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Mercyska Suryandari , *Identification and quantification of major polyphenols*
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IDENTIFICATION AND QUANTIFICATION OF MAJOR POLYPHENOLS IN DIFFERENT TYPES OF OLIVE OIL: A SYSTEMATIC REVIEW OF HEALTH BENEFITS

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ABSTRAK

Minyak zaitun adalah komponen kunci diet Mediterania, dengan kandungan polifenolnya yang memiliki sifat antioksidan yang kuat, melindungi sel dari stres oksidatif dan mengurangi risiko penyakit kronis seperti penyakit kardiovaskular, kanker, dan gangguan neuro degeneratif. Penelitian ini bertujuan mengidentifikasi dan mengukur polifenol utama dalam berbagai jenis minyak zaitun, termasuk Extra Virgin Olive Oil (EVOO), VirginOlive Oil (VOO), Refined Olive Oil (ROO), Pure Olive Oil (POO), dan Pomace Olive Oil. Dengan pendekatan kualitatif dan analisis deskriptif, dilakukan studi literatur komprehensif untukmengumpulkan dan mengevaluasi penelitian tentang kandungan polifenol dalam berbagai minyak zaitun. Hasilnya menunjukkan perbedaan signifikan dalam profil polifenol. EVOO, yang diproduksi melalui pengepresan dingin tanpa panas atau bahan kimia, memiliki kandungan polifenol tertinggi, menawarkan manfaat Kesehatan superior dan rasa kompleks. VOO, meskipun lebih diproses, tetap mengandung polifenol cukup tinggi, cocok untuk memasak suhu sedang. ROO, yang diproses secara ekstensif, memiliki kadar polifenol lebih rendah, ideal untuk memasak suhu tinggi namun dengan manfaat kesehatan lebih sedikit. POO, campuran VOO dan ROO, menawarkan keseimbangan rasa dan kepraktisan. Pomace Olive Oil, dengan kandungan polifenol terendah, digunakan terutama untuk menggoreng industri karena titik asapnya tinggi. Kesimpulannya, penelitian ini menekankan pentingnya memilih jenis minyak zaitun berdasarkan penggunaan dan manfaat kesehatannya. EVOO optimal untuk hidangan mentah atau dimasak ringan, VOO untuk memasak serbaguna, dan ROO serta Pomace Olive Oil untuk aplikasi suhu tinggi. Penelitian ini membimbing konsumen dan produsen dalam membuat pilihan tepat untuk mengoptimalkan manfaat kesehatan minyak zaitun.

Kata kunci: Profil Polifenol, Rasa Minyak Zaitun, Manfaat Kesehatan Minyak Zaitun, Produksi Minyak Zaitun, Pengolahan Minyak Zaitun

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ABSTRACT

Olive oil is a key component of the Mediterranean diet, renowned for its flavor and health benefits, especially for its polyphenol content. These polyphenols have strong antioxidant properties, protecting cells from oxidative stress and reducing the risk of chronic diseases such as cardiovascular disease, cancer, and neurodegenerative disorders. This study aims to systematically identify and quantify the main polyphenols in different types of olive oil, including Extra Virgin Olive Oil (EVOO), Virgin Olive Oil (VOO), Refined Olive Oil (ROO), Pure Olive Oil (POO), and Pomace Olive Oil. Using a qualitative approach and descriptive analysis, a comprehensive literature study was conducted to collect and evaluate research on polyphenol content in various olive oils. The results showed significant differences in polyphenol profiles. EVOO, which is produced through cold pressing without heat or chemicals, has the highest polyphenol content, offers superior health benefits and complex flavors. VOO, although more processed, still contained moderately high polyphenols, suitable for medium temperature cooking. ROO, which is extensively processed, has lower polyphenol levels, ideal for high temperature cooking but with fewer health benefits. POO, a blend of VOO and ROO, offers a balance of flavor and practicality. Pomace Olive Oil, with the lowest polyphenol content, is used mainly for industrial frying due to its high smoke point. In conclusion, this study emphasizes the importance of choosing the type of olive oil based on its use and health benefits. EVOO is optimal for raw or lightly cooked dishes, VOO for all- purpose cooking, and ROO and Pomace Olive Oil for high temperature applications. This research guides consumers and manufacturers in making the right choice to optimize the health benefits of olive oil.

