proceedings

MDPI

Proceedings

Extra Virgin Olive Oil: Processing, Quality, Safety, Authenticity, Nutritional, Health and Oral Health Aspects †

Maria Antoniadou [1] and Theodoros Varzakas [2,*]

[1] National and Kapodistrian University of Athens, Dental School, City, Post code, Country; mantonia@dent.uoa.gr

[2] University of the Peloponnese, Dept. Food Science and Technology; City, Post code, Country t.varzakas@uop.gr

* Correspondence: t.varzakas@uop.gr; Tel.: +30-27-2104-5279

† Presented at the 1st International Electronic Conference on Food Science and Functional Foods, 10–25 November 2020; Available online: https://foods_2020.sciforum.net/

Submitted: date; Accepted: date; Published: date

Abstract: Olive is one of the most ancient fruit tree species that is cultivated in the Mediterranean Basin, with great socioeconomic impact for the countries present in the area. Olive production throughout the world uses more than 1275 cultivars and 4200 genotypes. Most cultivars have been identified in southern European countries, including 538 in Italy, 183 in Spain, 88 in France and 52 in Greece. However, Greece has more cultivars than those described in the National Catalogue of Agricultural Plant Varieties, the majority of which remain unexploited. Many studies have acknowledged olive oil as a healthy food with multiple benefits for the human body. The consumption of extra virgin olive oil is steadily increasing due to its unique sensory, nutritive qualities, biological properties and health promoting effects. In this review paper recent advances in quality, safety, authenticity, processing, nutrition and health of extra virgin olive oil (EVOO) have been discussed and outlined. Regarding safety different tools such as FMEA, and Ishikawa have been used along with food safety management systems. Finally, various health and oral health benefits were mentioned.

Keywords: extra virgin olive oil; processing; quality; safety; authenticity; nutrition; health; oral health

1. Introduction

Many studies have acknowledged olive oil as a healthy food with multiple utilities in, and benefits for the human body [1,2]. The consumption of extra virgin olive oil (EVOO) is steadily increasing due to its unique sensory, nutritive qualities, biological properties and health promoting effects. Greece is the third olive oil producing country in the world after Spain and Italy, with about 16% of the global annual production of which 80% being extra virgin. Hence, the superior quality of Greek olive oil, the significant diversity, the domestic diversification and its recognized nutritional value are tangible evidence of the importance that should be given for the promotion of Greek olive oil as a precious national product. However, the Greek market has been unable until now to properly and fully exploit it.

Geographically speaking, almost 70% of olive oil production in Greece is centered in two regions—Peloponnese (39%) and Crete (30%)—with the prefecture of Messinia being the dominant olivegrowing area of Peloponnese. Koroneiki cultivar (*Olea europeae* var. *Microcarpa alba*) is the

indigenous variety in Messinia—the name of which derives from Koroni, a small seaside village southeast of Messinia. The scope of this paper is to review key aspects of EVOO such as processing, quality, safety, authenticity, nutritional, health and oral health aspects.

2. Processing Aspects-Two-phase and 3-phase Olive Mills

In the 1970s and 1980s, olive processing by the continuous centrifugation system, called at threephases, spread over many countries of the Mediterranean area. This system is called at three-phases because the centrifugal decanter allows the separation of three flows of matter, as olive oil, pomace and vegetable waste water, and it needs lukewarm water added to dilute olive paste, as was shown in some papers [3–5]. This causes the reduction of natural antioxidants of oil, the production of moister pomace and a considerable volume of vegetable waste water (80–100 l/100 kg of olives. At the beginning of the 1990s, some olive oil plant manufacturers have launched new models of decanters in the market. These are able to separate the oily phase from the olive paste without requiring the addition of lukewarm water and without producing vegetable waste water.

These decanters have two exits producing oil and pomace, and hence are called at two-phases. They produce a very wet pomace, with a water content variable between 65 and 70% by weight [6,7].

