Virgin olive oil and nutrition

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review

Summary

Numerous medical studies (a study in seven countries, Monika study, Dart studies, etc.) have shown that olive oil is one of the most important ingredient of "Mediterranean diet" associated with a reduction in cardiovascular disease and certain types of cancerous diseases. Nutritional and health value of virgin olive oil is attributed to the large proportion of monounsaturated fatty acids (mainly oleic, 55-83 %), and precious unsaponifiable ingredients that include aliphatic and triterpene alcohols, sterols (mainly β-sitosterol), hydrocarbons (squalene), volatile compounds, tocopherols (preferably α-tocopherol), pigments (chlorophylls and carotenoids) and antioxidants. Oleic acid is the most abundant fatty acid in olive oil that is claimed to affect the increase in level of high density lipoprotein (HDL) and reducing levels of low-density lipoprotein (LDL) in the blood plasma. For this reason it is considered that oleic acid could prevent the occurrence of certain cardiovascular diseases which are still one of the major causes of death. Besides the already mentioned high level of oleic acid, virgin olive oil is characterized by a highly valuable unsaponifiable ingredients which are attributed to exceptional biological value as virgin olive oil is classified as functional food.

Keywords: virgin olive, oil, fatty acids, biological value, Mediterranean diet

Introduction

Virgin olive oil is, unlike most seed oils, obtained by using a series of mechanical operations at a specific temperature (up to 28 ºC) whose purpose is to extract the oil droplets in cells of the pulp of olives. The resulting oil is fat naturally created in olive fruit and has a unique chemical composition and specific pleasant aroma. Therefore, it can be consumed directly without any further refining treatment. Today its biological, nutritional and health effects are scientifically and professionally recognized worldwide (Boskou, 2006).

Virgin olive oil contains two main fractions: the oil or saponifiable fraction and unsaponifiable fraction. Saponifiable fraction are mainly triacylglycerols, diacylglycerols, monoacylglycerols, free fatty acids and phospholipids, and they represent nearly 98.5 %-99.5 % of the oil chemical composition. Unsaponifiable fraction consisting of hydrocarbons, tocopherols, coloring pigments, sterols, phenols, triterpenes and other compounds which contribute around 0.5 % to 1.5 % of the oil composition. The olive oil triacylglycerols is the most common monounsaturated fatty acids (oleic acid), together with small amounts of saturated and significant amounts of polyunsaturated fatty acids (mainly linoleic acid) (Aparicio et al., 2000). The quality and biological value of olive oil depends on the following factors: variety, soil management and agrotechnical procedures, climatic conditions, health of the fruit, degree of maturity, method of harvesting and transportation of fruits, handling of fruits during storage to processing period and processing method. Preserving the quality and biological value of olive oil depends on the time and conditions of storage of oil. Today, the parameters of quality and biological value of olive oil are: fatty acid composition, the ratio of polyunsaturated to saturated fatty acids, ratio of omega-6 and omega-3 fatty acids, the amount of total phenols, the ratio of total phenols and polyunsaturated fatty acids, sterol composition, free acidity, peroxide value and sensory evaluation. Extra virgin olive oil, beside a high content of oleic acid, contains polyunsaturated essential fatty acids, linoleic and linolenic. The essential ingredients of olive oil can be found in unsaponifiable part which consists of, up to now, about four hundred identified compounds. These compounds play an important role in many physiological and biochemical processes in the body. In addition to the positive impact on the health of consumers, significantly affect the sensory properties of the oil (flavor, aroma and color), and antioxidant activity due to increased resistance to oxidative deterioration of oil. Among these compounds are especially important antioxidants, particularly phenols, tocopherols, pigments, pro-vitamins and vitamins (Gugić, 2010).

