i>Sambucus nigra</i> (elderberry flowers) | | | raw | 2 months |
| <i>Urtica dioica</i> (nettle) | Tomme fermière aux orties, | | raw | 8 months |
| | spinosen aux orties | | raw | 8 months |
| Sheep milk | | | | |
| <i>Capsicum annuum</i> (smoked paprika) | The Black Sheep | New Zealand | pasteurized | 10 months |
| <i>Piper nigrum</i> (pepper) | Piacentinu ennese | Italy | raw/pasteurized | 3 to 12 months |
| <i>Thymus vulgaris</i> (thyme) | Brebichou au Thym (Thyme EO) | France | raw | 2 weeks |

| Cheeses with plant extract addition for coagulation | | | | |
|-----------------------------------------------------|--------------------------------|-------------|-----------------|----------------|
| Cow milk | | | | |
| <i>Calotropis procera</i> (apple of Sodom) | Peulh cheese | Benin | raw | 12 days |
| <i>Gallium verum</i> (lady's bedstraw) | Gloucester cheese | U.K. | raw/pasteurized | 4-12 weeks |
| Goat milk | | | | |
| <i>Ficus carica sylvestris</i> (caprifig) | Ficu, Cacioricotta | Italia | pasteurized | 35 days |
| Sheep milk | | | | |
| <i>Cynara spp.</i> (wild cardoon flower) | Serra da Estrala | Portugal | raw | 30 days |
| | Serpa | | 2 years | |
| | Azeitao | | 20 days | |
| | Nisa | | 45 days | |
| | Castelo Branco | Spain | raw | 8 days |
| | Torta del Casar | | | 60 days |
| | La Serena | | | 60 days |
| | Los Pedroches | | | 60-80 days |
| Addition of plants on the surface of cheese | | | | |
| Cow milk | | | | |
| <i>Allium sativum</i> (garlic) | Cabris* (along with shallots) | France | raw/pasteurized | 2 weeks |
| <i>Allium schoenoprasum</i> L (chives) | Boulette de la Pierre-qui-Vire | | raw | 2-3 weeks |
| <i>Brassica nigra/Sinapis nigra</i> (Mustard) | Délice de Pommard | | pasteurized | none |
| <i>Capsicum annuum</i> (paprika) | Boeren-Leidse met sleutels | Netherlands | raw | 3 to 12 months |
| | Ridge line | U.S.A | raw | 2 months |
| | Boulette d'Avesnes, | France | pasteurized | None |
| | Figurette | | raw | none |
| <i>Piper nigrum</i> (pepper) | Vergalor | | raw | 4 months |
| | Colombier de Sivry | | raw | 4 weeks |
| | Rigotte au poivre | | pasteurized | 2-3 weeks |
| <i>Rosmarinus officinalis</i> (rosemary) | Colombier de Sivry | | raw | 4 weeks |
| <i>Salvia sclarea/Salvia officinalis</i> (sage) | Colombier de Sivry | | raw | 4 weeks |