3. Quality and Safety Aspects

3.1. Quality-Polyphenols and other Compounds

Some of the EVOO polyphenols are unique due to their presence in this food and for their sensory properties (possess a very distinctive bitter and pungent taste). Among them oleacein and oleocanthal, 2 secoiridoids that are naturally formed during the production of EVOO. These molecules are gaining attention for their anti-inflammatory properties along with the hydroxytyrosol found in urine after the consumption of EVOO [8]. Other interesting bioactive compounds are oleuropein, another polyphenol, and some triterpenes, such as squalene and oleanolic and maslinic acids. Ongoing feeding trials are evaluating the effects of functional olive oils (EVOO enriched with these compounds) to increase the antioxidant and anti-inflammatory effects of the original EVOO [9]. Part of the salutary health effects of olive oil are attributed to its content in oleic acid, which is found in all types of olive oil. However, the >200 minor components that include mainly phenolic compounds, but also tocopherols, phytosterols, carotenoids, luteolin, and triterpenic acids, which are enriched in EVOO play a significant role.

3.2. Safety Aspects—The HACCP and ISO22000 Approach

Hazard Analysis Critical Point Control (HACCP) is a structured approach to the identification, assessment of risk (likelihood of occurrence and severity), and control of hazards associated with a food production process or practice.

Design and implementation of a HACCP system involves the well-known seven basic principles or steps including hazard analysis, identification of the critical control points (CCPs) in food preparation, establishment of critical limits for preventive measures associated with each CCP, establishment of procedures to monitor CCP's, establishment of corrective action to be taken when monitoring shows that a critical limit has been exceeded, establishment of an effective record keeping system that documents the HACCP, and establishment of procedures to verify that the HACCP system is working. ISO 22000 specifies the requirements of a Food Safety Management System, encompassing all the range of food organizations involved in the food chain from farmers to catering businesses. ISO 22000 creates a uniform and homogeneous platform of requirements, acceptable to all authorities worldwide. The adoption of ISO 22000 was carried out in the year 2005 and a new version has been adopted in 2018.

Table 1 shows a table based on a tree diagram with questions for CCP and OPRP detection in extra virgin olive oil processing with examples of 2 processing steps according to Decision of EC 2016/C278/01.

Table 2S a. depicts a HACCP plan for filtration of olive oil (CCP 1, P) whereas Table 2S b. shows an OPrP plan for storage of packaged olive oil (supplementary material).

Figure S1 shows the flow diagram of extra virgin olive oil processing (supplementary material).

Table 1. Questions referring to tree diagram for CCP and OPRP detection in extra virgin olive oil processing with examples of 2 processing steps. (Decision of EC 2016/C278/01)

Processing step	Q1	Q2	Q3	Q4	
	Do preventative control measures exist? (Yes/No)	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level? (Yes/No)	Could contamination with identified hazard(s) occur or could this increase to unacceptable levels? (Yes/No)	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels? (Yes/No)	Is this step a critical control point? (Yes/No)
Receiving of olive fruits	Y	N	Y	N	OPRP
Filtration	Y	Y			CCP1 (P)

FMEA

In FMEA analysis, risk of contamination and its presence at Hazardous Fraction in the final product, is expressed with the Risk Priority Number (RPN) which is defined as follows:

$$RPN = S \times O \times D \quad (1)$$

where S: Severity of contamination risk, O: Occurrence of contaminated ingredient, D: Detection probability of contaminated ingredient.

where S: severity, O: occurrence, D: detection.

Corrective action is carried out when RPN is greater than 130.

The classification of hazardous elements occurs according to the RPN assessment as can be seen in Table 3 and corrective actions are proposed per identified hazard. Following calculation of the new RPN (the RPN′ after undertaking corrective actions), a new classification of Hazardous Elements is takes place. Here it was not necessary since RPN < 130.

Table 3. FMEA table of hazardous processing methods for extra virgin olive oil.