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Fatty acids of virgin olive oil

Saturated fatty acids: lauric, myristic, palmitic, stearic, arachidic, behenic and lignoceric are present in olive oil. Unsaturated fatty acids are an important factor by which the olive oil is distinguished from other fats. The most common monounsaturated fatty acid in olive oil is oleic acid (18:1 n-9), and in the composition of the total fatty acids it is represented with 55-83 %. It has a great biological nutritional value and is easily digestible. That's why olive oil is a representative of the oleic acid oil group (Šarolić, 2014). In 2004 Agency for Food and Drug Administration in the United States (FDA) allowed the claim to be printed on the labels of virgin olive oil which stated "benefit of reducing the risk of heart disease and cardiovascular system while consuming about two tablespoons (23 g) of virgin olive oil daily, thanks to its high content of oleic acid " (Ghanbari et al., 2012). It is believed that oleic acid (C18:1), the most common fatty acid in olive oil increases the level of high density lipoprotein (HDL) and apoprotein A1 and reduces the level of low density lipoprotein (LDL) and apoprotein B (Ghanbari et al., 2012). Therefore, the oleic acid can prevent cardiovascular diseases which are the main cause of death today (Ranalli et al., 1996). Certain factors such as growing area, variety, altitude, climate and degree of ripeness of the fruit significantly affect the fatty acid composition of olive oil. Besides the oleic acid in olive oil there are other polyunsaturated fatty acids: palmitoleic acid (16:1, n-7), gadoleic acid (20:, n-11), which is represented in a very small quantity (up to 0.5 % of the total amount of fatty acids). The most important essential fatty acid in olive oil are linoleic (18:2, n-6), in an amount of 3.5 to 21 %, and linolenic acid (18:3, n-3) in an amount up to 0.9 % (Boskou, 2006). Polyunsaturated fatty acids (PUFA) with 18 carbon atoms known as essential fatty acids are linoleic acid (18:2, ω-6) in an amount of 3.5 to 21 % and α-linolenic (18:3, ω-3) in an amount up to 0.9 %. Since the body cannot synthesize it these should be taken in with food. These fatty acids are essential for life because they regulate membrane fluidity, permitting action of cell organelles, are included in the composition of lipoproteins that carry blood lipids, participate in biochemical processes and immunologic processes, reduce blood cholesterol levels by activating cell receptors for LDL and are precursors of long-chain polyunsaturated fatty acids such as gamma-linolenic or GLA (20:3 omega-6), arachidonic acid or AA (20:4 omega-6), EPA or eicosapentaenoic (20:5 omega-3) and docosahexaenoic or DHA (22:6 omega-3). The daily intake of EFAs should be about 6-8 % of the calories of the total ingested fats (Viola, 2009).

At the present time nutritionist recommendations for a balanced diet fit for a general input equal to 30 % of calories, following the distribution of fatty acids:

- saturated fatty acid, 6-8 %
- monounsaturated fatty acids, 12-16 %
- polyunsaturated fatty acids ω-6, 6-7 %
- polyunsaturated fatty acids ω-3, 0,5-1,5 %

Table 1. Group of fatty acids of olive oil compared to other edible oils and fats (Viola, 2009)

Type of oil/fat	saturated fatty acids (%)	monounsaturated fatty acids (%)	ω – 6 (%)	ω – 3 (%)
butter	45-55	35-55	1.5-2.5	0.5
seam	40-46	42-44	6-8	0.5-0.9
olive oil	8-14	65-83	6-15	0.2-1.5
peanut oil	17-21	40-70	13-28	-
corn oil	12-28	32-35	40-62	0.1-0.5
soybean oil	10-18	18-30	35-52	6.6-9
sunflower oil	5-13	21-35	56-66	-

