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Review

Use of essential oils in active food packaging: Recent advances and future trends

Regiane Ribeiro-Santos [a, b], Mariana Andrade [a, c], Nathália Ramos de Melo [b, d], Ana Sanches-Silva [a, e, *]

[a] Department of Food and Nutrition, National Institute of Health Dr. Ricardo Jorge, I.P., Av. Padre Cruz, 1649-016 Lisbon, Portugal
[b] Department of Food Technology, Institute of Technology, Federal Rural University of Rio de Janeiro, Rodovia BR 465 - Km 7, 23851-970, Seropédica, Brazil
[c] Faculty of Sciences, University of Lisbon, Lisbon, Portugal
[d] Department of Agribusiness Engineering Federal Fluminense University, Av. dos Trabalhadores, 420, 27255125, Volta Redonda, RJ, Brazil
[e] Animal Science Studies Centre (CECA), University of Oporto, Oporto, Portugal

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ABSTRACT

Background: Essential oils (EOs) extracted from plants have been the focus of numerous researches due to their potential in the food and pharmaceutical industries and aromatherapy.
Scope and approach: The effectiveness of EO may be observed in antimicrobial and antioxidant tests. Volatile compounds are present in EOs and are responsible by their biological activities, namely antimicrobial and antioxidant capacity. Several manuscripts and patents have emerged with applications of EOs and their constituents, and their incorporation into food packaging. These packages with EOs have shown efficiency against microorganisms and oxidants *in vitro*, in tests with food and/or food simulants evaluation tests. In line with this, chromatographic techniques can be used to identify the main volatile compounds present in EOs or to determine the compounds that migrated from packaging to food or food simulants. This review provides a concise and critical insight in the use of EOs with emphasis in food applications. The innovative food packaging applications are highlighted and future trends are discussed.
Key findings and conclusions: In general, EOs extend food stability during storage, inhibiting the growth of spoilage or pathogenic microorganisms and protecting against oxidation. Moreover, in spite of the potential of EOs, more studies should evaluate their safety and possible side effects before considering their use for food purposes.

1. Introduction

Food packaging is designed to protect food from external factors, such as temperature, light and humidity, that can lead to their degradation (Carocho, Morales, & Ferreira, 2015; Thøgersen, 1996). Moreover, packages also protect its content from others environmental influences such as: odors, microorganisms, shocks, dust, vibrations and compressive forces (Robertson, 2012). The globalization phenomenon has brought the possibility to access to countless foods from every part of the globe, so the importance of preserving their original organoleptic properties is increasing. Food industry was forced to develop new ways and technologies to satisfy the consumers' demands. In line with this, active packaging has emerged.

Active packaging interacts with the product. It is intended to extend the food shelf-life, maintaining or improving the properties of the packaged food. The packaging materials used in these systems can incorporate components intended to be released into the food or absorb substances from the packaged food responsible by its deterioration. The substances responsible for the active function of packaging may be in a separate container or be directly incorporated into the packaging material (European Commission, 2004, 2009).

The active package allows foods to arrive at the consumers with their original or enhanced organoleptic properties, with longer shelf-life and safety (Dainelli, Gontard, Spyropoulos, Zondervan-van den Beuken, & Tobback, 2008; Ozdemir & Floros, 2004; Suppakul, Miltz, Sonneveld, & Bigger, 2003; Vermeiren, Devlieghere,

* Corresponding author. Department of Food and Nutrition, National Institute of Health Dr Ricardo Jorge, Av. Padre Cruz, 1649-016 Lisboa, Portugal.
E-mail addresses: ana.silva@insa.min-saude.pt, anateress@gmail.com (A. Sanches-Silva).

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van Beest, de Kruif, & Debevere, 2000). With better preservation and extended shelf-life products, food waste can be greatly reduced (Galanakis, 2012).

Another issue regarding food preservation is the use of synthetic additives. All food additives are carefully regulated by Food safety agencies such as United States-Food and Drug Administration (U.S.FDA), Brazil National Health Surveillance Agency (ANVISA), European Commission, which are responsible by authorized of food additives before they can be used in foods. Only additives for which the proposed uses were considered safe are authorized to be used as food additives. However, synthetic additives are associated with various adverse effects on human health (Honikel, 2008; Pôlonio & Peres, 2009; Proestos, Sereli, & Komaitis, 2006). Therefore, new alternatives from natural sources have been studied such as the use of essential oils.

Essentials oils (EOs), from aromatic plants, have been the focus of extensive research not only for being a natural product but also because they have demonstrated benefits in food and in human health. Currently, they are mainly studied for their different biological properties such as antioxidant, antimicrobial, anti-tumour, analgesic, insecticidal, anti-diabetic and anti-inflammatory (Brahmi et al., 2016; Ocaña-Fuentes, Arranz-Gutiérrez, Señorans, & Reglero, 2010; Periasamy, Athinarayanan, & Alshatwi, 2016; Yen, Hsieh, Hsieh, Chang, & Wang, 2015).

Essential oils can be marketed with “aromatherapy” claims, indicating they will treat health problems or improve well-being. FDA approves these products for safety and effectiveness before they go on the market (FDA, 2014a).

