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

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Abstract

Plants have been traditionnally used for centuries in cheese manufacturing, either for their aromatic properties or as technological auxiliaries (e.g. milk-clotting enzyme preparations, cheese wrappers). Some of these plants are known to have antimicrobial and / or antioxidant properties and could also act as natural preservatives for raw milk and derived dairy products.

This review examined the traditional uses of plants in dairy processing, and then focuses on known antimicrobial and antioxidant properties of their extracts (e.g. maceration, decoction, essential oil). Known effects of theses plants on technological flora (starter cultures and microorganisms implicated in cheese ripening) were also summarized, and the potential for plant extracts used in combination with hurdle technologies was explored. Then, legal restriction and bioactivity variations from a culture media to a food matrix was reviewed: non-toxic bioactive molecules found in plants, extract preparation modes suitable with foodgrade processing restrictions, the role of the food matrix as a hindrance to the efficiency of bioactive compounds, and a review of food legislation. Finally, some commercial plant extracts for milk preservation were discussed.

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

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1. Introduction

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

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

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

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

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 schalotts, chives; and less commonly tarragon, oregano, mustard seed or bran, nettles, nutmeg, basil, and horseradish. Traditionnally, 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).

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

2.2 Use of plant extracts for milk-clotting

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

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

With this method, milk-clotting is the result of the action of cardosins and cyprosins, a kind of aspartic proteases also known as phytepsins (EC 3.4.23.40), that have a high specificity towards κ-casein (Vairo Cavalli, Lufrano, Colombo, & Priolo, 2013). The use of serine and cysteine proteases from plants for milk clotting has also been reported (Shah et al., 2014). Current uses in cheese making include caprifig extracts in Ficu and Cacioricotta (Faccia et al., 2012).

2.3. Addition of plants on cheese, after coagulation

While some cheeses are traditionally rolled into crushed herbs or spices such as garlic, pepper, sage, chives, rosemary, the whole plant is sometimes used directly on the cheese surface for flavouring and/or aesthetic purposes (Table 1). Among French cheeses, thyme or rosemary sprigs or even glasswort (Galette du Paludier) can be encountered. Wood, leaves have long been used in cheese processing and packaging around the globe. Aromatic effect most often appeared as a side-effect of that packaging process while the initial intention was cheese preservation (Froc, 2007). Chestnut, gentian, avizzo, or vine leaves, for example, were (or are still) used as cheese interleaves (Cantin, Gaudin, & Leser, 2013), as moisture absorbers or for cheese wrapping. In France, Banon goat cheese is ripened wrapped in chestnut leaves (Décret du 23 juillet 2003 relatif à l'appellation d'origine contrôlée « Banon », 2003) which brings specific flavours thanks to anaerobic fermentation and to the tannin-rich rot-proof leaves. These traditionnal uses participate in the taste of the final product (Collectif, 1998; Froc, 2007; Sicard, 2018), which directly suggests molecule migrations from the organic matter to the cheese surface and/or curd. In the U.K., the Cornish Yarg is wrapped in nettle or wild garlic leaves to form an mouldy edible rind. In Italy, Pecorino is sometimes covered with a fresh walnut leaf, Ubriaco with a fig leaf and Seirass with hay for decorative purposes (Sicard, 2018).

Little is known concerning possible migration of molecules, such as phenolic compounds from the leaf to the cheese, and concerning their potent action as natural preservatives during cheese storage and ripening. Terpenes arising from the surface of mint leave springling, during the manufacture of the cheese, were detected in Halloumi cheese curd (Papademas & Robinson, 2001). Their role as flavouring molecules is reported, but while the role of mint as a preservative in this cheese is traditionally claimed, as the cheese is entirely covered in folded mint leaves during the ripening period (Sicard, 2018), it has never been scientifically investigated.

3. Biopreservation of milk and cheeses with plants

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

3.1. Dairy products with addition of essential oils

As the demand for natural preservatives increases, essential oil addition in cheese was particularly explored (Table 2). For example, *E. coli* O157:H7 and *L. monocytogenes* growth were inhibited in feta cheese by adding essential oil of thyme (at a dose of 0.1 mL/100 g) (Govaris, Botsoglou, Sergelidis, & Chatzopoulou, 2011) or oregano (0.1 or 0.2 mL/100 g) (Govaris et al., 2011). Antimicrobial activity of these 2 essential oil was also demonstrated in fresh goat cheese (Zantar et al., 2014). Original approaches, such as the use of antimicrobial sachets containing rosemary and thyme oils, designed to enhance the shelf-life of shredded mozzarella, were also reported (Han, Patel, Kim, & Min, 2014).
The recent review of Khorshidian et al. (Khorshidian, Yousefi, Khanniri, & Mortazavian, 2018) on preservation of cheese with essential oils can be consulted for further information.

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

In spite of the proven antibacterial effect of essential oil for cheese preservation, several factors limit their application: intense flavour and potential interactions with food components may be an hindrance to their efficiency. Other concerns include their price (Calo, Crandall, O'Bryan, & Ricke, 2015; Hyldgaard, Mygind, & Meyer, 2012; Perricone, Arace, Corbo, Sinigaglia, & Bevilacqua, 2015), and their potential toxicity at high doses despite their GRAS status. For these reasons, recent studies on dairy product preservation have focused on the effects of plant extracts other than essential oil (Table 2). Rosemary extract was thus successfully used as an antioxidant for the lipid preservation of cow milk enriched with fish oil (Qiu, Jacobsen, & Sørensen, 2018). Rosemary extract also inhibited the growth of *L.monocytogenes* ($4x10^5$ $CFU.mL^{-1}$) incubated at 37°C for 24 hours in cheddar base media at a concentration of 750 $\mu g.mL^{-1}$ (Tayel, Hussein, Sorour, & El-Tras, 2015). Rosemary alcoholic extracts enhanced the oxidative stability of butter at temperatures of 60 and 110°C, when added at concentrations such as 400 mg of phenolic compounds per kg of butter (Santos, Shetty, & da Silva Miglioranza, 2014). A clove extract (625 µg.mL^{-1}) inhibited a population of *L.monocytogenes* (4x10^{5} CFU.mL^{-1}) incubated at 37°C for 24 hours in cheddar based media (Tayel et al., 2015). In the same study, an oregano extract (950 µg.mL^{-1}) yielded similar results.

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

The use of plant extracts, as preservatives can also be a source of innovative products by creating new tastes as a side effect. Low fat Kalari (Indian hard and dry cheese) was sprayed with 0%, 2.5% and 5.0% pine needles extract (*Cedrus deodara*) and aerobically packaged in low-density polyethylene pouches. This resulted in lower thiobarbituric acid reactive substances, free fatty acid (% oleic acid) values, and lower total plate, counts of psychrophilic bacteria, yeast and mould (Mahajan, Bhat, & Kumar, 2016). Addition of *Inula britanica* flower extract during cheddar-type cheese making increased antioxidant properties (Lee, Jeewanthi, Park, & Paik, 2016). Clove (*Syzygium aromaticum*) extract increased the stability of cheese against lipid oxidation (Shan, Cai, Brooks, & Corke, 2011) and was also efficient against *L. monocytogenes*, *S. aureus*, and *Salmonella enterica* in cheese at room temperature (Shan et al., 2011). Finally, fresh ovine Greek cheese was supplemented with saffron, resulting in a significant decrease of the total aerobic bacteria counts, with an antibacterial activity against coliform and enterococci groups (Aktypis et al., 2018).

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

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

3.3. Dairy products with raw plant additions

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

Carocho et al. (Carocho et al., 2016) compared the effect of the incorporation of decoctions and dehydrated basil in Serra da Estrela cheese. Basil leaves provided antioxidant activity to the cheeses, reduced the moisture and preserved the unsaturated fatty acids and proteins; while the basil decoction showed an antimicrobial effect against eight bacterial and eight fungi strains in culture media. These bioactivities were not studied in cheese, though. Josipovick (Josipović et al., 2015) added fresh or dried parsley, dill, pepper, garlic and rosemary to cottage cheese. This plant addition did not reduce the concentration of foodborne pathogens, contrary to the plant extract. Soft cheese supplemented with either 1% garlic or 1% clove powders showed no improvement in antimicrobial effects against *L. monocytogenes* after one or two weeks at 37°C and at 4°C (Leuschner & Ielsch, 2003).