| Goat milk | | | | | |
|----------------------------------------------------|-----------------------------------------------|--------|-----------------|--|--------------------|
| <i>Cuminum cyminum</i> (cumin) | Figuette, Lou Pèbre | | raw | | None |
| <i>Piper nigrum</i> (pepper) | Chabis de Gâtine au poivre, Lou Pèbre | | raw | | None |
| <i>Rosmarinus officinalis</i> (rosemary) | Bouyguette | | raw | | 2-3 weeks |
| <i>Thymus vulgaris</i> (thyme) | Rovethym | | raw | | 3 weeks |
| <i>Rosmarinus officinalis</i> (rosemary) | Brin d'amour (+Juniper Berries and savory) | | raw /whey | | 30-45 days |
| Sheep milk | | | | | |
| <i>Mentha viridis</i> (spearmint) | Halloumi | Cyprus | pasteurized | | 40 days , in brine |
| <i>Thymus vulgaris</i> (thyme) | Saveur du Maquis (+ oregano, savory, majoram) | France | pasteurized | | None |
| Cheeses with tree leave | | | | | |
| Cow milk | | | | | |
| <i>Acer pseudoplatanus</i> (sycamore maple leaves) | Valdeón* | Spain | raw/pasteurized | | 2-3 months |
| <i>Allium ursinum</i> (wild/bear's garlic leaves) | Wild Garlic Yarg | U.K. | pasteurized | | 5 weeks |
| <i>Castanea sativa</i> (chestnut leaves) | Feuille de Dreux | France | pasteurized | | 2 weeks |
| | Rogue river blue | U.S.A. | raw | | 8 months |
| <i>Urtica dioica</i> (nettle leaves) | Cornish Yarg | U.K. | pasteurized | | 5 weeks |
| <i>Vitis vinifera</i> (grape leaves) | Rogue river blue | U.S.A. | raw | | 8 months |
| Goat milk | | | | | |
| <i>Acer pseudoplatanus</i> (sycamore maple leaves) | River's Edge Up in Smoke | U.S.A. | pasteurized | | 1 week |
| <i>Castanea sativa</i> (chestnut leaves) | Banon, | France | raw | | 15 days |
| | Mothais-sur-feuille | | raw | | 4 weeks |
| | Cabrales (trad.) | Spain | Raw* | | 2 months |
| <i>Ficus carica sylvestris</i> (caprifig) | Ficu, Ubriaco* | Italy | pasteurized | | 2-12 months |
| <i>Platanus xhispanica</i> (plane tree leaves) | Couhé verac | France | raw | | 3-4 weeks |
| <i>Prunus avium</i> (cherry leaves) | Robiola La Rossa | Italy | raw | | 10-15 days |
| <i>Piper auritum</i> (hoja santa leaves) | Hoja Santa | U.S.A. | pasteurized | | 1-6 months |
| Sheep milk | | | | | |
| <i>Juglans regia</i> L. (walnut leaves) | Pecorino Foglie di | Italy | raw | | 3 months |

| | | | | |
|-----------------------------------|-----------------------------------------------------------|-------|-------------|----------|
| | Noce | | | |
| <i>Olea europea</i> (oliv leaves) | Pecorino "L'Ulivastro", Foglie di ulivo, L'Ulivo | Italy | pasteurized | 3 months |
| 1091 | *other milks also used | | | |

