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Chemical composition of olive oil – an essential component of the Mediterranean diet and its impact on human health

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ABSTRACT

The Mediterranean diet is known for its many health benefits, including the low prevalence of cardiovascular disease, atherosclerosis, diabetes, obesity, and cancer. Olive oil is considered an essential component of the Mediterranean diet. The consumption of olive oil is associated with many beneficial effects on the human body, most of which are attributed to its phenol content, which varies between cultivars due to different processing and extraction procedures, with only 0.3-1.5% of phenols being transferred to the oil from the olive fruit. Many studies suggest that olive oil phenolic compounds have a protective role in preventing cardiovascular diseases, cancer, diabetes mellitus type 2, metabolic syndrome, obesity, inflammation, and neurodegenerative diseases. Additionally, recent epidemiological research has shown that regular olive oil consumption is associated with increased longevity.

Keywords: olive oil, phenols, health benefits

INTRODUCTION

Olive oil is prepared from the healthy fruits of the olive tree *Olea europaea*, one of the oldest known cultivated trees in the world [1]. The primary production of olive oil is in Mediterranean countries, including Spain, Greece, Italy, Morocco, Turkey, and Tunisia. Olive oils are also produced in other regions of the world, including the USA, California, Mexico, and Australia [2-3]. Olive oil is an essential part of the Mediterranean diet and is recognized by the World Health Organization as a nutritional reference model [4]. The Mediterranean diet consists of fish, fruit, vegetables, whole grains, cereals, legumes, nuts, dairy products, low meat intake, moderate fish and seafood intake, moderate alcohol consumption, and is accompanied by regular intake of olive oil (virgin or extra virgin). Olive oil consumption is between 25-50 ml per day, approximately two tablespoons [5-6].

Consumption of olive oil is associated with many health benefits. Many studies reported its beneficial effect on cardiovascular diseases, cancer, diabetes mellitus type 2, metabolic syndrome, obesity, inflammation, and neurodegenerative diseases [1,3,7-8]. Most of the positive effects of olive oil are associated with its chemical composition. Olive oil contains mainly monounsaturated fatty acids, polyphenols, nutrients, vitamins, and minerals. Polyphenols are an essential component due to their high antioxidant properties [7,9]. At present, there is a well-functioning export-import between countries, and therefore in each country, individuals can choose from hundreds of different olive oils that are available to consumers. The quality of olive oil is influenced by the sort of fruit, the region, and how the olives were grown. Also, the maturity of the olive fruit at harvest is important. To obtain high-quality olive oil, the olive fruits must be harvested without breaking the fruit skins. Thus, the most important factors are olive oil extraction, how it is processed and stored, and the time since harvest [2,7]. Each olive oil has a different taste, storage quality, and price, and they also differ in their antioxidant content [2]. Olive oil is commonly used in cooking, cosmetics, and pharmaceuticals. It has found its application in religious customs, and sometimes it is used as fuel for traditional oil lamps [1].

***Chemical composition of olive oil*:** Several factors influence the chemical composition of olive oil, such as geographical zone, climatic conditions, cultivars, ripeness of the fruit during harvest, storage time and conditions, and oil extraction technology (Figure 1) [9-10]. Olive oil contains saturated (7.5-20% palmitic acid), monounsaturated (83% oleic acid), and polyunsaturated fatty acids (2.5-21% linoleic acid) bound in triacylglycerols, representing 98-99% of olive oil components (Table 1). In addition to the main ingredients, olive oil contains small amounts of free fatty acids, phosphatides, glycerol, sterols (mainly beta-sitosterol), color pigments (chlorophylls, carotenoids), aromatic compounds, waxes, aldehydes, ketones, and phenolic compounds. [5,11]. Polyphenols appear to be key compounds responsible for many of the positive effects of olive oil on the human body. Differences in the amount of phenolic compounds have been observed in different cultivars [10]. In summary, olives fruits contain hydrophilic phenol compounds, including simple phenolic compounds (such as vanillic acid, gallic acid, coumaric acid, caffeic acid, hydroxytyrosol, and tyrosol), complex compounds (for example, secoiridoids, including oleuropein and ligstroside), and lipophilic lignans (for example 1-acetoxypinoresinol and pinoresinol) [3].