The ratio of polyunsaturated and monounsaturated fatty acids

As already stated monounsaturated oleic acid (18:1, ω-9) predominates in the olive oil, while polyunsaturated fatty acids, especially linoleic and linolenic prevail, in the seed oils in varying concentrations. Discussing the importance of linoleic acid a few years ago, a classification of different seed oils which were considered better for the food since they had a higher concentration of linoleic acid was made, while olive oil was considered "neutral" to human health, because monounsaturated fatty acids weren`t given any special importance. Today's findings on this issue are quite different. It is considered enough to provide the necessary amounts of essential fatty acids, and reduce the intake of saturated fatty acids because of the risk for the cardiovascular system and the possible risk of tumors, and generally speaking that the main source

of energy intake should be from monounsaturated fatty acids. The balanced diet ratio of polyunsaturated : monounsaturated : saturated fatty acid is 1:2:1, the olive oil is about 0,5:5:1, while the value of the seed oils of about 5:2:1. From the above relations of fatty acid in olive oil, its stability and resistance against oxidation change are derived, taking into account that the degree of oxidation of linoleic acid to be ten times higher than oleic acid (Viola, 2003). It is considered that the good sensory characteristics of virgin olive oil are to be expected if the proportion of oleic acid in the oil is below 73 % and linoleic below 10 %, and when the ratio of oleic acid : linoleic acid is over seven (Koprivnjak et al., 1998).

The ratio of polyunsaturated and saturated fatty acids

Relatively high proportion of monounsaturated, a small proportion of saturated and a substantial proportion of essential fatty acids give olive oil a high nutritional value. Virgin olive oil, obtained exclusively by mechanical extraction methods from olive fruits are characterized by antioxidant activity as well as beneficial effects on human health due to the presence of highly valuable minor ingredients such as phenols (Covacs et al., 2006; Covacs et al., 2008, Tuck et al., 2002). Polyunsaturated fatty acids are recommended to reduce blood cholesterol levels and to prevent the development of atherosclerosis. Saturated fatty acids increase blood cholesterol levels and act as "promotors" of development of certain cancerous diseases. Since our initial recommendations, according to which it was necessary to maintain the ratio of P/S=2, ie for each gram of saturated, there should be two grams intake of polyunsaturated, the latest findings have shown that the best ratio of P/S=1, which means that for every gram of saturated it would be good to enter a gram of polyunsaturated fatty acids. This ratio is most favorable in olive oil (Viola, 2003).

The ratio of ω-6 and ω-3 fatty acids

Linoleic acid and alpha-linolenic acid, as has already been said, cannot be biosynthesized and must be therefore, already formed, taken with food. For this reason, they are defined as "essential fatty acids" or EFA (Essential Fatty Acids) and are compared to essential amino acids, vitamins and minerals. According to LARN - in (Livelli di Assunzione Raccomandati dei Nutrienti - Italian Society of Human Nutrition) total intake of polyunsaturated fatty acids in turn should not exceed 15 % of total calories and a desired ratio between the two series for adults is 10:1 and 5:1 for childrens and an old people. Having determined that it is necessary to enter a certain amount of EFA, it is very important, as noted above, to establish the most favorable possible ratio between the two series of polyunsaturated fatty acids, because, as we have seen, excessive amounts of linoleic acid can affect the elongation of alpha-linolenic which has negative effects on the body. The World Health Organisation has recommended ratio omega-6/omega-3 valued 5:1 to 10:1. This ratio is extremely important especially during growth and development, as polyunsaturated fatty acids of omega-3 series, except participating in the construction of the brain and retina, have an important function in male sex glands, helping the child`s development and preventive effect on the development of vasculopathy and various malignant disease (Viola, 2009). Since olive oil contains about 10 % of linoleic and less than 1 % of linolenic acid this ratio is completely satisfied with olive oil, which can not be said for the seed oil, especially for corn oil, where this ratio is 50:1, while in sunflower oil reaches 150:1. Good concentration of omega-3 fatty acids is found in soybean oil, but in this oil there is a significant imbalance in the ratio of antioxidants and polyunsaturated fatty acids with an increased risk of peroxidation (Viola, 2003).