Table 2: Biological activities of plants traditionally used for cheese-making

| Species | Part of the plant and/or extraction method | Biological activity | Model / Food | Reference |
|-------------------------------------|---------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|--------------------------------------------------------|
| <i>Allium ascalonicum</i> (shallot) | Essential oil | Antimicrobial activity against <i>EC</i> O157:H7 | Iranian white brined cheese | Ehsani & Mahmoudi, 2012 |
| <i>Allium ursinum</i> (Wild garlic) | Powder of leaves extracted with ethanol, water, methanol | Antioxidant properties, antimicrobial activity against <i>Salmonella enteritidis</i> , <i>EC</i> , <i>Proteus mirabilis</i> and <i>Enterococcus faecalis</i> | <i>in vitro</i> tests | Pavlović et al., 2017 |
| <i>Allium roseum</i> (rosy garlic) | Dried methanol extract of fresh aerial parts and bulbs | Antioxydant properties, anti <i>Candida sp.</i> activity Antimicrobial activity against 13 Gram-negative strains including <i>ST</i> , <i>S. anatum</i> , <i>S. enteridis</i> and <i>EC</i> and three Gram-positive strains including <i>SA</i> | <i>in vitro</i> tests | Snoussi et al., 2016 |
| <i>Allium sativum</i> (garlic) | Aqueous extract | Antimicrobial activity against <i>SE</i> and <i>Salmonella spp.</i> | <i>in vitro</i> tests | El-Azzouny, El-Demerdash, Seadawy, & Abou-Khadra, 2018 |
| | Ethanol extracts of fresh and dried plants | Antioxydant properties, antimicrobial activity against <i>ST</i> , <i>EC</i> , <i>SA</i> and <i>Enterococcus faecalis</i> | Cottage cheese | Josipović et al., 2015 |
| | Ethanol extract | Antimicrobial activity against <i>ST</i> , <i>EC</i> , <i>SA</i> and <i>LM</i> | Dairy based media | Tayel et al., 2015 |
| <i>Bixa orellana</i> (achiote tree) | Commercial Annato extract | Antimicrobial activity against numerous food borne pathogens | <i>in vitro</i> tests | Galindo-Cuspinera et al., 2003 |
| <i>Castanea sativa</i> (chestnut) | Crude methanol extract of the ground leaves | Quorum sensing inhibitory activity against <i>SA</i> | <i>in vitro</i> tests. | Quave et al., 2015 |
| | Aqueous extract | Antimicrobial activity against <i>SA</i> , <i>Streptococcus pneumonia</i> , <i>EC</i> , <i>Klebsiella pneumoniae</i> , <i>Proteus mirabilis</i> and <i>Pseudomonas aeruginosa</i> | <i>in vitro</i> tests | Dashtdar, shirazi, & Khan, 2013 |
| | Aqueous sulfuric acid extract (pH = 3) of leaves | Antimicrobial activity against <i>SA</i> , <i>Proteus vulgaris</i> , <i>Klebsiella pneumoniae</i> , <i>Pseudomonas aeruginosa</i> , <i>EC</i> , <i>ST</i> and <i>Enterobacter aerogens</i> | <i>in vitro</i> tests | Basile et al., 2000 |
| <i>Cedrus deodara</i> (pine) | Aqueous extract of needles | Antimicrobial activity: lower values for total plate count, psychrophilic count and yeast and mould count | Cheese | Mahajan et al., 2016 |
| <i>Crocus sativus</i> (saffron) | Saffron dried stigmas thread like parts of the flower extract | Antioxydant properties, antimicrobial activity against coliform and <i>enterococci</i> groups | Fresh ovine cheese | Aktypis et al., 2018 |
| <i>Cynara</i> | Solutions obtained from dry ethanolic | Antioxidant, antimicrobial activity against <i>ST</i> , <i>EC</i> , | <i>in vitro</i> tests | Kukić et al., 2008 |

| | | | | |
|-------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|-------------------------------------------------|
| <i>cardunculus</i> (cardoon) | Extract of leaf submitted to diverse liquid-liquid partition | <i>Bacillus subtilis</i> , SE , SA , and eight fungi strains | | |
| | Lyophilized aqueous extract from flowers | No antibacterial effect | ewes' milk cheese | Galán et al., 2012 |
| | Leaves, flowers and seeds Solvent: hexane, acetone, methanol, water | Antioxydant properties, antimicrobial activity | <i>in vitro</i> tests | Falleh et al., 2008 |
| <i>Cuminum cyminum</i> (cumin) | Essential oil | Antimicrobial activity against SA , no effect against <i>Lactobacillus acidophilus</i> | Iranian white brined cheese | Sadeghi et al., 2013 |
| | Seed oil | Antimicrobial activity against <i>Salmonella enterides</i> and EC | Domiaty cheese | Mahgoub et al., 2013; Hassanien et al., 2014 |
| | Ethanol extract from seeds | Antimicrobial activity against SA | <i>in vitro</i> tests | Mostafa et al., 2018 |
| <i>Inula britannica</i> (British yellowhead) | Lyophilized aqueous extract from flowers | Antioxidant properties | Cheddar type cheese | N.-K. Lee et al., 2016 |
| <i>Matricaria recutita</i> (chamomille) | Dried chamomile and decoction of dried chamomile | Antioxidant and antifungi properties Antimicrobial activity against SA , <i>Bacillus cereus</i> , LM , <i>Pseudomonas aeruginosa</i> , EC , <i>Enterobacter. cloacae</i> and ST | Cottage cheese | Caleja et al., 2015 |
| Olive | Commercial olive leaf extract | Antimicrobial activity against numerous microorganisms among which LM , SA , EC and <i>Salmonella sp.</i> | <i>in vitro</i> tests | Sudjana et al., 2009 |
| | Polyphenol extract from olive oil by-product | Antimicrobial activity against <i>Pseudomonas fluorescens</i> and <i>Enterobacteriaceae</i> | Fior di latte cheese | (Roila et al., 2019) |
| <i>Origanum vulgare</i> (oregano) | Essential oil | Antimicrobial activity | fresh goat cheese | Zantar et al., 2014 |
| | Essential oil from aerial parts | Antimicrobial activity against <i>Enterobacter sp.</i> but no effect on lactic starter cultures | Traditional Argentinean cheese | Marcial et al., 2016 |
| | Essential oil | Antimicrobial activity against EC O157:H7 and LM | Feta cheese | Govariz et al., 2011 |
| | Ethanol extract from leaves | Antimicrobial activity against ST , EC O157:H7, SA and LM | Dairy based media | Tayel et al., 2015 |
| | Essential oil | Antimicrobial activity against EC O157:H7 | Fresh cheese | (Diniz-Silva et al., 2019) |
| | Essential oil | Antimicrobial activity against EC O157:H7 | Minas frescal cheese | (Diniz-Silva et al., 2019) |