Defective Products Estimated Corrective Actions Result										
Production Step	**Hazards**	**Causes**	**S′**	**O′**	**D′**	**RPN**	**Corrective Actions**	**S'**	**O'**	**D'**	**RPN'**
Receiving of olive fruits Tr = <18 °C Environment matter.	Pathogens, chemical residues, foreign	Wrong handling	7	4	4	112	Not required	-	-	-	-

Cause and effect diagrams

Ishikawa diagram or fishbone diagram was invented by Dr. Kaoru Ishikawa, a Japanese quality control statistician [10]. The fishbone diagram or cause-and-effect diagram is an analysis tool that provides a systematic way of looking at effects and the causes that create or contribute to those effects. Due to its resemblance to fish skeleton it is often referred to as the fishbone diagram (**Figure 2**) (supplementary material).

4. Different Authenticity Methodologies for Detection of Adulteration

Olive oil is often illegally adulterated with other less expensive vegetable oils. Oils widely used for this purpose include olive pomace oil, corn oil, peanut oil, cottonseed oil, sunflower oil, soybean oil and poppy seed oil [11,12]. Among the various chemical and physical methods employed towards detection of adulteration of olive oil by low-grade olive oils and seed oils are:

a) Sterol analysis (presence of stigmasterol, β-sitosterol)
b) Alkane analysis (C_{27}, C_{29} and C_{31})
c) Wax and aliphatic alcohol analysis
d) Fatty acids/(with HPLC) *trans* fatty acid
e) Triacylglycerol

Classification of virgin olive oils according to its variety and/or geographical origin is of great importance for the producers, importers and consumers. Towards this target of olive oil classification, the most usually multivariate statistical procedures include cluster analysis, factor analysis, multidimensional scaling, discriminant analysis, correspondence analysis, canonical analysis and Procrustes analysis. Recently, artificial intelligence has also been applied for solving food characterization problems. Fuzzy logic (generalization of theory offsets widely known as membership functions), neural networks (computer programs learning from experience) and expert systems (empirical data in conjunction with independently built rules) [13]. Different analytical approaches have been employed for adulteration of olive oil.

One analytical approach consisted of capillary column gas chromatography-mass spectrometry (GC/MS) and the novel technique of compound-specific isotope analysis (CSIA) through gas chromatography coupled to a stable isotope ratio mass spectrometer (IRMS) via a combustion (C) interface (GC/C/IRMS). The $\delta^{13}C$ values of the virgin olive oil fatty acids varied between −26.5 and −35.5‰. The values for oil of different C3 source plants and distinct quality fall into this broad range. Olive oil is readily separated from the other oils (especially sunflower, walnut, and hazelnut) by principal component classification combining the fatty acid composition and the carbon isotope data of the bulk oil and the major fatty acids [14].

5. Health aspects

Scientific evidence from several sources has accumulated on the beneficial effects of the Mediterranean diet in preventing cardiovascular disease [15] and in reducing overall mortality [16]. The nutritional guidelines of several international scientific organizations now recommend a healthy diet compatible with the main characteristics of the "Mediterranean diet model" to prevent cardiovascular disease and other conditions related with oxidation processes [17].

The benefits of the Mediterranean diet have been attributed, in part, to the antioxidant effect of some of its components. It has been reported that polyphenolic compounds such as hydroxytyrosol (HT) and hydroxytyrosol acetate (HT-AC), have clear antioxidant effects [18]. *Direct Benefits from the consumption of EVOO*

Heart Disease and Stroke

Studies consistently link a diet high in monounsaturated fat with favorable effects on markers of cardiovascular disease (heart disease and stroke) [19]. This includes a reduction in markers of chronic inflammation, blood pressure, cholesterol levels and blood glucose levels.

Type II diabetes

Type 2 diabetes is characterised by the reduced effectiveness of insulin, the hormone that moves glucose (sugar) out of the blood and into cells to be used as energy. It's thought that the phenolic compounds present in EVOO aid in glucose metabolism and improve the sensitivity and effectiveness of insulin.

A large analysis found that including olive oil in the daily diet could reduce the risk of type 2 diabetes by 13%. In comparison to a low-fat diet, a diet high in olive oil was also found to help normalise blood glucose in people who already had type 2 diabetes [20].