Biological mechanisms of defense against free radicals

During normal oxidation of nutrients in producing energy (respiratory chain), a small portion of oxygen escapes the normal use and leads to the creation of free radicals, highly reactive and volatile compounds. Oxygen free radicals, if not neutralized, affect some macromolecules such as DNA (responsible for the genetic code), some specialized proteins and especially polyunsaturated fatty acids, which are an integral part of the phospholipids of cell membranes (disrupting their structure and function) and lipoproteins that carry cholesterol (altering their ability to deliver cholesterol to the cells that need it). The body defends itself against harmful effects of free radicals due to enzymatic and non-enzymatic antioxidant substances that are partly innate and partly to be brought in with food. This shows how important it is to increase the number of antioxidant substances, but given that we cannot influence the innate structure, we should increase our intake of antioxidants through food and at the same time try to reduce the causes which may favor the formation of free radicals. In case that there is imbalance between oxidant and antioxidant factors, an "oxidative stress" occurs, which is a condition that leads to changes in

cell function which can result in a complete disruption of cellular activities (Viola, 2009). Oxidative stress is considered one of the main factors that cause various diseases such as cancer, aging, inflammation, atherosclerosis, cardiovascular disease and certain neurodegenerative diseases such as Parkinson's disease (Jenner et al., 1996). Today it is widely accepted that the risk of oxidative damage may reduce the high intake of plant antioxidants. In this sense, olive oil phenols act as "scavengers" of oxygen free radicals (Ghanbari, 2012). It is clear, therefore, why it is so important to eat fresh fruits and vegetables as well as extra virgin olive oil. It is also clear that it would be better to avoid the intake of easily oxidizing substrate, ie, polyunsaturated fatty acids. The olive oil ratio of antioxidants and polyunsaturated fatty acids is more than satisfactory, while it can not be said for seed oil in which, as already mentioned, is dominated by gamma and delta tocopherols which organism practically does not use, while polyphenols are completely absent (Viola, 2003).

The first line of defense (present in the body)	Second Line of Defense (entered through food)
superoxide dismutase	β-carotene
catalase	nonvitamin carotenoids
glutathione peroxidase	α-tocopherol
uric acid	ascorbic acid
bilirubin	phenolic compounds
transferrin	selenium

The ratio of α-tocopherol and polyunsaturated fatty acids

Tocopherols have natural antioxidant activity and inhibit the process of oxidative deterioration of oil. Average tocopherol in olive oil is 150-330 mg/kg (Koprivnjak et al., 1998). It is believed that the recommended daily intake of tocopherol is the amount of 1 mg of α-tocopherol. However, the optimum amount depends on the composition of fatty acids in the oil. The maximum amount is represented by α-form (vitamin E), which has significant biological activity. Quantity of the predominat tocopherol α -tocopherol varies from a few mg up to 300 mg/kg. Significant concentrations of α-tocopherol in virgin olive oils support the ideal ratio of vitamin E/polyunsaturated fatty acids. This ratio is expressed as mg of vitamin E per g of polyunsaturated fatty acids. This ratio should not be less than 0.5, and it is rarely found in seed oils, but in virgin olive oils it is in the range of 1.5 to 2 (Viola, 2009). Together with α-tocopherol, β, γ, and δ forms are also found in olive oil. These forms of tocopherol are found in virgin olive oils in amounts from several to 25 mg/kg (Ghanbari et al., 2012). It is believed that the ratio of α-tocopherol/polyunsaturated fatty acid in the presence of other antioxidants is sufficient to satisfy the need for vitamin E, and the protection of the fatty acids oxidation (Covian 1988). Reduction of tocopherol in olive oil occurs during fruit ripening and the process of refining of oils.