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

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

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

As previously described, some plant extracts, such as *Cynara cardunculus* var *sylvestris* flower extracts, may be used for milk clotting. (Ben Amira et al., 2017). Besides this application, some studies have shown the antioxidant and antimicrobial effect of different organs of the *C. cardunculus* species, due to phenolic compounds with bioactive properties. The three main *C. cardunculus* taxa are the domestic cardoon (*C. cardunculus* var. *altilis* DC), the globe artichoke (*C. cardunculus* var. *scolymus* L.) and the wild cardoon (*C. cardunculus* var. *Sylvestris* (Lamk) Fiori).

Falleh et al. (Falleh et al., 2008) compared extracts from domestic cardoon leaves, flowers and seeds. The phenolics/flavonoids contents of leaves and seeds were similar (approximatively 14 mg GAE g^{-1} DW) and 2 times higher than those in flowers. Seed extracts displayed the highest DPPH·; followed by leaves, and flowers; IC_{50} values were 23, 53 and 118 μg.mL^{-1} respectively. In contrast, leave extract showed the highest capacity to quench superoxide compared to seeds and flowers, IC_{50} values were 1. 6 and 9 μg.mL^{-1} respectively. Only an extract from leaves was tested for antimicrobial activity, showing growth inhibition of *S. aureus* and *E. coli*. Kukić et al. (Kukić et al., 2008) also showed the antioxidant and antimicrobial effects of cardoon leave extracts. Besides their strong antioxidant activity, the cardoon inflorescences showed antibacterial activity against Gram-positive strains, the lowest MIC being observed for *L. monocytogenes* (Dias et al., 2018). However, this antimicrobial effect was not found in food media when comparing Ewes' cheese produced with plant coagulant from cardoon *C. cardunculus* (21 g.100 L^{-1}) and cheese produced with a calf rennet (Galán, Cabezas, & Fernández-Salguero, 2012). Throughout the ripening of the cheeses, no significant differences in microbial counts were observed between the ones made with these two types of coagulant. It can also be noted that Silva et al. (Silva, Pihlanto, & Malcata, 2006) studied ovine and caprine cheeselike systems manufactured with proteases from *C. cardunculus* and showed that it is a source of peptides with antioxidant activities.

3.5. Effect of plant extract on pro-technological flora

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

Thymus vulgaris essential oil affected *S. aureus, L. monocytogenes* growth (1.3 log CFU.mL^{-1} reduction at 10°C for 24h), but also the mesophilic starter co-culture in cheese-mimicking models (cheese-based broth and in a semi-solid (*coalho*) cheese) (R. J. de Carvalho et al., 2015). Some essential oils met this criterion successfully, though : a rosemary essential oil (215mg.L^{-1} in sheep milk cheese) inhibited *Clostridium ssp*. during the 5 month ripening period while not reducing the population of lactic acid bacteria (Moro, Librán, Berruga, Carmona, & Zalacain, 2015). *Cuminum cyminum* essential oil (0, 7.5, 15 and 30 µL.100mL^{-1} in cow milk) used in synergy with *Lactobacillus acidophilus* strains also inhibited *S. aureus* in Iranian white brined cheese (Sadeghi, Akhondzadeh Basti, Noori, Khanjari, & Partovi, 2013). Oregano essential oil (200 mg.L^{-1} in cow milk) impeded the growth of enterobacteria in a traditionnal Argentinean cheese while not affecting starters (Marcial et al., 2016). Thyme or sage essential oils added at doses of 1500 mg.kg^{-1} to Fior di Latte cheese inhibited *Pseudomonas* spp. and coliforms stored at 10°C for 6 days while not reducing the population of lactic acid bacteria (Gammariello, Di Giulio, Conte, & Del Nobile, 2008). Grape seed extract of *Vitis vinifera* showed important anti- *L. monocytogenes* effects (Rhodes, Mitchell, Wilson, & Melton, 2006), while the addition of grape seed extract of *Vitis vinifera* did not affect yoghurts *Lactobacilli* count (Chouchouli et al., 2013). Galindo et al. (Galindo-Cuspinera, Westhoff, & Rankin, 2003) studied the antimicrobial properties of a commercial Annato extract against pathogenic, lactic acid and spoilage microorganisms. Indeed, Annato is an orange-red condiment and food coloring extracted from the achiote tree (*Bixa orellana*), and added to obtain the color of numerous cheeses e.g. Cheddar, Mimolette, Edam and Livarot. The effect was very variable between studied strains. An inhibitory effect on pathogenic *Bacillus cereus, Clostridium perfringens*, and *S. aureus*, with MICs values of 0.08, 0.31, and 0.16% (vol/vol) was respectively observed. Higher concentrations of Annato (0.63%, vol/vol) were needed to inhibit the growth of pro-technological *Streptococcus thermophilus*, *Lactobacillus casei* subsp. *casei* and *Lactococcus lactis*. However, at this concentration, the growth of *L. monocytogenes* and *Enterococcus durans* were not inhibited (MICs: 1.25 and 2.5%, vol/vol, respectively). No activity was detected against *Lactobacillus plantarum, Bifidobacterium bifidum*, yeasts, or selected Gram-negative bacteria.

3.6. Synergic effect and hurdle technology

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

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

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

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

4.1 Plant bioactive compounds families with potential use as food preservatives

Most of the compounds from plants that are of interest in biopreservation solutions are secondary metabolites with various functions in plant survival, among which is the antimicrobial activity. Plant metabolite content varies according to the taxa, the organ, the stage of growth and development, the season, and the stress conditions, for example. Metabolites are classified into different categories depending on the chemical structure and the main ones are presented in Table 3.

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

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

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

4.2 Sample preparations and extractive techniques suitable for the food industry

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

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

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

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

Introduced in the 90s, pressurized liquid extraction is characterized by high temperature (from 50 to 200 °C) and high pressure (from 500 to 3000 psi), mainly to keep the solvent liquid, resulting in high performance (yield, quantities of solvent, duration) (Azmir et al., 2013). A high temperature disturbs weak interactions (Van der Walls, hydrogen bond and dipolar interaction) and decreases solvent viscosity. High pressure increases contact between solvent and matrices. Some limitations for the technique include its cost and the degradation of thermo sensible compounds (Mustafa & Turner, 2011).

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

Essential oils are composed of volatile and lipophilic compounds, which are mainly lighly hydroxylated terpenoid and low molecular weight aromatic compounds. They can be obtained by different means, among which hydrodistillation, steam distillation, maceration in apolar solvent and supercritical extraction (Tyśkiewicz, Gieysztor, Konkol, Szałas, & Rój, 2018). Hydrosols, which are acqueous products of hydrodistillation (also known as floral waters), might be considered too, since they usually are food grade products, and some (cumin, clove, garlic, mustard, oregano, rosemary, sage and thyme hydrosols) exhibited antimicrobial activities against food relevant strains (D'Amato, Serio, López, & Paparella, 2018). Hydrodistillation using a Clevenger apparatus is a common method for essential oil extraction because it is cheap and easy to use, but some of its disadvantages are a low yield, losses of volatile compounds, and long extraction times. Moreover, the degradation of unsaturated compounds, partial hydrolysis and deterioration due to heat-sensitive compounds might occur (Puri et al., 2012). Nevertheless, recent innovations improving yield and decreasing the extraction time have been reported. These were hydrodistillation coupled with ultrasonic extraction and ohmic hydrodistillation. During ohmic hydrodistillation, an alternative current is passed through the round bottom flask to generate heat within the medium (Gavahian, Farahnaky, Shavezipur, & Sastry, 2016).

Most expensive, the supercritical fluids extraction (SFE) can be performed at temperatures around 313 K thereby preserving original oil composition and properties. SFE is mostly performed with carbon dioxide (CO_2) because it has low critical pressure (73.8 bar) and temperature (31.1°C). In addition, it is relatively non-toxic, nonflammable, and relatively cheap (Sodeifian, Sajadian, & Saadati Ardestani, 2016, Ivanovic, Misic, Zizovic, & Ristic, 2012), nevertheless other solvents (or co-solvent), including water, may be used (Da Silva et al., 2016). SFE is valuable for the food industry especially for products such as de-caffeinated or de-alcoholized beverages, zero-fat potato ships, and others (Brunner, 2005).