Cancer

It is reported already that nutrition influences cancer risk. Observational studies have shown a lower incidence of some cancers in regions where olive oil consumption is high [21]. Phenols of EVOO are its most studied components with recognized antitumor properties. Phenolic compounds can be divided into three groups: simple phenols (i.e., tyrosol, hydroxytyrosol or 3,4dihydroxyphenylethanol), phenolic acids (i.e., caffeic acid), and flavonoids (i.e., quercetin).

Oral health

Olive oil can have a healing effect in xerostomia and general hyposalivation of the mouth which causes dental caries as a physical lubricant of the xerostomic cavity. Either by food consuming or by oil pulling olive oil can have a therapeutic effect in all oral soft and hard tissues either directly or indirectly.

Olive oil may indirectly contribute to the health of hard dental tissues too in cases of erosion or dental caries in the mouth of geriatric patients or younger ones with specific erosive habits or through the better absorption of vitamin E and C mentioned before and known for beneficial attributes in the oral cavity [22,23].

Olive oil offered protection against enamel and dentin erosion when applied as 2% emulsion or 2% olive-oil-containing mouthrinse, but is not effective when applied as pure oil (100%). However, 2% olive oil emulsion is less effective in reducing erosion compared to the acidic 13.2 $mol \cdot l^{-1}$ fluoride solution [24].

6. Conclusions

The consumption of extra virgin olive oil is steadily increasing due to its unique sensory, nutritive qualities, biological properties and health promoting effects.

We have described recent advances in quality, safety, authenticity, nutrition, health and oral health of extra virgin olive oil (EVOO). Food safety management systems need the incorporation of other management tools such as FMEA, and Ishikawa in order to prevent nutritional crisis and fraud.

Supplementary Materials: The following are available online at http://www.xxxxx, Figure S1: Flow diagram of EVOO processing, Table 2Sa, b: HACCP plan for filtration of olive oil (CCP 1, P), OPrP Plan for Storage of Packaged Olive Oil

Author Contributions: The authors contributed equally to this work.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Preddy, V.R.; Watson, R.R. Olives and Olive Oil in Health and Disease Prevention, 1st Edition; Academic Press: Oxford, UK, 2010; pp. 1103–1109.
2. Galaris, D.; Briasoulis, E.; Barbouti, E. Protective effects of olive oil components against hydrogen peroxide-induced DNA damage: The potential role of iron chelation. In *Olives and Olive Oil in Health and Disease Prevention;* Preedy, V.R., Watson, R.R., Eds, 1st ed.; Academic Press: Oxford, UK, 2010; pp. 1103−1109.
3. Martinez Suarez, J.M.; Munoz Aranda, E.; Alba Mendoza, J.; Lanzon Rey, A. Elaboracion del aceite de oliva por centrifugation en continuo. *Grasas y Aceites* **1974**, *25*, 148–159.
4. De Felice, M., Gomes, T.; Catalano, M. Estrazione dell'olio dalle olive con sistemi continui di centrifugazione delle paste. Risultati di ricerche triennali. *Rivista Italiana Sost. Grasse* **1979**, *56*, 361–369.
5. Di Giovacchino, L.; Mascolo, A.; Cucurachi, A.; Solinas, M.; Angerosa, F. Influence of extraction systems on some characteristics of olive oil quality. Chania, Greece. In Proceedings of 3th Intern. Congress on "Biological Value of Olive Oil", 8–12 September 1980, pp. 627–638.

