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Review

Antimicrobial activity of *Olea europaea* Linné extracts and their applicability as natural food preservative agents

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ABSTRACT

The antimicrobial activity of phenolic compounds from *Olea* (*O.*) *europaea* Linné (L.) is part of the scientific discussion regarding the use of natural plant extracts as alternative food preservative agents. Although, the basic knowledge on the antimicrobial potential of certain molecules such as oleuropein, hydroxytyrosol or elenolic acid derivatives is given, there is still little information regarding their applicability for food preservation. This might be primarily due to the lack of information regarding the full antimicrobial spectrum of the compounds, their synergisms in natural or artificial combinations and their interaction with food ingredients. The present review accumulates available literature from the past 40 years, investigating the antimicrobial activity of *O. europaea* L. derived extracts and compounds *in vitro* and in food matrices, in order to evaluate their food applicability. In summary, defined extracts from olive fruit or leaves, containing the strongest antimicrobial compounds hydroxytyrosol, oleacein or oleacanthal in considerable concentrations, appear to be suitable for food preservation. Nonetheless there is still need for consequent research on the compounds activity in food matrices, their effect on the natural microbiota of certain foods and their influence on the sensorial properties of the targeted products.

Contents

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1. Introduction

Fueled by trends towards minimally processed foods with an apparent natural and healthy character, researchers are intensively searching for plant derived natural preservative agents (Tiwari et al., 2009). These should prolong shelf-life on the one and ensure food safety on the other hand, replacing traditional preservatives (Burt, 2004). The latter, which are often rejected by consumers, do not fit the "green" character of modern, minimally processed foods as for example fresh cut vegetables or fruits (Negi, 2012).

Many attempts have been made to find and apply suitable natural preservatives from plant sources (Tiwari et al., 2009). As for example the use of crude extracts or single compounds, such as oregano essential oil (Lambert et al., 2001; Skandamis and Nychas, 2001) and its major constituent carvacrol, even in combination with physical preservation processes (Karatzas et al., 2001; Kim et al., 1995). The plant diversity estimated on earth (approx. >250,000 species (Borris, 1996)) enables extensive research regarding useable antimicrobial secondary metabolites, but also hinders the identification of the most promising candidates (Silva and Fernandes, 2010).

One of the plants whose antimicrobial potential has been scientifically known since the early 1970s is *Olea europaea* Linné, commonly known as the olive tree. Its antibacterial activity was first observed due to problems regarding olive fruit fermentation (Etchells et al., 1966), an issue which is still under scientific investigation (Medina et al., 2008). Besides, *Olea europaea* is more prevalently known for its antioxidant capacities and the associated dietary health aspects (Benavente-García et al., 2000; Brenes et al., 2007; Markin et al., 2003). It is scientifically accepted that *O. europaea* products, such as the fruits and the virgin olive oil, have beneficial health effects when they are a regular part of the human diet (Keys, 1970). The contribution of antioxidant compounds from *O. europaea* to health protective effects has been extensively studied and reviewed (Ghanbari et al., 2012; Martin-Pelaez et al., 2013; Sofi et al., 2008; Visioli, 2012). These scientific findings already led to health claim proposals (EFSA, 2011). But besides the exploitation of these antioxidant activities there are also intentions regarding the application of olive extracts or contained compounds as natural food preservatives (Brenes et al., 2007; Soni et al., 2006).

To develop a preservative olive extract with an overall natural character for food applications appears to be a promising approach in order to exploit the bioactivities of *Olea europaea*. This review was conducted to aggregate available scientific information upon the antimicrobial activity of crude extracts derived from *O. europaea* L. plant parts and the contained antimicrobial active phenolic constituents from secoiridoid hydrolysis. The cited reports are presented in a chronological manner, focusing on antibacterial activity. Antifungal potential is highlighted individually. Reports about application trials of antimicrobial extracts from olive plant parts in food products are also evaluated. The gathered information is assessed critically towards possible technological benefits from olive extracts and compounds in terms of shelf-life prolongation and microbiological food safety.

2. The olive tree *Olea europaea* L., products and by-products

The olive tree *O. europaea* L. is native to the Mediterranean countries. Although its cultivation is spreading globally 98% of olive agriculture is still domiciled in the Mediterranean basin (Peralbo-Molina and de Castro, 2013). Olive trees are preferably cultivated for the production of table olives and olive oil, two of the most representative components of the Mediterranean diet (Obied et al., 2012). The fruits of the *O. europaea* tree also referred to as drupes, consist of a hard stone (endocarp) containing the seed, embedded in a cortex of soft fruity flesh (mesocarp), which is covered by a waxy skin (epicarp). They are generally composed of water (50.0%), oil (22.0%) and sugar (19.1%), accompanied by cellulose (5.8%), proteins (1.6%) and ash (1.5%) (Niaounakis and Halvadakis, 2006). Approximately 1.5 million tons of fermented table olives are produced annually (Medina et al., 2009b).