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

4.3. Food legislation

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

Similarly to raw milk, raw-milk derived products are considered as “risky foods.” Heat treatment applied to milk (pasteurization or sterilization) leads to an alteration of cheese properties (i. e. typical aromas, texture, flavors). In developed countries, cheeses are manufactured with pasteurized milk, and raw-milk cheese diffusion is limited, even in Europe, despite a derogative directive (92/46) of the EEC (Licitra, Caccamo, & Lortal, 2019). However, traditional and artisan raw-milk cheeses are produced worldwide and have an important economic role, and also a social and a cultural role. As plants are already traditionally used in cheese production methods for their aromatic properties, or in other food products, plant additions in raw-milk in order to enhance the safety of cheeses respect the existing legislation (Food an Drug Administration - Food Ingredients & Packaging, 2019; Regulation EC N°1334/2008, 2008).

4.4. Commercial innovative systems with plant extracts

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

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

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

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

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

5. Conclusion

Numerous plants are traditionnally used in cheese making, for their flavouring properties as well as for their technological properties (e.g. milk clotting, packaging). Some of those plants contain peptides and/or secondary metabolites that exhibit antimicrobial properties against foodborne pathogens. In Mediterranean countries, dairy products, mainly raw milk, play an important role in the local economic sector, and in the diet of local consumers. However, the contamination level of raw milk with pathogenic strains might be enhanced by the lack of refrigeration or adequate transformation equipments. Thus, delaying microbial contamination of raw milk with plants traditionally associated with dairy products might be part of the solution. Such solutions can be developped in all the Mediterranean coutries while respecting regulations and economic considerations. Also, scientific studies must prouve the antimicrobial effect against pathogenic and spoilage microorganisms, while preserving the technological flora implicated in milk clotting and ripening.

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References

Ahmed, A. M., Rabii, N. S., Garbaj, A. M., & Abolghait, S. K. (2014). Antibacterial effect of olive (*Olea europaea* L.) leaves extract in raw peeled undeveined shrimp (*Penaeus semisulcatus*). *International Journal of Veterinary Science and Medicine*, *2*(1), 53–56. https://doi.org/10.1016/j.ijvsm.2014.04.002

Aksu, M. I., & Kaya, M. (2004). Effect of usage *Urtica dioica* L. on microbiological properties of sucuk, a Turkish dry-fermented sausage. *Food Control*, *15*(8), 591–595. https://doi.org/10.1016/j.foodcont.2003.09.006

Aktypis, A., Christodoulou, E. D., Manolopoulou, E., Georgala, A., Daferera, D., & Polysiou, M. (2018). Fresh ovine cheese supplemented with saffron (*Crocus sativus* L.): Impact on microbiological, physicochemical, antioxidant, color and sensory characteristics during storage. *Small Ruminant Research*, *167*, 32–38. https://doi.org/10.1016/j.smallrumres.2018.07.016

Alp, E., & Aksu, M. İ. (2010). Effects of water extract of *Urtica dioica* L. and modified atmosphere packaging on the shelf life of ground beef. *Meat Science*, *86*(2), 468–473. https://doi.org/10.1016/j.meatsci.2010.05.036

Alp Erbay, E., Dağtekin, B. B. (Gözü), Türe, M., Yeşilsu, A. F., & Torres-Giner, S. (2017). Quality improvement of rainbow trout fillets by whey protein isolate coatings containing electrospun poly(ε-caprolactone) nanofibers with *Urtica dioica* L. extract during storage. *LWT - Food Science and Technology*, *78*, 340–351. https://doi.org/10.1016/j.lwt.2017.01.002

Aluko, R. E. (2008). *Determination of Nutritional and Bioactive Properties of Peptides in Enzymatic Pea, Chickpea, and Mung Bean Protein Hydrolysates*. *91*(10), 947–956.

Aouidi, F. (2012). *Etude et valorisation des feuilles d'Olivier Olea europaea dans l'industrie Agro-Alimentaire* (Université de Carthage). Retrieved from 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

IMG%2Fpdf%2Fre-38_2012_aouidi_these_version_soutenance.pdf%3F932%2F1696e160fbaaf69aaf4d32d8211b77fd483c397e&usg=AOvVaw0LvM9ISz0lYgK-uWcjw6Uy

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

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

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

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

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

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

Bleoancă, I., Saje, K., Mihalcea, L., Oniciuc, E.-A., Smole-Mozina, S., Nicolau, A. I., & Borda, D. (2016). Contribution of high pressure and thyme extract to control *Listeria monocytogenes* in fresh cheese - A hurdle approach. *Innovative Food Science & Emerging Technologies*, *38*, 7–14. https://doi.org/10.1016/j.ifset.2016.09.002

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

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

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

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

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

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

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

Calo, J. R., Crandall, P. G., O'Bryan, C. A., & Ricke, S. C. (2015). Essential oils as antimicrobials in food systems – A review. *Food Control*, *54*, 111–119. https://doi.org/10.1016/j.foodcont.2014.12.040

Cantin, M.-A., Gaudin, C., & Leser, N. (2013). *Guide de l'amateur de fromages*. Paris: A. Michel.

Carocho, M., Barros, L., Barreira, J. C. M., Calhelha, R. C., Soković, M., Fernández-Ruiz, V., Ferreira, I. C. F. R. (2016). Basil as functional and preserving ingredient in "Serra da Estrela" cheese. *Food Chemistry*, *207*, 51–59. https://doi.org/10.1016/j.foodchem.2016.03.085

Carvalho, F., Rodrigues, A., Gomes, D. M. G. S., Ferreira, F. M. L., Dias, S. P., Pereira, C. J. D., & Henriques, M. H. F. (2018). Chapter 7 - Improvement of Ripened Cheese Quality and Safety With Thymus mastichina L. Bioactive Extracts. In A. M. Holban & A. M. Grumezescu (Eds.), *Advances in Biotechnology for Food Industry* (pp. 197–211). https://doi.org/10.1016/B978-0-12-811443-8.00007-4

Chanwitheesuk, A., Teerawutgulrag, A., Kilburn, J. D., & Rakariyatham, N. (2007). Antimicrobial gallic acid from *Caesalpinia mimosoides* Lamk. *Food Chemistry*, *100*(3), 1044–1048. https://doi.org/10.1016/j.foodchem.2005.11.008

Chen, J.-R., Yang, S.-C., Suetsuna, K., & Chao, J. C.-J. (2004). Soybean protein-derived hydrolysate affects blood pressure in spontaneously hypertensive rats. *Journal of Food Biochemistry*, *28*(1), 61–73. https://doi.org/10.1111/j.1745-4514.2004.tb00055.x

Chouchouli, V., Kalogeropoulos, N., Konteles, S. J., Karvela, E., Makris, D. P., & Karathanos, V. T. (2013). Fortification of yoghurts with grape (*Vitis vinifera*) seed extracts. *LWT - Food Science and Technology*, *53*(2), 522–529. https://doi.org/10.1016/j.lwt.2013.03.008

Claeys, W. L., Cardoen, S., Daube, G., De Block, J., Dewettinck, K., Dierick, K., Herman, L. (2013). Raw or heated cow milk consumption: Review of risks and benefits. *Food Control*, *31*(1), 251–262. https://doi.org/10.1016/j.foodcont.2012.09.035

Collectif. (1998). *L'inventaire du patrimoine culinaire de la France. Auvergne. Produits de terroir et recettes traditionnelles*. Albin Michel.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Food an Drug Administration - Food Ingredients & Packaging.

Froc, J. (2007). *Balade au pays des fromages: Les traditions fromagères en France*. Versailles: Quae.

Galán, E., Cabezas, L., & Fernández-Salguero, J. (2012). Proteolysis, microbiology and sensory properties of ewes' milk cheese produced with plant coagulant from cardoon *Cynara cardunculus*, calf rennet or a mixture thereof. *International Dairy Journal*, *25*(2), 92–96. https://doi.org/10.1016/j.idairyj.2012.02.001

Galindo-Cuspinera, V., Westhoff, D. C., & Rankin, S. A. (2003). Antimicrobial properties of commercial annatto extracts against selected pathogenic, lactic acid, and spoilage microorganisms. *Journal of Food Protection*, *66*(6), 1074–1078.