| | | | | |
|---------------------------------------------|----------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|-----------------------------------------------------|
| <i>Ocimum basilicum</i> (basil) | Leaves in dehydrated form or decoction | Antioxydant properties, antimicrobial activity against eight bacteria and eight fungi strains | “Serra da Estrela” cheese | Carocho et al., 2016 |
| <i>Pimpinella anisum</i> (anise) | Essential oils | Antimicrobial activity against <i>EC</i> O157:H7 | Iranian white brined cheese | Ehsani & Mahmoudi, 2012 |
| <i>Rosmarinus officinalis</i> (rosemary) | Rosemary extract (Type HT-125) | Antioxydant properties | cow and soy milk enriched with fish oil | Qiu 2018 |
| | Aqueous ethanolic and methanolic extracts on aerial part | Antimicrobial activity against five Gram-positive strains including <i>SA</i> , <i>SE</i> and <i>LM</i> and seven Gram-negative strains | <i>in vitro</i> tests | Kozłowska, Laudy, Przybył, Ziarno, & Majewska, 2015 |
| | Ethanol and acetone extract | Antioxydant, antimicrobial activity against <i>ST</i> , <i>EC</i> , <i>SA</i> and <i>LM</i> | Cottage Cheese | Josipović et al., 2015 |
| | Essential oil | Antimicrobial activity against <i>EC</i> O157:H7 | Fresh cheese | (Diniz-Silva et al., 2019) |
| | Essential oil | Antimicrobial activity against <i>EC</i> O157:H7 | Minas frescal cheese | (Diniz-Silva et al., 2019) |
| <i>Salvia officinalis</i> (sage) | Aerial part | Antimicrobial activity against five Gram-positive strains including <i>SA</i> , <i>SE</i> and <i>LM</i> and four Gram-negative strains | <i>in vitro</i> tests | Kozłowska, Laudy, Przybył, Ziarno, & Majewska, 2015 |
| | Aqueous ethanolic and methanolic extracts | | | |
| | Ethanol extract from leaves | Antimicrobial activity against <i>ST</i> , <i>EC</i> O157:H7, <i>SA</i> and <i>LM</i> | Dairy based media | Tayel et al., 2015 |
| <i>Syzygium aromaticum</i> (clove) | Extracted with a mixture of ethanol/water (4:1) | Antioxydant, antimicrobial activity against <i>Salmonella enterica</i> , <i>LM</i> , <i>SA</i> | cheese | Shan et al., 2011 |
| <i>Thymus vulgaris</i> (thyme) | Essential oil | Antimicrobial activity | fresh goat cheese | Zantar et al., 2014 |
| | Essential oil | Antimicrobial activity against <i>EC</i> O157:H7 and <i>LM</i> | Feta cheese | Govaris et al., 2011 |
| | Essential oil | Antimicrobial activity against <i>SA</i> , <i>LM</i> and mesophilic starter | Cheese mimicking models | de Carvalho et al., 2015 |
| | Aerial part | Antimicrobial activity against four Gram-positive strains including <i>SA</i> and <i>SE</i> , and six Gram-negative strains | <i>in vitro</i> tests | Kozłowska, Laudy, Przybył, Ziarno, & Majewska, 2015 |
| | Aqueous ethanolic and methanolic extracts | | | |
| | Leaves | Antimicrobial effect against <i>SA</i> and <i>P. aeruginosa</i> . | <i>in vitro</i> tests | Mostafa et al., 2018 |
| | Ethanolic extract | | | |