However, despite the proven health benefits, the use of EO as drugs, intended for use in the diagnosis, cure, mitigation, treatment, or prevention of disease, is not regulated by FDA. The FDA has responded with harsh criticism to the marketing and distribution of EO without their approved applications (FDA, 2014b).

The European Medicines Agency (EMA) has a list that provide an overview of the recommendations for use of the herbal preparations, including EO as mentioned in the European Union monographs. The list presents the indications, therapeutic area, herbal substances and/or preparations referred in the monograph, dosage form and method of administration, target population and any limitations of use of EO from the Committee on Herbal Medicinal Products (HMPC). Despite this, the EMA does not recommend the use of drug containing EO due to lack of adequate experience (EMA, 2016).

In general, the major components of EOs are the main responsible for their biological properties, but it is known that the minor compounds can also contribute for it and they can exhibit a synergetic activity (Burt, 2004). Both EOs and their components can be added directly to the food or incorporated into food packaging in order to be released during transportation and/or storage of food and contributing to increase food shelf-life. EOs are constituted by compounds, including phenolic compounds, with antimicrobial and antioxidant activity that minimize or even eliminate the presence of microorganisms and/or reduce the phenomenon of lipid oxidation. Therefore, they can reduce or replace the use of synthetic additives.

Several materials used in food packaging can be used to incorporate EOs. The polymeric matrices used can be derived from non-renewable materials, such as polypropylene, or from biomaterials such as chitosan (López, Sánchez, Batlle, & Nerín, 2007; Ruiz-Navajas, Viuda-Martos, Sendra, Perez-Alvarez, & Fernández-López, 2013).

The use of aromatic plants has been promoted. A large variety of EOs from different aromatic plants has been applied to food packaging and these are Generally Recognized as Safe (GRAS) by the Food and Drug Administration (FDA) (Food And Drug Administration (FDA), 2016).

One of the main trends in the area of food packaging is the use of materials from renewable sources and biodegradable, contributing to food chain sustainability.

An extensive review of scientific publications, in which EOs were incorporated into polymer packaging, was performed. The characteristics of the polymer matrix, the selected EOs, their main active compounds and the techniques used for their determination and the main results were reviewed and discussed. The main objective of this review was to access the current status, recent advances and the future trends regarding the use of EOs in active food packaging.

2. Essential oils

Most of plants, especially aromatic plants, are known for their potential benefits to human health because of their biological such as anti-cancer, anti-inflammatory, anti-diabetic, antiulcerogenic, antidepressant, antianxiety, including antioxidant and antimicrobial properties and because of their organoleptic properties (Anderson et al., 2015; Costa et al., 2015; Kim et al., 2015; Ribeiro-Santos et al., 2015). Essential oils are aromatic substances produced by plants generally belonging to angiospermic families that can be used by several industries for different purposes (Pavela, 2015). Thus, EOs are natural products obtained from plant materials such as flowers, buds, leaves, stem, bark and seeds (Aidi Wannes et al., 2010; Dvaranauskaité et al., 2009; Hill, Gomes, & Taylor, 2013; Lv et al., 2012). The composition and quality of EOs are naturally affected by the plant characteristics, such as development stage, variety, geographical origin, part of the plant used, age, season and condition of the plant when harvested. But is also affected by the extraction method, analysis conditions and the solvent used (Hussain, Anwar, Hussain Sherazi, & Przybylski, 2008; Khajeh, Yamini, Bahramifar, Sefidkon, & Reza Pirmoradei, 2005; Negi, 2012; Riahi et al., 2013). Major components can constitute up to 85% of an EO and usually they define their biological properties. However, the other 15% is composed by minor components that, although present at trace levels, have a significant role in the biological activities, acting in synergy with the major components (Burt, 2004; Pavela, 2015). A synergism effect occurs when the effect of the combined substances is greater than the sum of the individual effects (Burt, 2004).

The use of EOs as natural food additives has been the focus of countless investigation reports due to the possibility of these active mixtures replace the synthetic food additives. As mentioned previously, synthetic additives have negative side effects to human health and consumers are beginning to be aware of those facts and are starting to reject products with non-natural additives (Cacho, Campillo, Viñas, & Hernández-Córdoba, 2016). They can be incorporated in food packaging for releasing their compounds to the food through time. A large variety of EOs from different plants such as basil (*Ocimum basilicum* L.), chamomile flowers (*Matricaria chamomilla* L.), cardamom seeds (*Elettaria cardamomum* (L.) Maton) and rosemary (*Rosmarinus officinalis* L.), has been applied to food or food packaging as antimicrobial and antioxidant and they are considered as GRAS (Food and Drug Administration (FDA), 2016).

2.1. Application of essential oils to food and food packaging

When applied to food, EOs can perform antimicrobial, antioxidant or flavouring function. The most important action of an EO is to minimize or even eliminate the presence of microorganisms and/or reduce the phenomenon of lipid oxidation.

These EOs can be added directly to the food, contained in a separate container or incorporated into the packaging material