Gammariello, D., Di Giulio, S., Conte, A., & Del Nobile, M. A. (2008). Effects of Natural Compounds on Microbial Safety and Sensory Quality of Fior di Latte Cheese, a Typical Italian Cheese. *Journal of Dairy Science*, *91*(11), 4138–4146. https://doi.org/10.3168/jds.2008-1146

Gavahian, M., Farahnaky, A., Shavezipur, M., & Sastry, S. (2016). Ethanol concentration of fermented broth by ohmic-assisted hydrodistillation. *Innovative Food Science & Emerging Technologies*, *35*, 45–51. https://doi.org/10.1016/j.ifset.2016.04.001

Govaris, A., Botsoglou, E., Sergelidis, D., & Chatzopoulou, P. S. (2011). Antibacterial activity of oregano and thyme essential oils against *Listeria monocytogenes* and *Escherichia coli* O157:H7 in feta cheese packaged under modified atmosphere. *LWT - Food Science and Technology*, *44*(4), 1240–1244. https://doi.org/10.1016/j.lwt.2010.09.022

Guang, C., & Phillips, R. D. (2009). Plant Food-Derived Angiotensin I Converting Enzyme Inhibitory Peptides. *Journal of Agricultural and Food Chemistry*, *57*(12), 5113–5120. https://doi.org/10.1021/jf900494d

Guarda, A., Rubilar, J. F., Miltz, J., & Galotto, M. J. (2011). The antimicrobial activity of microencapsulated thymol and carvacrol. *International Journal of Food Microbiology*, *146*(2), 144–150. https://doi.org/10.1016/j.ijfoodmicro.2011.02.011

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Kirkland, D., Edwards, J., Woehrle, T., & Beilstein, P. (2015). Investigations into the genotoxic potential of olive extracts. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*, *777*, 17–28. https://doi.org/10.1016/j.mrgentox.2014.10.012

Kozłowska, M., Laudy, A. E., Przybył, J., Ziarno, M., & Majewska, E. (2015). Chemical composition and antibacterial activity of some medicinal plants from Lamiaceae family. *Acta Poloniae Pharmaceutica*, *72*(4), 757–767.

Kukić, J., Popović, V., Petrović, S., Mucaji, P., Ćirić, A., Stojković, D., & Soković, M. (2008). Antioxidant and antimicrobial activity of *Cynara cardunculus* extracts. *Food Chemistry*, *107*(2), 861–868. https://doi.org/10.1016/j.foodchem.2007.09.005

Lahti, E., Rehn, M., Ockborn, G., Hansson, I., Ågren, J., Engvall, E. O., & Jernberg, C. (2017). Outbreak of Campylobacteriosis Following a Dairy Farm Visit: Confirmation by Genotyping. *Foodborne Pathogens and Disease*, *14*(6), 326–332. https://doi.org/10.1089/fpd.2016.2257

Lee, J.-H., Kim, Y.-G., Shi Yong Ryu, Cho, M. H., & Lee, J. (2014). Resveratrol Oligomers Inhibit Biofilm Formation of *Escherichia coli* O157:H7 and *Pseudomonas aeruginosa*. *Journal of Natural Products*, *77*(1), 168–172. https://doi.org/10.1021/np400756g

Lee, N.-K., Jeewanthi, R. K. C., Park, E.-H., & Paik, H.-D. (2016). Short communication: Physicochemical and antioxidant properties of Cheddar-type cheese fortified with *Inula britannica extract*. *Journal of Dairy Science*, *99*(1), 83–88. https://doi.org/10.3168/jds.2015-9935

Leuschner, R. G. K., & Ielsch, V. (2003). Antimicrobial effects of garlic, clove and red hot chilli on *Listeria monocytogenes* in broth model systems and soft cheese. *International Journal of Food Sciences and Nutrition*, *54*(2), 127–133. https://doi.org/10.1080/0963748031000084070

Licitra, G., Caccamo, M., & Lortal, S. (2019). Artisanal Products Made With Raw Milk. In *Raw Milk* (pp. 175–221). https://doi.org/10.1016/B978-0-12-810530-6.00009-2

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

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

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

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

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

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

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

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

Marcial, G. E., Gerez, C. L., de Kairuz, M. N., Araoz, V. C., Schuff, C., & de Valdez, G. F. (2016). Influence of oregano essential oil on traditional Argentinean cheese elaboration: Effect on lactic starter cultures. *Revista Argentina de Microbiología*, *48*(3), 229–235. https://doi.org/10.1016/j.ram.2016.04.006

Marinho, M. T., Bersot, L. dos S., Nogueira, A., Colman, T. A. D., & Schnitzler, E. (2015). Antioxidant effect of dehydrated rosemary leaves in ripened semi-hard cheese: A study using coupled TG–DSC–FTIR (EGA). *LWT - Food Science and Technology*, *63*(2), 1023–1028. https://doi.org/10.1016/j.lwt.2015.03.108

Mogoşanu, G. D., Grumezescu, A. M., Bejenaru, C., & Bejenaru, L. E. (2017). Natural products used for food preservation. In *Food Preservation* (pp. 365–411). https://doi.org/10.1016/B978-0-12-804303-5.00011-0

Moro, A., Librán, C. M., Berruga, M. I., Carmona, M., & Zalacain, A. (2015). Dairy matrix effect on the transference of rosemary (*Rosmarinus officinalis*) essential oil compounds during cheese making. *Journal of the Science of Food and Agriculture*, *95*(7), 1507–1513. https://doi.org/10.1002/jsfa.6853

Mostafa, A. A., Al-Askar, A. A., Almaary, K. S., Dawoud, T. M., Sholkamy, E. N., & Bakri, M. M. (2018). Antimicrobial activity of some plant extracts against bacterial strains causing food poisoning diseases. *Saudi Journal of Biological Sciences*, *25*(2), 361–366. https://doi.org/10.1016/j.sjbs.2017.02.004

Muehlhoff, E., & FAO (Eds.). (2013). *Milk and dairy products in human nutrition*. Rome: FAO.

Mustafa, A., & Turner, C. (2011). Pressurized liquid extraction as a green approach in food and herbal plants extraction: A review. *Analytica Chimica Acta*, *703*(1), 8–18. https://doi.org/10.1016/j.aca.2011.07.018

Nero, A. L., & Carvalho, A. F. de. (2018). *Raw milk: balance between hazards and benefits* (1st ed., Vols. 1–1). Academic Press.

Nirmala, C., Bisht, M. S., Bajwa, H. K., & Santosh, O. (2018). Bamboo: A rich source of natural antioxidants and its applications in the food and pharmaceutical industry. *Trends in Food Science & Technology*, *77*, 91–99. https://doi.org/10.1016/j.tifs.2018.05.003

Olasupo, N. A., Fitzgerald, D. J., Gasson, M. J., & Narbad, A. (2003). Activity of natural antimicrobial compounds against *Escherichia coli* and *Salmonella enterica* serovar *Typhimurium*. *Letters in Applied Microbiology*, *37*(6), 448–451. https://doi.org/10.1046/j.1472-765X.2003.01427.x

Osman, A., Mahgoub, S., El-Masry, R., Al-Gaby, A., & Sitohy, M. (2014). Extending the Technological Validity of Raw Buffalo Milk at Room Temperature by Esterified Legume Proteins: Extending the Technological Validity of Raw Milk. *Journal of Food Processing and Preservation*, *38*(1), 223–231. https://doi.org/10.1111/j.1745-4549.2012.00768.x

Osman, A. O., Mahgoub, S. A., & Sitohy, M. Z. (2013). Preservative action of 11S (glycinin) and 7S (β-conglycinin) soy globulin on bovine raw milk stored either at 4 or 25 °C. *Journal of Dairy Research*, *80*(02), 174–183. https://doi.org/10.1017/S0022029913000095

Osman, Ali, Abbas, E., Mahgoub, S., & Sitohy, M. (2016). Inhibition of *Penicillium digitatum* in vitro and in postharvest orange fruit by a soy protein fraction containing mainly β-conglycinin. *Journal of General Plant Pathology*, *82*(6), 293–301. https://doi.org/10.1007/s10327-016-0686-3

Papademas, P., & Robinson, R. K. (2001). The sensory characteristics of different types of halloumi cheese as perceived by tasters of different ages. *International Journal of Dairy Technology*, *54*(3), 94–99. https://doi.org/10.1046/j.1364-727x.2001.00013.x