| | | | | |
|------------------------------------|------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|--------------------------------------------|
| <i>Thymus algeriensis</i> (thyme) | Essential oil | Antimicrobial activity against SA , ST , <i>Enterobacter cloacae</i> , EC , LM , <i>Pseudomonas aeruginosa</i> , <i>Micrococcus flavus</i> , <i>Bacillus cereus</i> | Soft cheese | (Bukvicki et al., 2018) |
| <i>Thymus mastichina</i> (thyme) | Ethanollic and aqueous extract | Antimicrobial activity | Cheese surfaces and ripening chamber | (F. Carvalho et al., 2018) |
| <i>Urtica doica</i> (nettles) | Water extract | Antimicrobial activity | Whey protein coating for preservation of rainbow trout fillets | Alp Erbay et al., 2017 Alp & Aksu, 2010 |
| <i>Vitis vinifera</i> (grape vine) | Grape seeds from Greece (two varieties). Powder, extracted with hexane | Antioxidant properties, did not affect <i>Lactobacilli</i> counts | Full-fat and non-fat yoghurts | Chouchouli et al., 2013 |
| | Grape juice and skin and seed extracts | Antimicrobial activity against LM | <i>in vitro</i> tests | Rhodes et al., 2006 |

1093
1094

EC: *Escherichia coli*, *ST*: *Salmonella Typhimurium*, *SA*: *Staphylococcus aureus*, *SE*: *Staphylococcus epidermidis*, *LI*: *Listeria innocua*, *LM*: *Listeria monocytogenes*

Table 3: Plant bioactive compounds families with potential use as food preservatives

| examples | Pathogen targeted | Source | Ref |
|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Alkaloids | | | |
| Berberine | Inhibition of <i>SE</i> biofilm formation. Antifungal against four <i>Candida</i> species: MIC = 16-128 $\mu\text{g mL}^{-1}$ | <i>Coptidis rhizoma</i> | Wang et al., 2009 |
| Piperine | <i>EC</i> , <i>Klebsiella pneumoniae</i> , <i>Salmonella enterica</i> , <i>SA</i> , <i>Enterococcus faecalis</i> : MIC = 625 $\mu\text{g.mL}^{-1}$ and <i>SE</i> , <i>Staphylococcus xylosus</i> , <i>Bacillus subtilis</i> : MIC = 312.5 $\mu\text{g.mL}^{-1}$ | <i>Piper nigrum</i> | Zarai, Boujelbene, Ben Salem, Gargouri, & Sayari, 2013 |
| No-flavonoid phenolics | | | |
| Cinnamic acid | Cinnamic acid | <i>ST</i> and <i>EC</i> : MIC = 7.5 and 5 mM respectively | <i>Arabidopsis thaliana</i> Olasupo, Fitzgerald, Gasson, & Narbad, 2003 |
| Cinnamic acid | Ferulic acid | <i>EC</i> , <i>Pseudomonas aeruginosa</i> , <i>SA</i> , <i>LM</i> : MIC = 0.1, 0.1, 1.1 and 1.25 mg.mL^{-1} respectively | Borges et al., 2013 |
| Lignans | Styryl juponoside A | <i>Candida albicans</i> , <i>Trichosporon beigeli</i> , <i>Malassezia furfur</i> : MIC = 20 $\mu\text{g.mL}^{-1}$ for the three strains | Park et al., 2010 |
| Phenyl propanoid | Eugenol | <i>ST</i> and <i>EC</i> : MIC = 3 and 2.5 mM respectively | <i>Solanum tuberosum</i> (potato) Olasupo et al., 2003 |
| Benzoic acid | Gallic acid | <i>EC</i> , <i>Pseudomonas aeruginosa</i> , <i>LM</i> , <i>ST</i> and <i>SA</i> : MIC = 1.5, 0.5, 2, 2;5 and 1.25 mg.mL^{-1} respectively | <i>Lawsonia inermis</i> (Henna) Borges, Ferreira, Saavedra, & Simões, 2013; Chanwitheesuk, Teerawutgulrag, Kilburn, & Rakariyatham, 2007 |
| Benzoic acid | Chlorogenic acid | <i>Streptococcus pneumoniae</i> , <i>SA</i> , <i>Bacillus subtilis</i> , <i>EC</i> , <i>Shigella dysenteriae</i> and <i>ST</i> , MIC = 20, 40, 40, 80, 20 and 40 $\mu\text{g.mL}^{-1}$ respectively | prune, aromatic herbs Lou, Wang, Zhu, Ma, & Wang, 2011 |
| Prenylated benzyl | Erybraedin A | five <i>Streptococcus</i> strains: MIC = 0.78-1.56 $\mu\text{g.mL}^{-1}$, <i>SA</i> : MIC = 3.13 $\mu\text{g.mL}^{-1}$ and seven drug-resistant strains of <i>SA</i> : MIC = 0.78-6.25 $\mu\text{g.mL}^{-1}$ | <i>Erythrina subumbrans</i> Rukachaisirikul et al., 2007 |
| Stilbene | E-resveratrol | Antioxidant and antimicrobial against <i>Penicillium expansum</i> and <i>Aspergillus niger</i> | (blackberries, grape skin) Filip, 2003; Stojanović, Sprinz, & Brede, 2001 |
| Stilbene | Vitisin B | <i>Pseudomonas aeruginosa</i> and <i>EC</i> : biofilm formation inhibition | <i>Paeonia lactiflora</i> (seed) Lee, Kim, Ryu, Cho, & Lee, 2014 |

