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Antimicrobial, antioxidant and anti-inflammatory phenolic activities in extra virgin olive oil

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The Mediterranean diet is associated with a lower incidence of chronic degenerative diseases and higher life expectancy. These health benefits have been partially attributed to the dietary consumption of extra virgin olive oil (EVOO) by Mediterranean populations, and more specifically the phenolic compounds naturally present in EVOO. Studies involving humans and animals (*in vivo* and *in vitro*) have demonstrated that olive oil phenolic compounds have potentially beneficial biological effects resulting from their antimicrobial, antioxidant and anti-inflammatory activities. This paper summarizes current knowledge on the biological activities of specific olive oil phenolic compounds together with information on their concentration in EVOO, bioavailability and stability over time.

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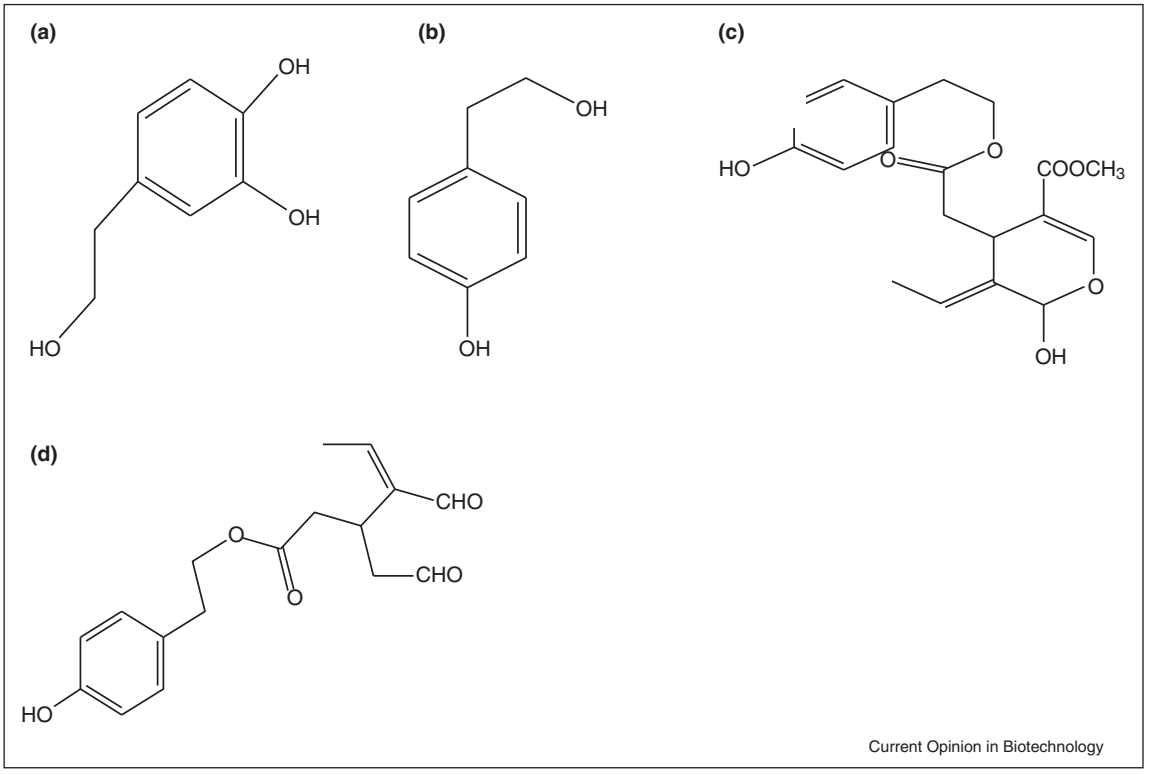
Introduction

The advantageous health effects of consuming a traditional Mediterranean diet were first reported in the Seven Countries Study [1], and these findings have been subsequently observed in further investigations [2,3•,4–7]. It is widely recognised that those residing in the Mediterranean region experience reduced rates of chronic disease (i.e. cardiovascular disease (CVD), atherosclerosis, some types of cancers, and Alzheimer's disease), and a higher life expectancy in comparison to other worldwide populations [8]. The Mediterranean style of eating encompasses a number of dietary components that are thought to contribute protective health effects, including the consumption of 25–50 ml/day of extra virgin olive oil (EVOO) [2]. EVOO contains a significant, albeit minor phenolic portion, which has been shown to possess antimicrobial, antioxidant and anti-inflammatory properties, *in vivo and in vitro* [9,10]. Therefore, the phenolic component of EVOO is of particular interest for its health promoting and protective effects. The following review provides insight into the modes of action in which EVOO phenolic compounds may exert their health protective effects, together with information on the concentrations in which they are found in EVOO, their degree of bioavailability and stability.