Keywords: Polyphenol Profile, Olive Oil Flavor, Olive Oil Health Benefits, Olive Oil Production, Olive Oil Processing

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1. INTRODUCTION

Olive oil is a cornerstone of the Mediterranean diet, renowned not only for its flavor but also for its many health benefits [1]. These benefits are largely due to the presence of bioactive compounds, particularly polyphenols. Polyphenols are a diverse group of natural organic compounds found in plants, known for their powerful antioxidant properties. They play an important role in protecting cells from oxidative stress and reducing the risk of chronic diseases such as cardiovascular diseases, certain cancers, and neurodegenerative disorders ([2]. Olive oil polyphenols are unique among all polyphenols, as they are the only polyphenols approved to claim health benefits, further emphasizing their importance in promoting well- being [3].

Among the various types of olive oil, extra virgin olive oil (EVOO) is known for its high quality and rich polyphenol content. EVOO is produced through mechanical means without the use of heat or chemical treatments [4]. This method ensures the oil retains its bioactive compounds, particularly polyphenols, which are important for health benefits. Virgin olive oil (VOO), although mechanically produced, undergoes slightly more processing than EVOO [5], resulting in lower polyphenol content. In contrast, refined olive oil undergoes extensive chemical and thermal treatment to neutralize its taste and remove impurities, which significantly reduces its polyphenol content [6].

The main polyphenols found in olive oil include oleuropein, hydroxytyrosol, and tyrosol. These compounds contribute significantly to the oil's health benefits. Oleuropein, mainly found in the leaves and fruits of the olive tree, is known for its bitter taste and strong antioxidant activity [7]. Hydroxytyrosol and tyrosol, the hydrolysis products of oleuropein, are the most potent natural antioxidants, providing strong protection against oxidative damage [8].

Although polyphenols have recognized health benefits, there is great variability in their concentration across different types of olive oil. The concentration of polyphenols in olive oil can be affected by various factors such as season, olive variety, region, soil, fruit maturity, and processing techniques [9]. Therefore, it is important to identify and quantify the major polyphenols in different types of olive oil to better understand their contribution to health and to guide consumers and producers in making the right choices. This study aims to systematically identify and quantify the major polyphenols in extra virgin, virgin and refined olive oils. This research will not only improve our understanding of the health benefits associated with different types of olive oil, but also provide information on olive oil polyphenols and their health implications

2. METHOD

The research was conducted using a qualitative approach with a descriptive analysis method, and the technique used was a literature study [10]. Literature study, which is a research method that collects, evaluates, and synthesizes existing research on a particular topic. This research paradigm allows researchers to identify trends, research gaps, and provide comprehensive insights into the topics studiedand focuses on identifying polyphenol content in various olive oils.

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3. RESULTS AND DISCUSSION

The identification and quantification of key polyphenols in different types of olive oil, including *Extra Virgin Olive Oil* (EVOO), *Virgin Olive Oil*(VOO), *Refined* Olive Oil (ROO), *Pure Olive* Oil (POO) and Pomace Olive Oil, showed significant differences in their polyphenol profiles. These differences are crucial in understanding the diverse health benefits associated with each type of olive oil.

3.1. Extra Virgin Olive Oil (EVOO)

Extra Virgin Olive Oil (EVOO) is a type of olive oil of the highest quality, obtained from fresh olives using a mechanical method (*cold pressing*) without heating or the use of chemicals, with very lowacidity, usually a maximum of 0.8% to 1% oleic acid [11,12]. This premium quality is thanks to a careful extraction process that preserves the natural flavors and beneficial compounds present in fresh olives.