Table 1. Chemical composition of olive oil

Major components		
Triacylglycerols (98-99%)		
Fatty acids in TAG		
	Monounsaturated	55-83% oleic acid
	Saturated	7.5-20% palmitic acid
	Polyunsaturated	2.5-21% linoleic acid
Minor components		
	Free fatty acids	
	Phosphatides	
	Glycerol	
	Sterols	Beta-sitosterol
	Color pigments	Chlorophylls
		Carotenoids
	Aldehydes	
	Ketones	
	Waxes	
	Phenolic compounds	

Jerman Klen et al. (2012) investigated phenol transfer rates from olive fruit to paste, oil, and waste. They also followed up on the antioxidant potential of phenols. They studied four different cultivars with the same ripening index and compared three available industrial-scale extraction systems. The first one was a traditional press, the second one a continuous two-phase centrifuge, and the third was a three-phase centrifuge. According to their results, similar phenol composition was found in fruits, paste, and wastes, but this phenol composition was significantly different from that in oil. It means that during oil processing, polyphenols are also transformed. Only 50-60% of the total phenols were transferred from the fruit into the paste, which means that most phenols are lost during crushing and malaxation. The further distribution of phenols between waste and oil depended significantly on their solubility, which was influenced by the extraction system used for oil processing. Only 0.3-1.5% of phenols from olive fruit were transferred into the oil, while > 40% ended up in waste. Phenols found in the oil are mainly of lipophilic nature, newly formed by complex biotransformation reactions. When comparing extraction systems, the highest transfer rate of phenols to oil was provided by a two-phase centrifuge (1.5%), with the highest antioxidant potential, followed by a traditional press (1.2%), and the lowest transfer rate of phenols to oil was provided by three-phase centrifuge (0.5%) [12]. Talhaoui et al. (2016) confirmed these results in their work, where they studied six different cultivars grown under the same agronomical and environmental conditions, so only 0.3-1.5% of available phenols were transferred to oil, while the rest (more than 40%) ended up in waste [10]. The content of polyphenols in different olive oils also varies due to different processing and extraction processes (Figure 1) and ranges from 50 to 1000 mg/kg. Phenolic compounds in olive oil are phenolic acids, phenolic alcohols (tyrosol, hydroxytyrosol), oleuropein derivatives, lignans, and flavonoids [9].

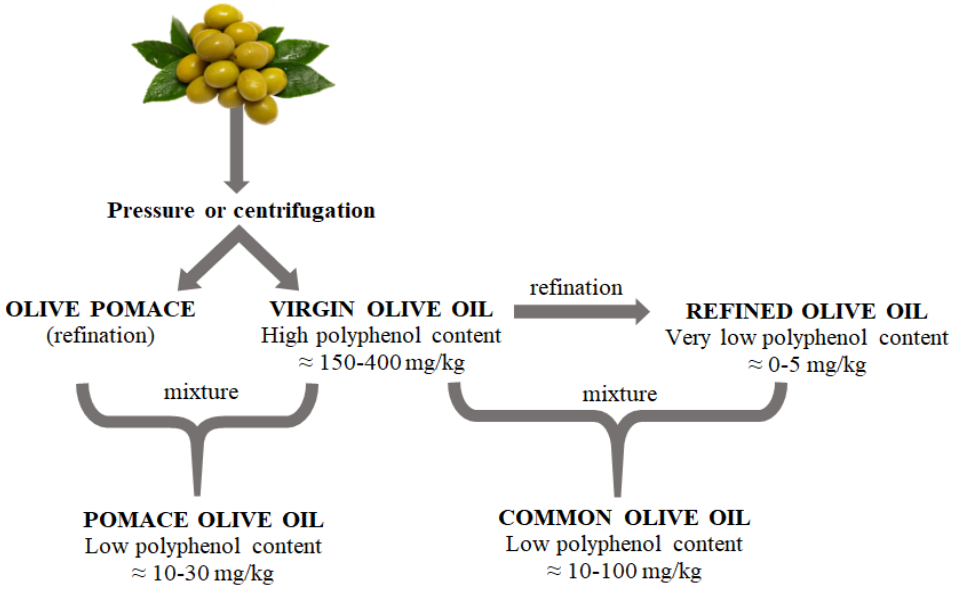

Figure 1. Concentration of polyphenols in different types of olive oils (adjusted according [13]).

The highest polyphenol content is found in extra virgin olive oil (acidity level < 0.8%) and virgin olive oil (acidity level < 2%). Extra virgin olive oil is obtained after the first pressing of fresh olives within 24h after harvesting, containing the highest polyphenol levels. Virgin olive oil is also obtained after the first pressing of olives but with a higher acidity level. Virgin olive oil contains phenols, phenolic acids, alcohols, flavonoids, lignans, and secoiridoids.

Refined olive oil is obtained after adding agents such as acids, alkalis, and heat to obtain additional oil from the olive pulp after the first pressing. Refined oil contains higher fat and acidity, and low polyphenol content. Pomace oil is the by-product of extraction, where the heat and hexane solvents are used to extract the residual oil from olive skin, pulp, and seeds. Pomace oil is refined and ultimately contains a low number of polyphenols [3].