| Flavonoïd | | | | |
|--------------------|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|---------------------------------------------------------------------------------------|
| flavanol | Epigallocatechin-3-O-gallate | <i>SA</i> , <i>Salmonella</i> (ATCC 9270 and ATCC 13314), <i>EC</i> and <i>Vibrio</i> (ATCC 17802): MIC = 98, 308, 602 and 68 µg.mL ⁻¹ respectively | | Taguri, Tanaka, & Kouno, 2004 |
| flavonol | Petalostemumol | <i>Candida albicans</i> , <i>Cryptococcus neoformans</i> , <i>Mycobacterium intracellulare</i> and <i>EC</i> : MIC = 12.5, 25, 6.25, 6.25 and 0.78 µg.mL ⁻¹ respectively | Purple prairie clover | Hufford et al., 1993 |
| Peptides | | | | |
| Defensin | Thionins | <i>LM</i> , <i>LI</i> , <i>Listeria ivanovii</i> : MIC = 2, 2, 5 µg.mL ⁻¹ respectively | <i>Triticum aestivum</i> (wheat) | Lopez-Solanilla, Gonzalez-Zorn, Novella, Vazquez-Boland, & Rodriguez-Palenzuela, 2003 |
| Cyclotide | Cycloviolacin O2 | <i>EC</i> , <i>Salmonella enterica</i> , MIC = 2.2, 8.75 µM respectively | <i>Viola odorata</i> (violet) | Pranting, Loov, Burman, Goransson, & Andersson, 2010 |
| Snakin | | <i>LM</i> , <i>LI</i> , <i>Listeria ivanovii</i> : MIC = 10 µg.mL ⁻¹ for all | <i>Impatiens balsamina</i> (balsam) | Lopez-Solanilla et al., 2003 |
| Terpenoïds | | | | |
| monoterpene | Thymol | <i>ST</i> and <i>EC</i> : MIC = 1 and 1.2 mM respectively, then <i>SA</i> , <i>LI</i> , <i>EC</i> , <i>Aspergillus niger</i> : MIC = 250 ppm for all) and <i>Saccharomyces cerevisiae</i> : MIC = 125 ppm | <i>Oldenlandia affinis</i> | Guarda, Rubilar, Miltz, & Galotto, 2011; Olasupo et al., 2003 |
| monoterpene | Carvacrol | <i>ST</i> and <i>EC</i> : MIC = 1 and 1.5 mM respectively and <i>SA</i> , <i>LI</i> , <i>Aspergillus niger</i> : MIC = 225 ppm for all and <i>Saccharomyces cerevisiae</i> : MIC = 75 ppm | <i>Hordeum vulgare</i> (barley) | Guarda et al., 2011; Olasupo et al., 2003 |