EVOO is ideal for use in salad dressings, sauces, and as a finishing dish due to its strong flavor and aroma. The flavor of EVOO is strong and complex, with fruity, bitter, and slightly spicy characteristics [8]. Factors such asgeographical origin, olive cultivar, and ripening stageinfluence the flavor profile of EVOO [13]. The presence of fatty acids,phenols, tocopherols, pigments and volatilecompounds in EVOO contributes to its unique flavor profile and health benefits [14]. The bitter and nutty flavors are the main factors contributing to the sensory appeal of EVOO, with phenolic compounds such as oleuropein-aglycone derivatives playing an important role in antioxidant activity and flavor [15]. These compounds not only protect the oil from oxidation butalso enhance its flavor and aroma.

The color of EVOO varies from golden green to light yellow, depending on the olive variety, harvesttime, maturity of the olives, geographical origin, amount of irrigation water received, and extraction process used [16](Berenguer et al., 2006; [17]. Thepigments present in EVOO, such as carotenoids and chlorophyll derivatives, are responsible for its color and are directly related to the quality of the oil [18]. The color of EVOO isan important aspect as it has a direct influence on consumer preferences and quality perception [11].

EVOO is a key component of the diet in the Mediterranean region and is highly valued for its nutritional attributes and sensory properties [19]. It is rich in polyphenols, bioactive compounds known for their antioxidant properties andpotential health benefits [20]. EVOO typically contains various polyphenols, with concentrations varying from about 0 to 286 mg/kg [9], which may offer cardioprotectiveeffects and help reduce risk factors for cardiovasculardisease [21].

These include oleuropein, hydroxytyrosol, andtyrosol, which contain bioactive molecules such ashydroxytyrosol, oleuropein aglycone, tyrosol, 10-hydroxyoleocanthal, and oleocanthal [22]. Oleuropein aglycone (OA), which is the mainphenolic substance in extra virgin olive oil (EVOO),is now gaining global attention [22]. Inparticular, there has been success in the direct synthesis of oleacein, a rare component of extra-virgin olive oil, from oleuropein, which is

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abundant in oliveleaves [23]. Oleacein, along witholeocanthal, is a secoiridoid found in extra-virginolive oil that has been recognized for its health-promoting properties [24]. In conclusion, the synthesis and presence of oleacein, derived from the abundant oleuropein inolive leaves, indicates the importance of thiscompound in EVOO. EVOO consumption has beenassociated with various health benefits, includingimproving blood lipid and lipoprotein levels, thus potentially lowering the risk of coronary disease[9]. EVOO has a milder flavor profile[25] is ideal for use in saladdressings, sauces, and as a finishing dish due to itsstrong flavor and aroma, and is more expensive than other types of olive oil.

3.2. Virgin Olive Oil (VOO)

Virgin Olive Oil (VOO) is also obtained through mechanical methods without heating or chemicals, but may come from olives with slightly lower quality than EVOO. Virgin olive oil (VOO) is extracted by pressing and centrifuging the olives witha three-phase vertical decanter [26].

The acidity of VOO is slightly higher than thatof EVOO, typically ranging from 1% to 2% oleic acid [11,12]. This difference in acidity is a key factor in distinguishing between EVOO and VOO, where EVOO is generally of higher quality due to its lower acidity content. The acidity of olive oil is an important parameter that reflects the quality and freshness of the oil. The lowerthe acidity, the higher the quality of the olive oil.

The flavor of VOO is milder than EVOO, but still has a significant fruit flavor [9]. Thismilder flavor is due to the rich content of monounsaturated fatty acids, particularly oleic acid, inVOO [27]. Phenolic compounds, such as oleuropein, are abundant in virgin olive oil, giving it its characteristic flavor and contributing to its antioxidant properties [28,29]. The flavor complexity of VOO comes mainly from its volatile compounds and phenols, which vary based on the variety and maturity of the olives [30].