Concentration, bioavailability and stability of olive oil phenolic compounds in EVOO

At least 36 phenolic compounds have been identified in EVOO to date, and there is much variation in the composition and concentration of these phenolic compounds (0.02–600 mg/kg) [10]. Variation may be caused by numerous factors including: variety, region in which the olive is grown, agricultural techniques used to cultivate the olive, maturity of the olive fruit at harvest, and processing (for review see [10]). Although the phenolic concentration and composition of EVOO is an important consideration, the degree to which these components are bioavailable (absorbed, metabolised, distributed and eliminated) is fundamental in understanding and evaluating the health benefits associated with such compounds. To achieve an effect in specific tissues or organs, olive oil phenolic compounds must be bioavailable [11]. The majority of research regarding the bioavailability of these compounds has focused on the absorption and excretion of two major phenolics: hydroxytyrosol and tyrosol (Figure 1), and significant absorption (~40–95%) of these compounds has been demonstrated in humans (for review see [9]). Most recently, Garcia-Villalba *et al.* [12•] reported the presence of metabolites for the majority of olive oil phenolic compounds (i.e. secoiridoids, flavanoids and phenolic alcohols) in human urine, suggesting that these compounds are metabolised and absorbed post-ingestion. Varying rates of phenolic metabolism were noted in this study also. For instance, the largest number of metabolites was produced from the phenolics: hydroxytyrosol, oleuropein aglycone and oleocanthal, indicating significant post-absorption metabolism of these compounds. Conversely, the lowest number of metabolites came from tyrosol, luteolin, apigenin, pinoresinol and acetoxypinoresinol, suggesting that these compounds may have been excreted in faeces, destroyed in the gastrointestinal tract, excreted through another metabolic pathway or poorly absorbed [12•]. In the case of poorly absorbed phenolic compounds, it has been suggested that these components may exert local antioxidant activities in the gastrointestinal tract and this proposal is supported by research demonstrating the free radical scavenging capacity of olive oil phenolics in both the faecal matrix and intestinal epithelial cells [13]. Further, it is postulated that unabsorbed olive oil phenolics

Figure 1



Much research has been conducted to investigate the health-benefiting properties of **(a)** hydroxytyrosol, **(b)** tyrosol and **(c)** oleuropein aglycone. Oleocanthal **(d)** has fast become an olive oil phenolic of much interest due to its potent anti-inflammatory activity.

may exert antimicrobial activities in the gastrointestinal tract as has been demonstrated with tea and certain fruit phenolics [14•]. However, further research is required to substantiate these and to gain a more thorough understanding of the metabolism of the various phenolic compounds present in EVOO.

Another important consideration in regard to the healthful properties of olive oil phenolics is their stability upon storage. The maximum EVOO storage period is generally deemed to be 12–18 months [15] and a handful of studies have shown that olive oil phenolic concentration remains relatively stable during this period, provided EVOO is stored under conditions that limit excessive phenolic and fatty acid degradation (i.e. lowered temperature and reduced oxygen and light exposure) [16–23].

Antimicrobial properties of olive oil phenolic compounds

Compounds with antimicrobial properties may aid in the inhibition of the growth of microorganisms and act as therapeutic agents in the treatment of some infectious diseases [24]. Phenolic compounds found in EVOO including the dialdehydic form of decarboxymethyl oleuropein aglycon, oleocanthal, hydroxytyrosol and tyrosol have been shown to possess potent activity against several strains of bacteria responsible for intestinal and respiratory infections *in vitro* (Figure 2). However, they have also been found to exhibit bactericidal activity against the beneficial bacteria, *Lactobacillus acidophilus* and *Bifidobacterium bifidum* [25]. The inhibition of these health-benefiting bacteria may pose a detrimental effect on wellbeing and therefore requires further investigation.

The phenolic, oleocanthal has also been found to escape hydrolysis under stomach-simulated conditions and aid in inhibiting the growth of *Helicobacter pylori* bacteria, which have been associated with peptic ulcer and gastric cancer development [26]. More recently, the antimicrobial activities of olive oil phenolics were tested against three foodborne pathogenic bacteria: *Escherichia coli O157:H7*, *Listeria monocytogenes* and *Salmonella enteritidis in vitro*. A synergistic interaction was noted amongst various olive oil phenolic compounds and this synergism appeared to increase antimicrobial capacity compared to that of individual compounds. The study's authors concluded that the use of EVOO in foods may help to prevent foodborne disease [27•].

Overall, a small number of *in vitro* studies have demonstrated promising, health-benefiting properties of olive oil phenolics in relation to antimicrobial activity. However,