Park, C., Cho, J.-Y., Hwang, B.-M., Hwang, I.-S., Kim, M.-R., Woo, E.-R., & Lee, D.-G. (2010). Styraxjaponoside A and B, Antifungal Lignan Glycosides Isolated from Styrax japonica S. et Z. *Biomolecules and Therapeutics*, *18*(4), 420–425. https://doi.org/10.4062/biomolther.2010.18.4.420

Pavlović, D. R., Veljković, M., Stojanović, N. M., Gočmanac-Ignjatović, M., Mihailov-Krstev, T., Branković, S., Radenković, M. (2017). Influence of different wild-garlic (*Allium ursinum*) extracts on the gastrointestinal system: spasmolytic, antimicrobial and antioxidant properties. *Journal of Pharmacy and Pharmacology*, *69*(9), 1208–1218. https://doi.org/10.1111/jphp.12746

Perricone, M., Arace, E., Corbo, M. R., Sinigaglia, M., & Bevilacqua, A. (2015). Bioactivity of essential oils: a review on their interaction with food components. *Food Microbiology*, *6*, 76. https://doi.org/10.3389/fmicb.2015.00076

Pesavento, G., Calonico, C., Ducci, B., Magnanini, A., & Lo Nostro, A. (2014). Prevalence and antibiotic resistance of *Enterococcus spp.* isolated from retail cheese, ready-to-eat salads, ham, and raw meat. *Food Microbiology*, *41*, 1–7. https://doi.org/10.1016/j.fm.2014.01.008

Pina-Pérez, M. C., & Ferrús Pérez, M. A. (2018). Antimicrobial potential of legume extracts against foodborne pathogens: A review. *Trends in Food Science & Technology*, *72*, 114–124. https://doi.org/10.1016/j.tifs.2017.12.007

Pisoschi, A. M., Pop, A., Georgescu, C., Turcuş, V., Olah, N. K., & Mathe, E. (2018). An overview of natural antimicrobials role in food. *European Journal of Medicinal Chemistry*, *143*, 922–935. https://doi.org/10.1016/j.ejmech.2017.11.095

Pranting, M., Loov, C., Burman, R., Goransson, U., & Andersson, D. I. (2010). The cyclotide cycloviolacin O2 from *Viola odorata* has potent bactericidal activity against Gram-negative bacteria. *Journal of Antimicrobial Chemotherapy*, *65*(9), 1964–1971. https://doi.org/10.1093/jac/dkq220

Pulina, G., Milán, M. J., Lavín, M. P., Theodoridis, A., Morin, E., Capote, J., Caja, G. (2018). Invited review: Current production trends, farm structures, and economics of the dairy sheep and goat sectors. *Journal of Dairy Science*, *101*(8), 6715–6729. https://doi.org/10.3168/jds.2017-14015

Puri, M., Sharma, D., & Barrow, C. J. (2012). Enzyme-assisted extraction of bioactives from plants. *Trends in Biotechnology*, *30*(1), 37–44. https://doi.org/10.1016/j.tibtech.2011.06.014

Qiu, X., Jacobsen, C., & Sørensen, A.-D. M. (2018). The effect of rosemary (*Rosmarinus officinalis* L.) extract on the oxidative stability of lipids in cow and soy milk enriched with fish oil. *Food Chemistry*, *263*, 119–126. https://doi.org/10.1016/j.foodchem.2018.04.106

Quave, C. L., Lyles, J. T., Kavanaugh, J. S., Nelson, K., Parlet, C. P., Crosby, H. A., Horswill, A. R. (2015). *Castanea sativa* (European Chestnut) Leaf Extracts Rich in Ursene and Oleanene Derivatives Block *Staphylococcus aureus* Virulence and Pathogenesis without Detectable Resistance. *PLoS ONE*, *10*(8). https://doi.org/10.1371/journal.pone.0136486

Rai, M., Pandit, R., Gaikwad, S., & Kövics, G. (2016). Antimicrobial peptides as natural bio-preservative to enhance the shelf-life of food. *Journal of Food Science and Technology*, *53*(9), 3381–3394. https://doi.org/10.1007/s13197-016-2318-5

Rashidinejad, A., Birch, E. J., Sun-Waterhouse, D., & Everett, D. W. (2013). Effects of catechin on the phenolic content and antioxidant properties of low-fat cheese. *International Journal of Food Science & Technology*, *48*(12), 2448–2455. https://doi.org/10.1111/ijfs.12234

Regulation (EC) N°1334/2008.

Rhodes, P. L., Mitchell, J. W., Wilson, M. W., & Melton, L. D. (2006). Antilisterial activity of grape juice and grape extracts derived from *Vitis vinifera* variety Ribier. *International Journal of Food Microbiology*, *107*(3), 281–286. https://doi.org/10.1016/j.ijfoodmicro.2005.10.022

Robles-Almazan, M., Pulido-Moran, M., Moreno-Fernandez, J., Ramirez-Tortosa, C., Rodriguez-Garcia, C., Quiles, J. L., & Ramirez-Tortosa, Mc. (2018). Hydroxytyrosol: Bioavailability, toxicity, and clinical applications. *Food Research International*, *105*, 654–667. https://doi.org/10.1016/j.foodres.2017.11.053

Roila, R., Valiani, A., Ranucci, D., Ortenzi, R., Servili, M., Veneziani, G., & Branciari, R. (2019). Antimicrobial efficacy of a polyphenolic extract from olive oil by-product against "Fior di latte" cheese spoilage bacteria. *International Journal of Food Microbiology*, *295*, 49–53. https://doi.org/10.1016/j.ijfoodmicro.2019.02.013

Ruiz-Terán, F., Perez-Amador, I., & López-Munguia, A. (2001). Enzymatic Extraction and Transformation of Glucovanillin to Vanillin from Vanilla Green Pods. *Journal of Agricultural and Food Chemistry*, *49*(11), 5207–5209. https://doi.org/10.1021/jf010723h

Rukachaisirikul, T., Innok, P., Aroonrerk, N., Boonamnuaylap, W., Limrangsun, S., Boonyon, C., Suksamrarn, A. (2007). Antibacterial Pterocarpans from *Erythrina subumbrans*. *Journal of Ethnopharmacology*, *110*(1), 171–175. https://doi.org/10.1016/j.jep.2006.09.022

Sadeghi, E., Akhondzadeh Basti, A., Noori, N., Khanjari, A., & Partovi, R. (2013). Effect of *Cuminum cyminum* L. essential oil and *Lactobacillus acidophilus* (a probiotic) on *Sthaphilococcus aureus* during the manufacture, ripening and storage of white brined cheese: effect of essential oil and probiotic on *S. aureus*. *Journal of Food Processing and Preservation*, *37*(5), 449–455. https://doi.org/10.1111/j.1745-4549.2011.00664.x

Salas, C. E., Badillo-Corona, J. A., Ramírez-Sotelo, G., & Oliver-Salvador, C. (2015). Biologically Active and Antimicrobial Peptides from Plants. *BioMed Research International*, *2015*, 1–11. https://doi.org/10.1155/2015/102129

Santos, R. D., Shetty, K., & da Silva Miglioranza, L. H. (2014). Oxidative stability of butter with added phenolics from Lamiaceae herbs and *in vitro* evaluation of potential cytotoxicity of rosemary (*Rosmarinus officinalis* L.) extract. *International Journal of Food Science & Technology*, *49*(3), 768–775. https://doi.org/10.1111/ijfs.12364

Shah, M. A., Mir, S. A., & Paray, M. A. (2014). Plant proteases as milk-clotting enzymes in cheesemaking: a review. *Dairy Science & Technology*, *94*(1), 5–16. https://doi.org/10.1007/s13594-013-0144-3

Shan, B., Cai, Y.-Z., Brooks, J. D., & Corke, H. (2011). Potential Application of Spice and Herb Extracts as Natural Preservatives in Cheese. *Journal of Medicinal Food*, *14*(3), 284–290. https://doi.org/10.1089/jmf.2010.0009

Sicard, T. (2018). *L'atlas pratique des fromages: origines, terroirs, accords*.