Antioxidant and biologically valuable components of virgin olive oil

Virgin olive oil is considered an example of a natural functional food because of its active substances which contribute to prevention and treatment of various diseases (Bendini et al., 2007). Antioxidants are as their name says, substances that prevent or slow down the process of oxidation in the product and the body. According to these substances, virgin olive oil is significantly different from other vegetable oils. The most important antioxidants in virgin olive oils are phenolic compounds. As well as contributing to the health value of oil, they affect the sensory properties and increase the stability of the oil from oxidative deterioration. (Bendini et al., 2007). Many vegetable oils contain small amounts of tocopherols of natural phenolic antioxidant terpene origin. It is believed that the tocopherol (vitamin E) prevents free radicals oxidation of lipid membranes and thus slows down the aging process (Pine, 1996).
In addition to removing free radicals, tocopherols in virgin olive oil prevent photooxidation changes and so increase the oxidative stability of the oil during storage (Kamal-Eldin, et al, 1996). Tocopherols defend the body against free radical attacks, prevent atherosclerosis, skin diseases and prevent certain cancerous diseases. Tocopherols exhibit extremely synergistic effect in antioxidant activity with phenolic compounds (Hudson et al., 1983). Virgin olive oil is unique among all vegetable oils because of its high content of phenolic compounds. Their shares and composition could be the basis for assessing the quality of the oil, because phenols are the most important antioxidants that contribute significantly to the stability of the oil, and prevent many diseases (Tura et al., 2007). Purely mechanical method of processing fruits in oil contributes to the high proportion of phenolic compounds in virgin olive oil. In addition, phenol compounds have exceptional antioxidant, anti-

cancer and anti-inflammatory properties and are therefore important in the prevention of these diseases. Furthermore, it is important to highlight the impact of phenolic compounds on the sensory properties of virgin olive oil. Namely, the phenolic compounds are associated with the sensation of bitterness and pungency in oil (Bendini et al., 2007). Phenolic compounds, which are often referred in the literature as the polyphenols, in olive oil include a complex mixture of compounds of different chemical structure. The concentration and composition of phenolic compounds in virgin olive oil is determined by many factors, of which it is important to emphasize the variety, farming area, degree of ripeness of the fruit and the method of processing the fruit into oil (Lerma-García et al., 2009.). According to literature, the proportion of the phenolic compounds in olive oil is in the range of 40 to 1000 mg/kg (Serville, 2002.). The hydrophilic phenols of virgin olive oil belong to different substances classified into several groups: phenolic acids, phenyl-ethyl alcohols, hydroxy-isochromans, flavonoids, lignans and secoiridoids. Secoiridoids are specific to plants of the family *Oleaceae* and the principal component of the phenolic fraction. Many agro-technical and technological factors affect the proportion of phenols in virgin olive oil. The shelf life of this oil is considerably longer than other vegetable oils due to the presence of phenolic compounds that contain a catechol group such as hydroxytyrosol and derivatives secoiridoids.

Table 2. Biological activities and potential health benefits relating to olives/olive oil phenolics

Biological Activity	**Potential Clinical Target**
Antioxidant activity	Cardiovascular and degenerative diseases
Anti-inflammatory activity	Inhibition of proinflammatory enzymes
Antimicrobial activity	Infectious diseases
Anti-atherogenic activity	Coronary heart diseases, stroke
Anti tumor activity	Various cancers
Anti platelet aggregation	Coronary heart diseases, stroke
Anti-hypertensive activity	Hypertension
Increased vitamin A and β-carotene activity	Antiaging/skin protection
Increased immune activity	Infectious diseases; various cancers
Reduction in the levels of plasma cholesterol and oxidized LDL	Coronary heart diseases

Olive oil is the main source of fat in the Mediterranean diet, which is associated with a lower incidence of heart disease and circulatory system and some cancers. Extra virgin olive oil contains a considerable amount of phenolic compounds, for example, hydroxytyrosol and oleuropein, which are responsible for its distinct taste and high stability.

Conclusions

Virgin olive oil is an example of a natural functional food ingredients for which its activities contribute to prevention and treatment of various diseases. It contains a lot of antioxidants, it is dominated by monounsaturated fatty acids, low in saturated fatty acids, and contains essential fatty acids with a balanced ratio between a series of ω-6 and ω-3 fatty acids.

References

Aparicio, R., Aparicio-Ruíz, R. (2000): Authentication of vegetable oils by chromatographic techniques, *J. Chromatogr. A* 881, 93-104.