***Positive health benefit of olive oil phenolic compounds*:** Phenolic compounds represent a huge group of compounds naturally occurring in various foods. They represent the most numerous and widely distributed category of bioactive molecules. Polyphenols in their structure contain one or more benzene rings and different numbers of hydroxyl, carbonyl, and carboxylic acid groups attached to the ring, which usually occur with one or more sugar residues [14]. The positive effect of phenolic compounds on the human body is mainly attributed to their antioxidant properties. They are considered to be the leading and strongest antioxidants present in food. Polyphenols participate in the prevention of oxidative stress associated with many human chronic disorders, such as cardiovascular diseases, cancer, atherosclerosis, diabetes, and others (Figure 2). Polyphenols act as scavengers of free radicals, which leads to the reduction of reactive oxygen species (ROS) or reactive nitrogen species (RNS), and subsequently to the prevention of damage to biomolecules [15].

Olive oil intake is associated with a beneficial effect on cardiovascular disease (CVD). CVD prevention is associated with a healthy diet, including healthy sources of dietary fats (unsaturated fat and low saturated fat) and physical activity. Olive oil is rich in monounsaturated fat, such as oleic acid, and contains lipid molecules and polyphenols with high antioxidant properties, which as a part of the diet, could finally prevent CVD risk [17]. Donat-Vargas et al. (2022) carried out a study focusing on the effect of olive oil on cardiovascular diseases. In their study, three large

cohorts were included. They observed that the maximum benefit of olive oil intake could be obtained with consumption between 20 and 30 g/day. They confirmed that olive oil is associated with a lower risk of cardiovascular diseases and stroke. It seems that olive oil acts on the early stages of the disease, preventing the formation of atheroma plaques and coronary calcium in arteries [16]. The consumption of olive oil and the risk of CVD in the US population was studied by Guasch-Ferré et al. (2020) in two large cohort studies, where they observed a 5% to 7% lower risk of total CVD and coronary heart disease when replacing 5 g/day of margarine, butter, mayonnaise, or dairy fat with the equivalent amount of olive oil [17]. Another study by Guasch Ferré et al. (2014) included men and women at cardiovascular risk and studied the benefit of the olive oil (extra virgin and common) intake. They observed a positive effect of olive oil consumption (specifically the extra-virgin) on the risks of CVD and mortality in individuals at high cardiovascular risk. According to their study, for each 10 g/d increase in extra-virgin olive oil intake, cardiovascular disease decreased by 10%, and mortality risk decreased by 7% [18]. The study of Buil-Cosiales et al. (2008) included the sub-cohort of the PREDIMED (PREvención con DIeta MEDiterránea) study. They focused on the effect of olive oil consumption on intima-media thickness (IMT), which represents a valid marker for vascular disease. They observed the inverse association between olive oil intake and the carotid IMT, which pointed out the protective effect of olive oil against the development of carotid atherosclerosis in persons at high cardiovascular risk [19]. Casas et al. (2014) studied the effect of the Mediterranean diet on inflammatory biomarkers related to atherosclerosis and plaque vulnerability in individuals from the sub-cohort of the PREDIMED study. They observed the protective role of the Mediterranean diet against ischemic heart disease and observed increased levels of serum markers of atheroma plaque stability [20].

Mediterranean diet and olive oil intake are also associated with their beneficial effect on different types of cancers. In this type of disease, dietary interventions seem to be an effective measure in secondary or tertiary prevention, or as part of complementary therapy [21]. A randomized trial focused on the Mediterranean diet found that such a diet reduced cancer incidence (61%) and showed a cardioprotective effect [22]. A randomized trial by Toledo et al. (2015) suggested the beneficial effect of extra virgin olive oil (as a part of the Mediterranean diet) in the primary prevention of breast cancer [23]. The meta-analysis of Schwingshackl et al. (2017) suggested the positive effect of the Mediterranean diet on cancer mortality and risk of cancer. They confirmed an inverse association between the Mediterranean diet adherence and mortality of cancer, as well as the risk of several types of cancer (especially colorectal cancer). They also reported a slight decrease in breast cancer risk (6%) by combining seven cohort studies [21].

Schwingshackl et al. (2017), in their meta-analysis, detected the effects of olive oil on glycemic control in patients with type 2 diabetes. They observed a 16% reduced risk of type 2 diabetes in the group with the highest olive oil intake compared to the lowest [24]. Assaf-Balut et al. (2017) performed a randomized controlled trial centered on how the Mediterranean diet can help prevent gestational diabetes mellitus during pregnancy. They concluded that early nutritional intervention with Mediterranean diet supplements reduced the incidence of gestational diabetes mellitus and improved multiple outcomes in the mother and newborn [25].