Silva, S. V., Pihlanto, A., & Malcata, F. X. (2006). Bioactive Peptides in Ovine and Caprine Cheeselike Systems Prepared with Proteases from *Cynara cardunculus*. *Journal of Dairy Science*, *89*(9), 3336–3344. https://doi.org/10.3168/jds.S0022-0302(06)72370-0

Sitohy, M., Doheim, M., & Badr, H. (2007). Isolation and characterization of a lectin with antifungal activity from *Egyptian Pisum* sativum seeds. *Food Chemistry*, *104*(3), 971–979. https://doi.org/10.1016/j.foodchem.2007.01.026

Sitohy, M., Mahgoub, S., & Osman, A. (2011). Controlling psychrotrophic bacteria in raw buffalo milk preserved at 4 °C with esterified legume proteins. *LWT - Food Science and Technology*, *44*(8), 1697–1702. https://doi.org/10.1016/j.lwt.2011.03.008

Sitohy, M. Z., Mahgoub, S. A., & Osman, A. O. (2012). In vitro and in situ antimicrobial action and mechanism of glycinin and its basic subunit. *International Journal of Food Microbiology*, *154*(1–2), 19–29. https://doi.org/10.1016/j.ijfoodmicro.2011.12.004

Snoussi, M., Trabelsi, N., Dehmeni, A., Benzekri, R., Bouslama, L., Hajlaoui, B., Papetti, A. (2016). Phytochemical analysis, antimicrobial and antioxidant activities of *Allium roseum* var. *odoratissimum* (Desf.) Coss extracts. *Industrial Crops and Products*, *89*, 533–542. https://doi.org/10.1016/j.indcrop.2016.05.048

Sodeifian, G., Sajadian, S. A., & Saadati Ardestani, N. (2016). Optimization of essential oil extraction from Launaea acanthodes Boiss: Utilization of supercritical carbon dioxide and cosolvent. *The Journal of Supercritical Fluids*, *116*, 46–56. https://doi.org/10.1016/j.supflu.2016.05.015

Soni, M. G., Burdock, G. A., Christian, M. S., Bitler, C. M., & Crea, R. (2006). Safety assessment of aqueous olive pulp extract as an antioxidant or antimicrobial agent in foods. *Food and Chemical Toxicology*, *44*(7), 903–915. https://doi.org/10.1016/j.fct.2006.01.008

Stojanović, S., Sprinz, H., & Brede, O. (2001). Efficiency and Mechanism of the Antioxidant Action of trans-Resveratrol and Its Analogues in the Radical Liposome Oxidation. *Archives of Biochemistry and Biophysics*, *391*(1), 79–89. https://doi.org/10.1006/abbi.2001.2388

Sudjana, A. N., D'Orazio, C., Ryan, V., Rasool, N., Ng, J., Islam, N., Hammer, K. A. (2009). Antimicrobial activity of commercial *Olea europaea* (olive) leaf extract. *International Journal of Antimicrobial Agents*, *33*(5), 461–463. https://doi.org/10.1016/j.ijantimicag.2008.10.026

Taguri, T., Tanaka, T., & Kouno, I. (2004). Antimicrobial Activity of 10 Different Plant Polyphenols against Bacteria Causing Food-Borne Disease. *Biological & Pharmaceutical Bulletin*, *27*(12), 1965–1969. https://doi.org/10.1248/bpb.27.1965

Tanaka, A., Kim, H. J., Oda, S., Shimizu, K., & Kondo, R. (2011). Antibacterial activity of moso bamboo shoot skin (*Phyllostachys pubescens*) against *Staphylococcus aureus*. *Journal of Wood Science*, *57*(6), 542–544. https://doi.org/10.1007/s10086-011-1207-9

Tayel, A. A., Hussein, H., Sorour, N. M., & El-Tras, W. F. (2015). Foodborne Pathogens Prevention and Sensory Attributes Enhancement in Processed Cheese via Flavoring with Plant Extracts: Cheese protection using plant extracts. *Journal of Food Science*, *80*(12), M2886–M2891. https://doi.org/10.1111/1750-3841.13138

Thermo scientific. (2013). *Methods Optimization in Accelerated Solvent Extraction* (pp. 1–4).

Tsiraki, M. I., & Savvaidis, I. N. (2016). The effects of citrus extract (Citrox ©) on the naturally occurring microflora and inoculated pathogens, *Bacillus cereus* and *Salmonella enterica* , in a model food system and the traditional Greek yogurt-based salad Tzatziki. *Food Microbiology*, *53*, 150–155. https://doi.org/10.1016/j.fm.2015.09.015

Tsiraki, M. I., Yehia, H. M., Elobeid, T., Osaili, T., Sakkas, H., & Savvaidis, I. N. (2018). Viability of and *Escherichia coli* O157:H7 and *Listeria monocytogenes* in a delicatessen appetizer (yogurt-based) salad as affected by citrus extract (Citrox ©) and storage temperature. *Food Microbiology*, *69*, 11–17. https://doi.org/10.1016/j.fm.2017.07.014

Tyśkiewicz, K., Gieysztor, R., Konkol, M., Szałas, J., & Rój, E. (2018). Essential Oils from Humulus Lupulus scCO2 Extract by Hydrodistillation and Microwave-Assisted Hydrodistillation. *Molecules*, *23*(11), 2866. https://doi.org/10.3390/molecules23112866

Vairo Cavalli, S., Lufrano, D., Colombo, M. L., & Priolo, N. (2013). Properties and applications of phytepsins from thistle flowers. *Phytochemistry*, *92*, 16–32. https://doi.org/10.1016/j.phytochem.2013.04.013

Verraes, C., Vlaemynck, G., Van Weyenberg, S., De Zutter, L., Daube, G., Sindic, M., Herman, L. (2015). A review of the microbiological hazards of dairy products made from raw milk. *International Dairy Journal*, *50*, 32–44. https://doi.org/10.1016/j.idairyj.2015.05.011

Vilkhu, K., Mawson, R., Simons, L., & Bates, D. (2008). Applications and opportunities for ultrasound assisted extraction in the food industry — A review. *Innovative Food Science & Emerging Technologies*, *9*(2), 161–169. https://doi.org/10.1016/j.ifset.2007.04.014

Vongsak, B., Sithisarn, P., Mangmool, S., Thongpraditchote, S., Wongkrajang, Y., & Gritsanapan, W. (2013). Maximizing total phenolics, total flavonoids contents and antioxidant activity of Moringa oleifera leaf extract by the appropriate extraction method. *Industrial Crops and Products*, *44*, 566–571. https://doi.org/10.1016/j.indcrop.2012.09.021

Wahba, N. M., Ahmed, A. S., & Ebraheim, Z. Z. (2010). Antimicrobial Effects of Pepper, Parsley, and Dill and Their Roles in the Microbiological Quality Enhancement of Traditional Egyptian Kareish Cheese. *Foodborne Pathogens and Disease*, *7*(4), 411–418. https://doi.org/10.1089/fpd.2009.0412

Wang, L., & Weller, C. L. (2006). Recent advances in extraction of nutraceuticals from plants. *Trends in Food Science & Technology*, *17*(6), 300–312. https://doi.org/10.1016/j.tifs.2005.12.004

Wang, X., Yao, X., Zhu, Z., Tang, T., Dai, K., Sadovskaya, I., Jabbouri, S. (2009). Effect of berberine on *Staphylococcus epidermidis* biofilm formation. *International Journal of Antimicrobial Agents*, *34*(1), 60–66. https://doi.org/10.1016/j.ijantimicag.2008.10.033

Wijesinghe, W. A. J. P., & Jeon, Y.-J. (2012). Enzyme-assistant extraction (EAE) of bioactive components: A useful approach for recovery of industrially important metabolites from seaweeds: A review. *Fitoterapia*, *83*(1), 6–12. https://doi.org/10.1016/j.fitote.2011.10.016

Willis, C., Jørgensen, F., Aird, H., Elviss, N., Fox, A., Jenkins, C., McLauchlin, J. (2018). An assessment of the microbiological quality and safety of raw drinking milk on retail sale in England. *Journal of Applied Microbiology*, *124*(2), 535–546. https://doi.org/10.1111/jam.13660

Wu, J., & Ding, X. (2002). Characterization of inhibition and stability of soy-protein-derived angiotensin I-converting enzyme inhibitory peptides. *Food Research International*, *35*(4), 367–375. https://doi.org/10.1016/S0963-9969(01)00131-4

Yasuda, S., Kuwata, H., Kawamoto, K., Shirakawa, J., Atobe, S., Hoshi, Y., Igoshi, K. (2012). Effect of highly lipolyzed goat cheese on HL-60 human leukemia cells: Antiproliferative activity and induction of apoptotic DNA damage. *Journal of Dairy Science*, *95*(5), 2248–2260. https://doi.org/10.3168/jds.2011-4153