Bendini, A., Cerretani, L., Carrasco-Pancorbo, A., Gómez-Caravaca, A.M., Segura- Carretero, A., Fernández-Gutiérrez, A. (2007): Phenolic molecules in virgin olive oils: A survey of their sensory properties, health effects, antioxidant activity and analytical methods. An overview of the last decade, *Molecules* 12, 1679-1719.

Boskou, D. (2006): Olive Oil - Chemistry and Technology, Second Edition, AOCS Press, Champaign, Illinois.

Covas, M.I., Nyyssonen, K., Poulsen, H.E. (2006): The effect of polyphenols in olive oil on heart disease risk factors, *Ann. Int. Med.* 145, 333-431.

Covas, M.I. (2008): Bioactive effects of olive oil phenolic compounds in humans: Reduction of heart disease factors and oxidative damage, *Inflammopharmacology* 16, 216-218.

Covian, F.G. (1988): Scientific research on the biological value of olive oil, CIHEAM Options Méditerranéennes : Série Etudes V, 149- 152.

Gugić, M. (2010): Biološka vrijednost i kvaliteta ulja masline sorte Oblica u odnosu na područje uzgoja. Doktorski rad, Prehrambeno-tehnološki fakultet, Osijek.

Hudson, B., Lewis, J. (1983): Polyhydroxy flavonoid antioxidants for edible oils. Structural criteria for activity, *Food Chem.* 10, 47-55.

Jenner, P., Olanow, C.W. (1996): Oxidative stress and the pathogenesis of Parkinson's disease, *Neurology* 47, 161S-170S.

Kamal-Eldin, A., Appelqvist, A. (1996): The chemistry and antioxidant properties of tocopherols and tocotrienols, Lipids 31, 671-701.

Koprivnjak, O., Conte, L. (1998): Specific Components of Virgin Olive Oil as Active Participants in Oxidative Processes, *Food technology and biotechnology* 36 (3), 229-234.

Lerma-García, M.J., Lantano, C., Chiavaro, E., Cerretani L, Herrero-Martínez, J.M., Simó-Alfonso, E.F. (2009): Classification of extra virgin olive oils according to their geographical origin using phenolic compound profiles obtained by capillary electrochromatography, *Food Research International* 42, 1446-1452.

Pine, H.S. (1994): Organska kemija. Školska knjiga, Zagreb, 933.

Ranalli, A., Angerosa, F. (1996): Integral centrifuges for olive oil extraction - the qualitative characteristics of product, *Journal of the American Oil Chemists' Society* 73, 417-422.

Servili, M., Montedoro, G. (2002): Contribution of phenolic compounds of virgin olive oil quality, *Eur. J. Lipid Sci. Technol.* 104, 602- 613.

Šarolić, M. (2014): Karakterizacija ulja dalmatinskih sorti maslina. Doktorski rad, Prehrambeno-tehnološki fakultet, Osijek.

Tuck, K.L., Hayball, P.J. (2002): Major phenolic compounds in olive oil: Metabolism and health effects, *J. Nutr. Biochem.* 13, 636-644.

Tura, D., Gigliotti, C., Pedo, S., Failla, O., Bassi, D., Serraiocco, A. (2007): Influence of cultivar and site of cultivation on levels of lipophilic and hydrophilic antioxidants in virgin olive oils (Olea europea L) and correlations with oxidative stability, *Scientia Horticulturae* 112, 108-119.

Viola, P., Viola, M. (2009): Virgin olive oil as a fundamental nutritional component and skin protector, *Clin. Dermatol.* 27, 159-165.

Viola, P. (2003): Le nouve frontiere della qualita nutrizionale e salutistica degli oli vergini di oliva. Corso di aggiornamento L'estracione dell' olio d' oliva: aggiornamento sulle conoscenze biochimiche-tecnologicee e impiantistiche in relazione alla qalita dell' olio e allo smaltimento dei reflui. Accademia nazionale dell'olivo e dell'olio, Spoleto, 17-30.