EC: *Escherichia coli*, *ST*: *Salmonella Typhimurium*, *SA*: *Staphylococcus aureus*, *SE*: *Staphylococcus epidermidis*, *LI*: *Listeria innocua*, *LM*: *Listeria monocytogenes*

1096
1097

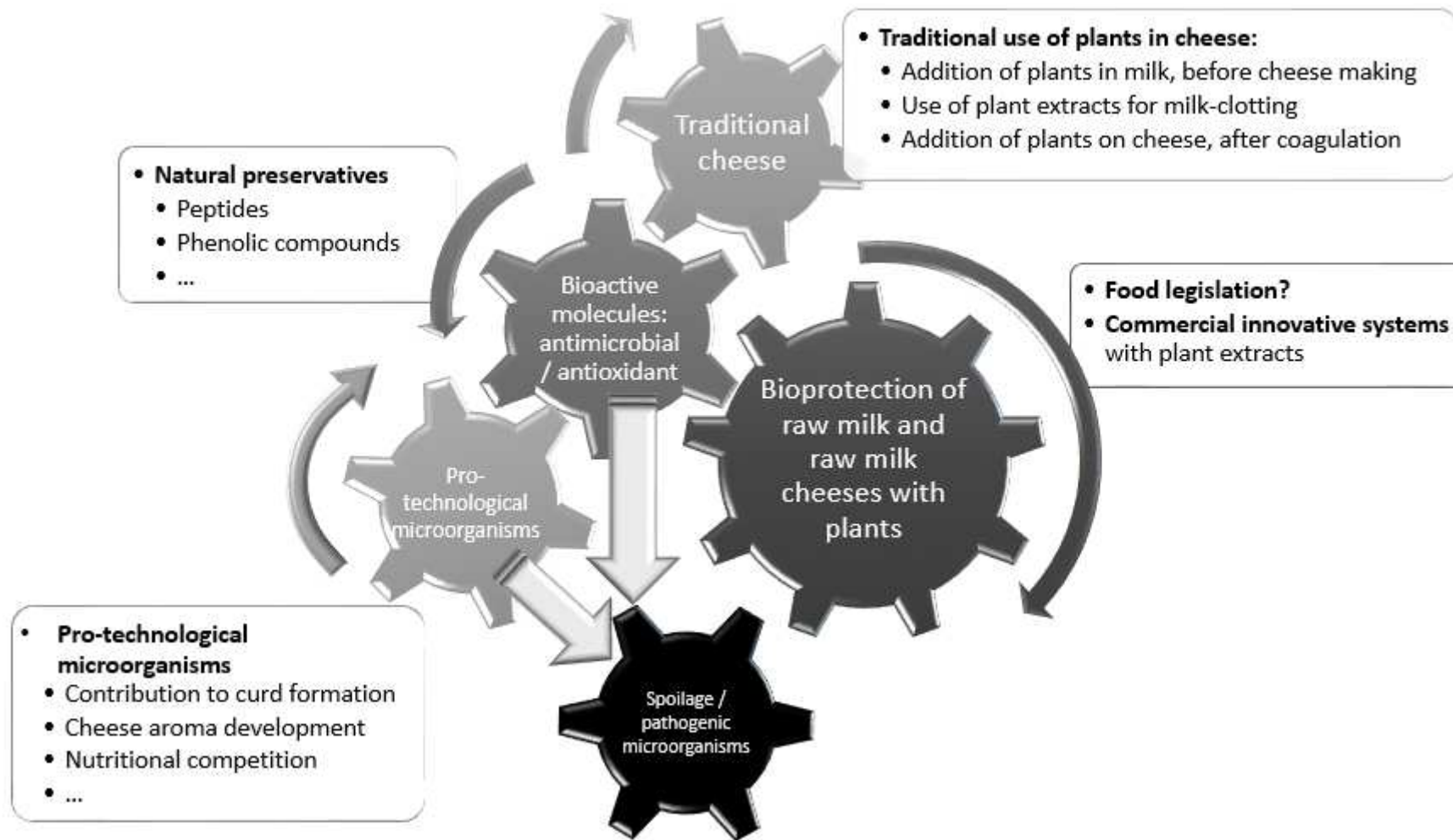


Figure 1

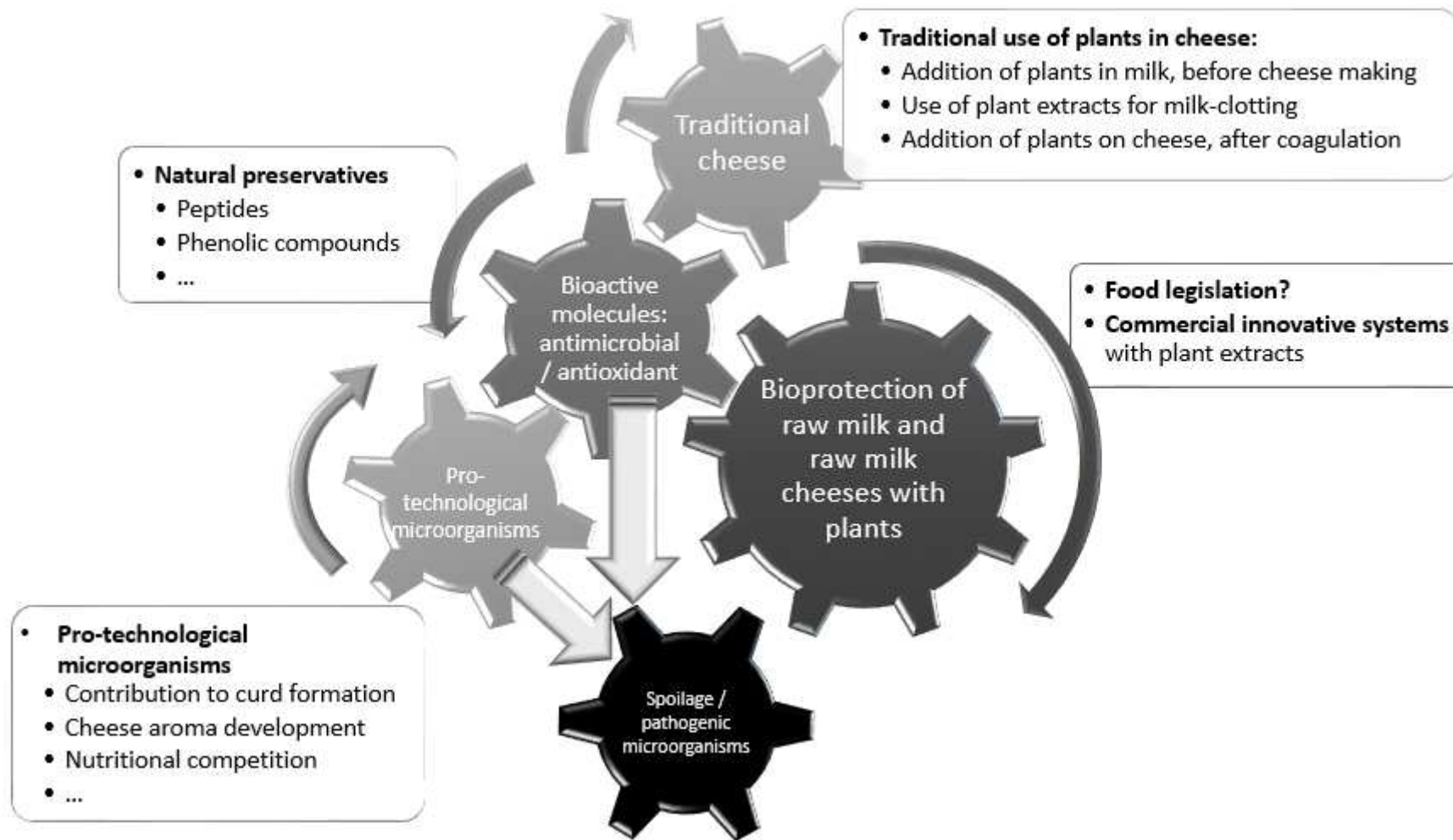


Figure 1