The color of VOO is similar to EVOO, but canbe paler. The color of VOO, ranging from yellowgreen to greenish gold, is influenced by pigments thatalso impact the perception of its quality [31]. The color of olive oils, including VOO, ismainly due to pigments such as carotenoids andchlorophyll derivatives [18]. Although the color of VOO may be paler compared toEVOO, both types of olive oil have similarities in theircolor profile due to the presence of these pigments. The pigments present in both types of olive oilcontribute to its color, with variations influenced byfactors such as fruit maturity and processing methods.The polyphenol content of Extra Virgin Olive

Oil (EVOO) is usually higher than that of Virgin Olive Oil [3]. However, EVOO still contains significant amounts of polyphenols that contribute to health benefits. The presence of polyphenols in olive oils, including VOO, is essential to improve their nutritional and organoleptic properties.

Research shows that the polyphenol content inVOO can range from 120 ppm in Greek olive oil to 700 ppm in monovarietal oils [32]. Although VOO has a lower polyphenol content compared to EVOO, it still contains significant amounts of these compounds, which are important for its health benefits [3]. Polyphenols in VOO, such as tyrosols, hydroxytyrosols, and other phenolic antioxidants, contribute to its overall quality and health-promoting properties [33]. The total polyphenolcontent in VOO is an important parameter to evaluateits quality and health benefits [34].

VOO, known for its health benefits, is a fundamental element in various culinary practices andcontains various bioactive components and antioxidants such as polyphenols, phytosterols and vitamin E [11,35]. These components contribute to its antioxidant properties, making it a preferred choice for cooking atmoderate temperatures such as sautéing and grilling [36], as well as also being used in salads and as a finishing oil. VOO can withstandtemperatures ranging from 170 to 190 °C and can be reused multiple times for frying [37].These characteristics make it suitable for various cooking methods while maintaining its properties.

3.3. Refined Olive Oil (ROO)

ROO is obtained from olive oil that has been chemically and heat processed to remove unwanted imperfections, odors, and flavors. The refining processinvolves the removal of free fatty acids, which improves the stability of the oil and increases itssmoke point, making it suitable for various cooking methods such as frying and baking (Hammouda et al., 2019). Despite the decrease in squalene content duringrefining, ROO still contains significant amounts of this compound, which is known for its health benefits [39]. In addition, ROO retainsbeneficial components such as tocopherols, thus contributing to its oxidative stability [38].

The acidity of this oil is very low, typically between 2% and 3.3% oleic acid [12,40]. The olive oil refining process helps to remove impurities, unwanted tastes and odors,resulting in a product with a low oleic acid content. This process can have an impact on the composition of the oil, including a decrease in squalene content during deodorization [39]. ROO can be enriched with natural antioxidants to improve its oxidative stability and nutritional value [41]. Enriching ROO with phenolic compounds extracted from olive leaves can improve its resistance to oxidation, increasing its shelf life andquality over time [42].

The flavor of ROO is neutral, lacking the fruityor spicy notes commonly found in EVOO. This flavorneutrality is the result of a refining process that aims to remove impurities and unwanted flavors from the oil [43]. While ROO may not have the flavor of EVOO, it still retains important components such as tocopherols, which contribute to its oxidative stability [44]. The additionof natural antioxidants to ROO can improve its stability and nutritional value without significantly changing its neutral flavor [6].

The color of ROO is lighter and more uniform, often pale yellow. Purification techniques, including caustic purification, bleaching, deodorization, adsorption, and membrane filtration, play an important role in reducing color intensity and achieving a consistent pale yellow appearance in ROO [25]. While the color of EVOO is often associated with high quality, the pale yellow color of ROO signifies its delicate nature and suitability for cooking and other uses [45].

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The polyphenol content of ROO is very low, asmost of the polyphenols are lost during the purification process [40]. This polyphenol reduction makes ROO less stable and more susceptible to rapid oxidation during storage. ROO as a product of the refining process, has less natural bioactive compounds such as polyphenols andantioxidants compared to EVOO and VOO types [21].

ROO is ideal for frying and cooking at high temperatures due to its higher smoke point [46], but is not suitable for use as a finishing oil or in dishes that require a distinctive olive oil flavor.