Zantar, S., Yedri, F., Mrabet, R., Laglaoui, A., Bakkali, M., & Zerrouk, M. H. (2014). Effect of *Thymus vulgaris* and *Origanum compactum* essential oils on the shelf life of fresh goat cheese. *Journal of Essential Oil Research*, *26*(2), 76–84. https://doi.org/10.1080/10412905.2013.871673

Zarai, Z., Boujelbene, E., Ben Salem, N., Gargouri, Y., & Sayari, A. (2013). Antioxidant and antimicrobial activities of various solvent extracts, piperine and piperic acid from Piper nigrum. *LWT - Food Science and Technology*, *50*(2), 634–641. https://doi.org/10.1016/j.lwt.2012.07.036

Zhang, H., He, P., Kang, H., & Li, X. (2018). Antioxidant and antimicrobial effects of edible coating based on chitosan and bamboo vinegar in ready to cook pork chops. *LWT*, *93*, 470–476. https://doi.org/10.1016/j.lwt.2018.04.005

Figure caption

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

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				
Allium sativum (garlic)	Gaperon Spinosien à l‘ail Boursin à l’ail, P‘Ail	France	raw, butter raw pasteurized	3 to 4 weeks 8 months none
Allium schoenoprasum L (chives)	Boursin		pasteurized	none
Allium ursinum (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
Brassica nigra/Sinapis nigra (Mustard)	Mustard seed Gouda	Netherlands	raw/pasteurized	2 months
Capsicum annuum (paprika)	Mossa	France	pasteurized	none
Cuminum cyminum (cumin)	Altenburger Ziegenkäse	Deutschland	raw*	4 weeks
	Cumin seed Gouda	Netherlands	raw/pasteurized	2 months
	Munster au cumin	France	raw/pasteurized	2-3 months
	Tomme vaudoise au cumin		raw/thermized	2 months
Piper nigrum (pepper)	Boursin au poivre, Mossa Gaperon		pasteurized raw, butter	none none 3 to 4 weeks
Sambucus nigra (elderberry flowers)	Holunderkas		pasteurized	3 weeks
Urtica dioica (nettle)	Tomme fermière aux orties, spinosien aux orties		raw raw	2 months 8 months
Sheep milk				
Capsicum annuum (smoked paprika)	The Black Sheep	New Zealand	pasteurized	10 months
Piper nigrum (pepper)	Piacentinu ennese	Italy	raw/pasteurized	3 to 12 months
Thymus vulgaris (thyme)	Brebichou au Thym (Thyme EO)	France	raw	2 weeks

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

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

	Noce			
Olea europea (oliv leaves)	Pecorino "L'Ulivastro", Foglie di ulivo, L'Ulivo	Italy	pasteurized	3 months

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

carduncului (cardoon)	Extract of leaf submitted to diverse liquid-liquid partition	*Bacillus subtilis*, ***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 Solvant: hexane, acetone, methanol, water	Antioxydant properties, antimicrobial activity	*in vitro* tests	Falleh et al., 2008
Cuminum cyminum (cumin)	Essential oil	Antimicrobial activity against ***SA***, no effect against *Lactobacillus acidophilus*	Iranian white brined cheese	Sadeghi et al., 2013
	Seed oil	Antimicrobial activity against *Salmonella enterides* and ***EC***	Domiati cheese	Mahgoub et al., 2013; Hassanien et al., 2014
	Ethanolic extract from seeds	Antimicrobial activity against ***SA***	*in vitro* tests	Mostafa et al., 2018
Inula britanica (British yellowhead)	Lyophilized aqueous extract from flowers	Antioxidant properties	Cheddar type cheese	N.-K. Lee et al., 2016
Matricaria recutita (chamomille)	Dried chamomile and decoction of dried chamomile	Antioxidant and antifungi properties Antimicrobial activity against ***SA***, *Bacillus cereus,* ***LM***, *Pseudomonas aeuruginosa*, ***EC***, *Enterobacter. cloacae* and ***ST***	Cottage cheese	Caleja et al., 2015
Olive	Commercial olive leaf extract	Antimicrobial activity against numerous microorganisms among which ***LM**, **SA**, **EC*** and *Salmonella sp.*	*in vitro* tests	Sudjana et al., 2009
	Polyphenol extract from olive oil by-product	Antimicrobial activity against *Pseudomonas fluorescens* and *Enterobacteriaceae*	Fior di latte cheese	(Roila et al., 2019)
Origanum vulgare (oregano)	Essential oil	Antimicrobial activity	fresh goat cheese	Zantar et al., 2014
	Essential oil from aerial parts	Antimicrobial activity against *Enterobacter sp.* 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	Govaris 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)

Ocimum basilicum (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
Pimpinella anisum (anise)	Essential oils	Antimicrobial activity against ***EC*** O157:H7	Iranian white brined cheese	Ehsani & Mahmoudi, 2012
Rosmarinus officinalis (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 ***SA***, ***SE*** and ***LM*** and seven Gram-negative strains	*in vitro* tests	Kozłowska, Laudy, Przybył, Ziarno, & Majewska, 2015
	Ethanol and acetone extract	Antioxydant, antimicrobial activity against ***ST***, ***EC***, ***SA*** and ***LM***	Cottage Cheese	Josipović 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)
Salvia officinalis (sage)	Aerial part Aqueous ethanolic and methanolic extracts	Antimicrobial activity against five Gram-positive strains including ***SA***, ***SE*** and ***LM*** and four Gram-negative strains	*in vitro* tests	Kozłowska, Laudy, Przybył, Ziarno, & Majewska, 2015
	Ethanol extract from leaves	Antimicrobial activity against ***ST***, ***EC*** O157:H7, ***SA*** and ***LM***	Dairy based media	Tayel et al., 2015
Syzygium aromaticum (clove)	Extracted with a mixture of ethanol/water (4:1)	Antioxydant, antimicrobial activity against *Salmonella enterica*, ***LM***, ***SA***	cheese	Shan et al., 2011
Thymus vulgaris (thyme)	Essential oil	Antimicrobial activity	fresh goat cheese	Zantar et al., 2014
	Essential oil	Antimicrobial activity against ***EC*** O157:H7 and ***LM***	Feta cheese	Govaris et al., 2011
	Essential oil	Antimicrobial activity against ***SA***, ***LM*** and mesophilic starter	Cheese mimicking models	de Carvalho et al., 2015
	Aerial part Aqueous ethanolic and methanolic extracts	Antimicrobial activity against four Gram-positive strains including ***SA*** and ***SE***, and six Gram-negative strains	*in vitro* tests	Kozłowska, Laudy, Przybył, Ziarno, & Majewska, 2015
	Leaves Ethanolic extract	Antimicrobial effect against ***SA*** and *P. aeruginosa.*	*in vitro* tests	Mostafa et al., 2018