6. Nergiz, C.; Unal, K. Effect of method of extraction on the total polyphenol, 1,2-diphenol content and stability of virgin olive oil. *J. Sci. Food Agri.* **1991**, *56*, 79–84.
7. Di Giovacchino, L.; Solinas, M.; Miccoli, M. Effect of extraction systems on the quality of virgin olive oil. *J. Am. Oil Chem. Soc.* **1994**, *71*, 1189–1194.
8. Romani, A, Ieri, F, Urciuoli, S., et al. Health effects of phenolic compounds found in extra-virgin olive oil, by-products, and leaf of Olea europaea L. *Nutr* **2019,** *11*, E1776.
9. Casas, R.; Estruch, R.; Sacanella, E. The protective effects of extra-virgin olive oil on immunemediated inflammatory response. *Endocr Metab Immune Disord Drug Targ.* **2018**, *18*, 23–35.
10. Ishikawa, K; *Guide to Quality Control, UNIPUB/Kraus International*, White Plains: New York, NY, USA; 1986.
11. Aparicio, R.; Calvente, J.J.; Morales, M.T. Sensory authentication of European extra-virgin olive oil varieties by mathematical procedures. *J. Sci. Food Agric.* **1996**, *72*, 435–447.
12. Kiritsakis, A.K. Flavor components of olive oil-A review. *JAOCS*, **1998,** *6,* 673–681.
13. Aparicio, A. and Christie, W.W. Analysis of edible Oils. In *Handbook of Olive Oil: Analysis and Properties*. J. Harwood, R. Aparicio. Eds.; Aspen Publishers Inc.: MD, USA, 2000; pp. 285–353.
14. Spangenberg, J.E.; Macko, S.A.; Hunziker, J. Characterization of Olive Oil by Carbon Isotope Analysis of Individual Fatty Acids: Implications for Authentication. *J. Agric. Food Chem.*, **1998**, *46*, 4179–4184.
15. Al-Ghamdi, S. The association between olive oil consumption and primary prevention of cardiovascular diseases. *J. Family Medic Primary Care*. **2018,** *5,* 859–864. doi: 10.4103/jfmpc.jfmpc_191_18.
16. Knoops, K.T.; de Groot, L.C.; Fidanza, F.; Alberti-Fidanza, A.; Kromhout, D.; van Staveren, W.A Comparison of three different dietary scores in relation to 10-year mortality in elderly European subjects: The HALE project. *European J Clin. Nutr.* **2006**, *60*, 746–755.
17. McCord, J.M.; Edeas, M.A. SOD, oxidative stress and human pathologies: A brief history and a future vision, *Biomedical Pharmacotherapy* **2005**, *59*, 139–142.
18. Gordon, M.H., Paiva-Martins, F.; Almeida, M. Antioxidant activity of hydroxytyrosol acetate compared with that of other olive oil polyphenols, *J. Agric Food Chem.* **2001**, *49*, 480–485.
19. https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds) (accessed on 30 June 2020).
20. Schwingshackl, L., Lampousi, A.-M.; Portillo, M. P.; Romaguera, D.; Hoffmann, G.; Boeing, H. Olive oil in the prevention and management of type 2 diabetes mellitus: A systematic review and metaanalysis of cohort studies and intervention trials. *Nutr. Diabet*. **2017**, *4,* e262. doi:10.1038/nutd.2017.12.
21. Grosso, G.; Bella, F.; Godos, J.; Sciacca, S.; Del Rio, D.; Ray, S.; Galvano, F.; Giovannucci, E.L. Possible role of diet in cancer: Systematic review and multiple meta-analyses of dietary patterns, lifestyle factors, and cancer risk. *Nutr. Rev*. **2017**, *75,* 405–419. doi:10.1093/nutrit/nux012.
22. Ionta, F.Q., Barros de Alencar, C.R.; Val, P.P.; Boteon, A.P.; Jordao, M.C.; Honorio, H.M.; Rabelo Buzalaf, M.A.; Rios, D. Effect of vegetable oils applied over acquired enamel pellicle on initial erosion. *J. Appl. Oral Sci.* **2017,** *4,* 420–426. doi:10.1590/1678-7757-2016-0436.
23. Antoniadou, M.; Varzakas, T. Breaking the vicious circle of diet, malnutrition and oral health for the independent elderly. *Critic. Rev. Food Sci. Nutri.* **2020.** doi:10.1080/10408398.2020.1793729.
24. Wiegand, A.; Gutsche, M.; Attin, T. Effect of Olive Oil and an Olive-Oil-Containing Fluoridated Mouthrinse on Enamel and Dentin Erosion in Vitro. *Acta Odontol Scand* **2007**, 6, 357–361, doi:10.1080/00016350701771843.