3.4. Pure Olive Oil (POO)

POO is a blend of virgin olive oil (VOO) and refined olive oil (ROO), as indicated by the addition of ROO to VOO to produce this particular type of olive oil [47]. Markets often sell blends of VOO and ROO, and most olive oils are soldin blended form [48]. These blends are commonly used in non-Mediterranean countries due to their milder flavor, making them moreacceptable for various culinary applications [25].

The acidity and polyphenol content of POO is highly dependent on the proportion of VOO in the blend. The acidity level of olive oil is an important parameter that indicates the quality and freshness of the oil. VOO is known to have a high polyphenol content, which contributes to its stability and health benefits [49]. The polyphenol content in olive oil is influenced by various factors such as olive variety, extraction method, and storage conditions. Therefore, the proportion of VOO in POOhas a direct impact on its acidity and polyphenolcontent, affecting its overall quality and health benefits.

The flavor of POO is milder than EVOO and VOO, but still has some of the flavor characteristics ofolive oil. The flavor profile of POO is influenced by various factors such as olive cultivar, fruit maturity, processing method [50], as well as the composition of the VOO mixed in. The addition of flavors, herbs, or spices to POO can enhance its taste and aroma, resulting in a flavorful olive oil with unique sensory attributes [51]. Olive oil sensory characteristics, including flavor and aroma, play an important role in consumer acceptance and preference [52]. Overall, POO provides a balance between the milder taste of refinedoils and the distinct flavor of virgin oils, thus offeringa versatile option for a variety of culinary uses.

The color of POO varies depending on the composition of the mixture, but is usually lighter thanEVOO and VOO. In addition, the color of POO can beaffected by the addition of coloring additives to enhance its appearance [53]. Olive oil color is an important sensory attribute that can influence consumer perception and acceptance [54]. Therefore, the color of POO, which is a mixture of VOO and ROO, tends to be lighter than EVOO and VOO Olive Oil, reflecting a milder flavor profile.

Its polyphenol content is lower than EVOO and VOO, but higher than ROO. EVOO, obtained throughcold pressing of olives, is rich in phenolic compounds,while ROO, obtained through solvent extraction, hasa much lower phenol content. The total polyphenol content in olive oil is critical forits antioxidant properties and health [55]. POO, which is a blend of VOO and ROO, falls

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between VOO and ROO in terms of polyphenol content, thus offering a balance between flavor and health benefits [6].

POO is versatile for a variety of cooking techniques, from sautéing to grilling, and is also used in salads and sauces, although it does not provide as strong a flavor as EVOO. POO, with its balance between the milder flavor of refined oils and the health benefits of virgin oils, can be used in cooking, salad dressings, and various culinary applications [56]. Moreover, the color, taste, and aroma of POO can vary based on the blend of VOO and ROO, thus offering a unique sensory experience [57,58]. Overall, POO stands out for its nutritional content, health benefits, and culinary versatility, making it a staple in many households and cuisines around the world.

3.5. Pomace Olive Oil

Olive pomace, a by-product of virgin olive oil processing, is very important in Mediterranean countries where olives are cultivated [59], containing higher levels of diglycerides than VOO, reaching 15-20% [60]. Olive pomace oil is derived from the residue left after VOO extraction, using solvents and subsequent refining processes [61]. The production of olive pomace oil involves the extraction of the remaining oil from the olive pomace,which consists of depleted pulp, skins, seeds and stones [62]. The acidity level of pomace olive oil is very low after refining. The olive pomace oil refining process involves steps such as degumming, neutralization, bleaching, and deodorization, whichhelp reduce impurities such as free fatty acids and diglycerides [59,63]. The initial acidity of olive-pomace oil can be significantly reduced through processes such as enzymatic glycerolysis [64]. Olive pomace oil is a promising source of bioactive triterpenoids, including oleanolic acid and maslinic acid, which have been associated with improved vascular function and glucose tolerance [65].