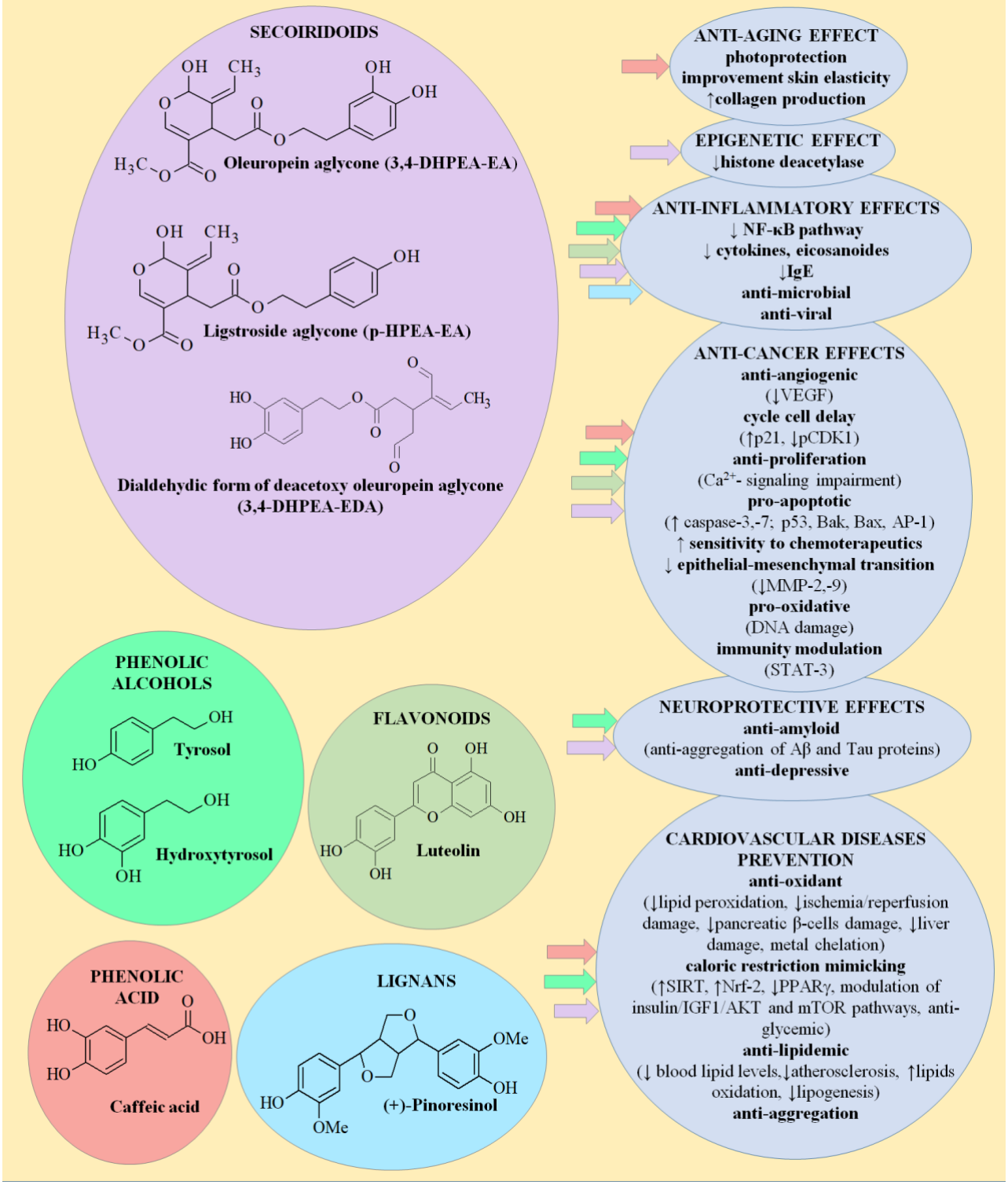

Figure 2. Main classes of phenolic compounds in olive oil and summarization of their health effects. Colored arrows pointing to effects mediated by groups marked with the same color (adjusted according [26-32]).

CONCLUSION

Recently, the number of studies dealing with the effects of olive oil consumption on the human body has increased. Studies and evidence to date confirm that the consumption of olive oil is beneficial for human health. Many studies also suggested its positive impact on the management and prevention of cardiovascular disease, several types of cancers, diabetes, and other diseases.

List of Abbreviations: ROS: reactive oxygen species, RNS: reactive nitrogen species, CVD: cardiovascular

diseases, IMT: intima-media thickness, PREDIMED: PREvención con DIeta MEDiterránea.

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