Virgin olive oil is the most valuable product from *O. europaea*, produced from the fruits by mechanical homogenization and pressing only. Except washing, decantation, centrifugation and filtration no further processing steps are applied. The produced virgin olive oil contains high amounts of phenolic constituents with several beneficial effects on human health (Caramia et al., 2012; Cicerale et al., 2010; Ghanbari et al., 2012; Kratzb and Cullenc, 2002).

The production of olives generates a vast amount of by-products. Olive tree cultivation and the necessary pruning, lead to the accumulation of olive leaves, approximately 25% per tree by weight (Talhaoui et al., 2015b). The vast amount of this residual material is usually burned or discarded otherwise (Romero-Garcia et al., 2014). The high content of bioactive phenols is consequently squandered (Bouaziz and Sayadi, 2005; Lee et al., 2009; Meirinhos et al., 2005).

Additionally, oil extraction leads to the remaining of olive press cakes and olive mill waste waters (OMWW). The waste water still contains high concentrations of phenolic components, up to 24 g/l (Niaounakis and Halvadakis, 2006). Due to the difficult disposal there have been many different considerations how to exploit their phenolic content (Morillo et al., 2009; Paredes et al., 2002; Roig et al., 2006).

3. The phenolic profile of *Olea europaea* L.

The phenolic profiles of olive leaves and fruits, as reviewed by Charoenprasert and Mitchell (2012) and Ye et al. (2014), are primarily dominated by phenolic acids (e.g. ferulic, vaillic, coumaric acd), phenolic alcohols (e.g. tyrosol and hydroxytyrosol), flavonoids (e.g. luteolin-7-glucoside, cyanidin-3-glucoside, cyanidin-3-rutinoside, rutin, apigenin-7-glucoside, quercetin-3-rhamnoside, luteolin) and secoiridoids (e.g. oleuropein, ligstroside). These phenolic compositions of olive fruit and leaves, and therefore their products, are strongly affected by the cultivar and environmental conditions, such as region, climate and irrigation and furthermore by point of harvest, ripeness and post-harvest processing (Romero et al., 2004; Salvador et al., 2001; Vinha et al., 2005).

Regarding the antimicrobial activity of *O. europaea* L. most studies focus on secoiridoid compounds and their derivatives. The bitter tasting secoiridoids oleuropein, demethyloleuropein and ligstroside are the predominant phenolic compounds in *O. europaea* L. and are exclusive to the plants of the *Oleaceae* family (Servili et al., 2004). These phytoalexins and their precursors are accumulated during fruit and leaf maturation, acting as defense molecules against herbivores and microbial pathogens (Kubo et al., 1985).

As shown in Fig. 1 oleuropein (3,4-DHPEA-EA) consists of an ester of hydroxytyrosol (3,4-DHPEA) and elenolic acid (EA) which is additionally β-glycosylated. Ligstroside (4-HPEA-EA) on the other hand represents the ester of β-glycosylated elenolic acid and tyrosol (4-HPEA). Demethyloleuropein is another derivate of oleuropein consisting of esterified hydroxytyrosol and decarboxymethyl elenolic acid. After the hydrolytic removal of the sugar component by β–glucosidase the remaining molecules are generally referred to as aglycones.

As shown in Fig. 2 the consequent enzymatic secoiridoid breakdown leads to the formation of free tyrosol, hydroxytyrosol or elenolic acid (Charoenprasert and Mitchell, 2012). The emergence of the dialdehydic form of decarboxymethyl elenolic acid (EDA), either linked to tyrosol (4-HPEA) or hydroxytyrosol (3,4-DHPEA), is also favored. Oleacein is the synonym for 3,4-DHPEA-EDA whereas 4-HPEA-EDA is referred to as oleocanthal (see Fig. 1) (Vougogiannopoulou et al., 2014). Regarding the antimicrobial activity of extracts from *O. europaea* L. plant parts the named compounds are the most often identified molecules. Table 1 gives a brief overview regarding the quantitative distribution of these molecules in *Olea europaea* L. fruit and leaves and their originating products.