The taste of this oil is very neutral, with almostno olive oil flavor, and the color is pale and uniform. The neutral taste and pale color are characteristic of pomace olive oil due to its refining process which removes impurities and flavors present in the crude oil. Pomace olive oil is obtained from olive pomace, which is the solid residue left after pressing olives forthe extraction of virgin olive oil. The subsequent bleaching process helps remove residual pigments andoff-flavors, resulting in a pale and uniform color.Deodorization is also an important step in refining olive pomace oil, as it helps remove any residual odoror taste, resulting in a neutral flavor profile. The application of microwave preheating has been shown to reduce the formation of polycyclic aromatic hydrocarbons (PAHs) in olive pomace oil [66]. The polyphenol content of olive oil pomace is significantly reduced due to the intensive refiningprocess it undergoes. Polyphenols are bioactive compounds found in olive oil that have antioxidant properties and contribute to health benefits. However,during the refining process of olive oil pomace, whichinvolves steps such as degumming, neutralization, bleaching, and deodorization, many polyphenols are removed, leading to a decrease in polyphenol content in the oil [6,32,67]. The total phenol content in refinedolive pomace oil was found to be higher than ROO, with an initial concentration of 105 mg/kg expressed as gallic acid equivalent [58].

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This pomace olive oil is used mainly in the food industry for frying due to its high smoke point, showing good stability against thermal oxidation and being particularly suitable for frying due to its high oleic acid content, and the presence of small components with antioxidant activity or protectiveeffects [67,68]. The neutral taste and pale color of refined olive pomace oil make it a versatile cooking oil that can beused in a variety of culinary applications without compromising the flavor of the dish. Its mild flavor profile makes it suitable for use in dishes that prefer neutral oils, such as baking, frying, and saladdressings.

4. CONCLUSION

This study systematically identified and quantified the main polyphenols present in different types of olive oil, including Extra Virgin Olive Oil (EVOO), Virgin Olive Oil (VOO), Refined Olive Oil (ROO), Pure Olive Oil (POO), and Pomace Olive Oil. The results highlighted significant differences in the polyphenol profiles of these oils, which is important for understanding their diverse health benefits. EVOO emerges as the highest quality olive oil,produced through cold pressing without the use of heator chemical treatments. This method preserves the rich content of bioactive polyphenols such as oleuropein, hydroxytyrosol and tyrosol. These compounds contribute to EVOO's powerful antioxidant propertiesand health benefits, including protection against cardiovascular disease and other chronic conditions. The high polyphenol content and complex flavor profile of EVOO make it ideal for raw applications such as salad dressings and finishing dishes. VOO, also produced mechanically but with slightly more processing than EVOO, retains a large amount of polyphenols, albeit to a lesser extent. It provides a milder flavor while still offering greathealth benefits, making it suitable for medium-heat cooking methods such as sautéing and grilling. ROO, which undergoes extensive chemicaland thermal processing, has a drastically reducedpolyphenol content. Its neutral flavor and highersmoke point make it ideal for high-temperaturecooking methods such as frying, yet it lacks the distinct flavor and health benefits of EVOO and VOO.POO, a blend of VOO and ROO, offers a balance between flavor and versatility. Its polyphenol content and acidity depend on the proportion of VOOin the blend, thus providing a compromise between the strength of EVOO and the neutrality of ROO. Olive Pomace Oil, derived from the residue left after VOO extraction and further refined, has the lowest polyphenol content among the oils studied. Its neutral flavor and high smoke point make it useful for industrial frying applications, although its health benefits are the least. In conclusion, this study underscores the importance of choosing the right type of olive oil based on its intended use and health benefits. EVOO, with its superior polyphenol content, is best suited for raw or lightly cooked dishes to maximize its health benefits and taste. VOO, with moderate polyphenol levels, is versatile for everyday cooking. ROO and Pomace Olive Oils, with minimal polyphenol content,are suitable for high temperature cooking but offer fewer health benefits. This research provides valuable insights for consumers and producers, guiding theright choices to optimize the nutritional and health benefits of olive oil consumption.

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