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

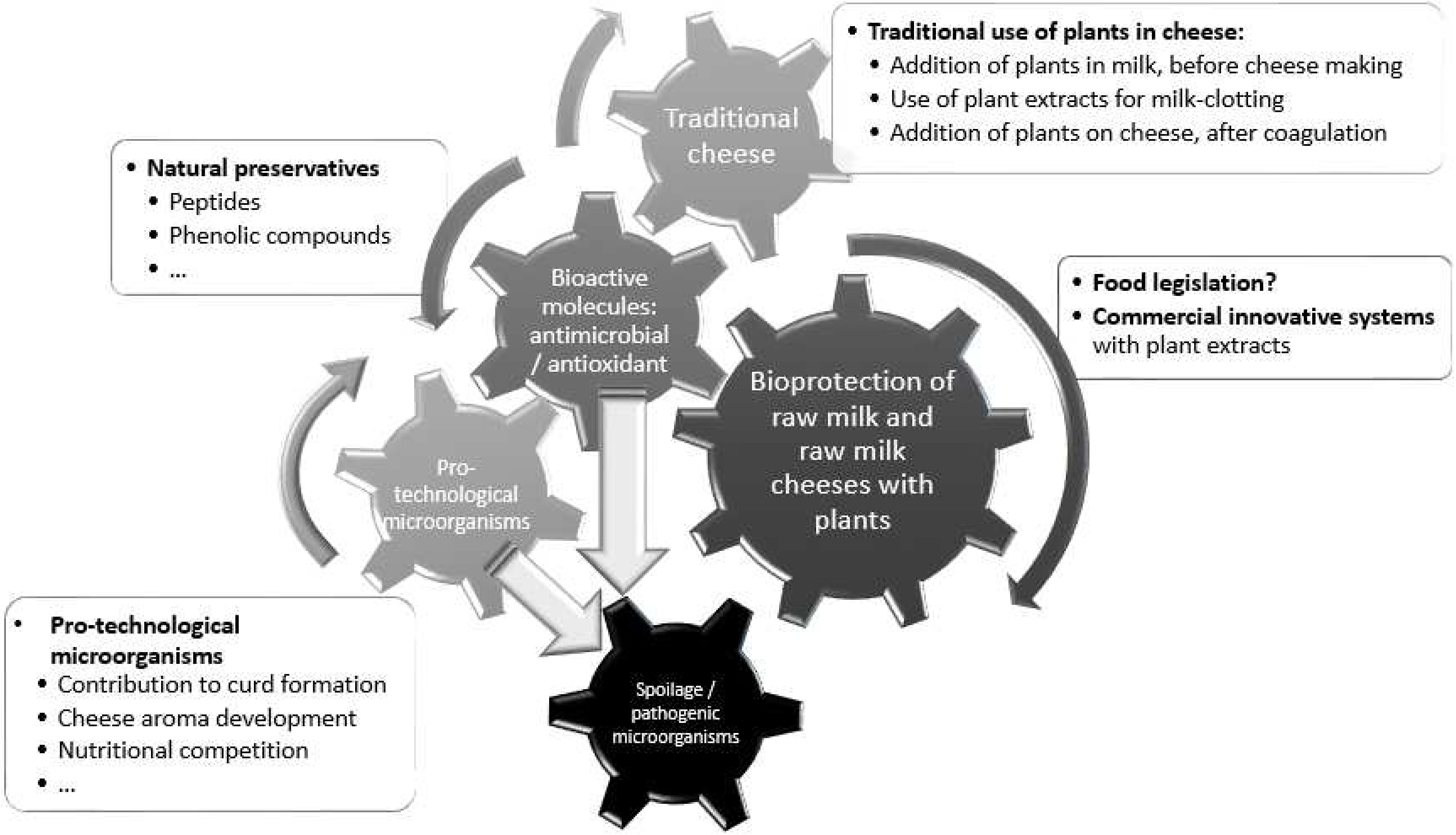
EC*: Escherichia coli,* ***ST****: Salmonella Typhimurium,* ***SA****: Staphyloccocus aureus,* ***SE****: Staphyloccocus epidermidis,* ***LI*** *: Listeria innocua,* ***LM*** *: Listeria monocytogenes*

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

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

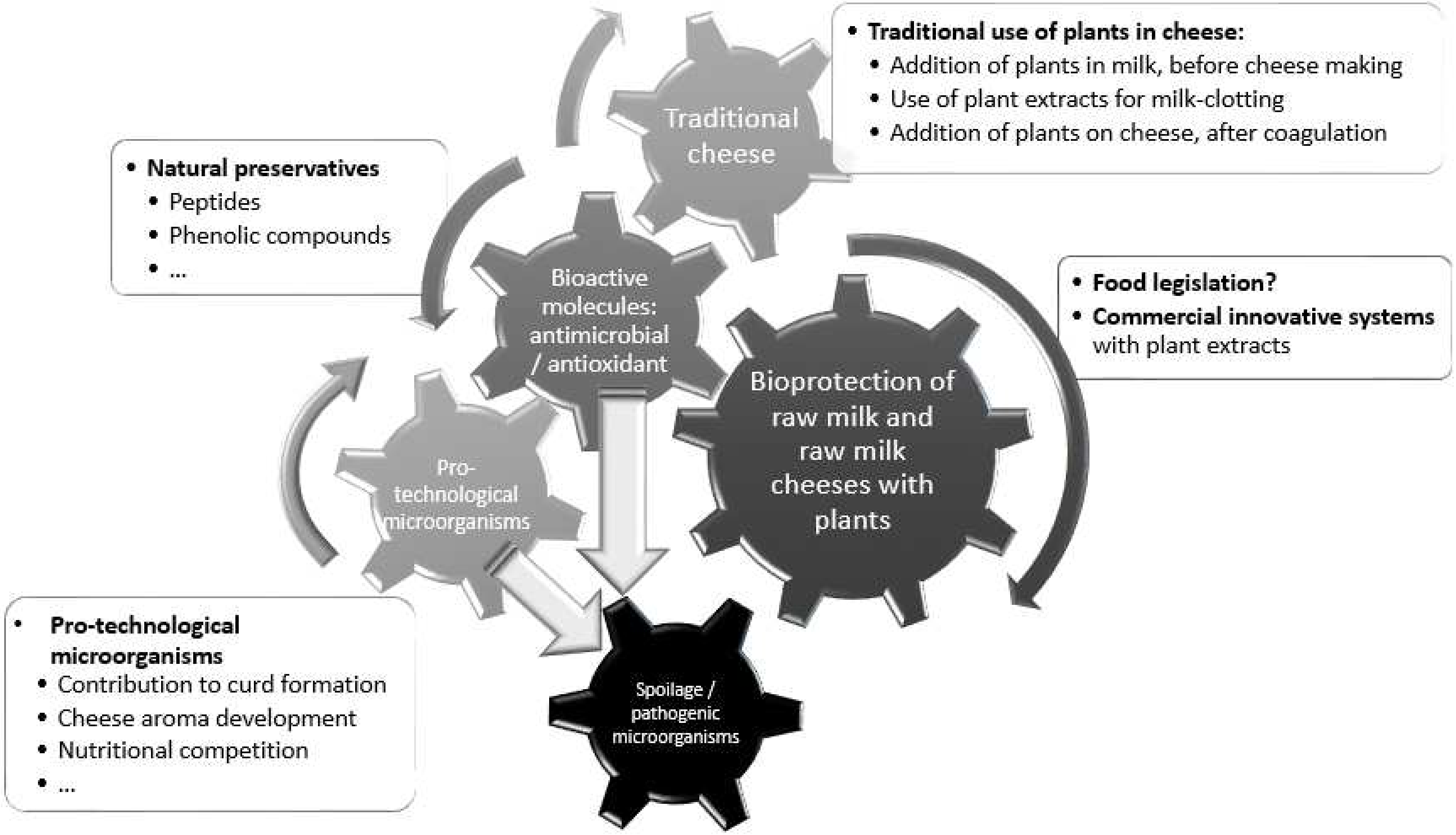
	Flavonoïd			
flavanol	Epigallocatechin -3-O-gallate	***SA***, *Salmonella* (ATCC 9270 and ATCC 13314), ***EC*** and *Vibrio* (ATCC 17802): MIC = 98, 308, 602 and 68 µg.mL^{-1} respectively		Taguri, Tanaka, & Kouno, 2004
flavonol	Petalostemumol	*Candida albicans, Cryptococcus neoformans, Mycobacterium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

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



• Traditional use of plants in cheese:
• Addition of plants in milk, before cheese making
• Use of plant extracts for milk-clotting
• Addition of plants on cheese, after coagulation
Traditional cheese
• Natural preservatives
• Peptides
• Phenolic compounds
• ...
Bioactive molecules: antimicrobial / antioxidant
• Food legislation?
• Commercial innovative systems with plant extracts
Bioprotection of raw milk and raw milk cheeses with plants
Pro-technological microorganisms
• Pro-technological microorganisms
• Contribution to curd formation
• Cheese aroma development
• Nutritional competition
• ...
Spoilage / pathogenic microorganisms

Figure 1



Traditional use of plants in cheese:
Addition of plants in milk, before cheese making
Use of plant extracts for milk-clotting
Addition of plants on cheese, after coagulation
Traditional cheese
Natural preservatives
Peptides
Phenolic compounds
...
Bioactive molecules: antimicrobial / antioxidant
Food legislation?
Commercial innovative systems with plant extracts
Bioprotection of raw milk and raw milk cheeses with plants
Pro-technological microorganisms
Pro-technological microorganisms
Contribution to curd formation
Cheese aroma development
Nutritional competition
...
Spoilage / pathogenic microorganisms

Figure 1