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Advances in Processing, Quality, Safety, Authenticity, Nutrition, Health, and Oral Health of Extra Virgin Olive Oil †

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Abstract: Olive fruit exerts great socioeconomic impact. Many studies have shown the multiple benefits of healthy olive oil for the human body. The increase in consumption of extra virgin olive oil is mainly 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, health, and oral health of extra virgin olive oil (EVOO) have been discussed and outlined. Regarding safety, the effect of food safety management systems in EVOO has been reported along with the use of different tools such as FMEA and Ishikawa.

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

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1. Introduction

Olive oil is has multiple benefits for the human organism according to many research studies [1,2]. The increase in the consumption of extra virgin olive oil (EVOO) can be attributed to its unique sensory, nutritive qualities, biological properties, and health-promoting effects. Across the globe, Greece ranks third in its production quantity of olive oil after Spain and Italy, producing about 16% of the global annual production, of which 80% is 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 seems to be unable to control the full exploitation of this protected origin product.

Geographically speaking, two regions in Greece Peloponnese (39%) and Crete (30%) account for almost 70% of olive oil production. The prefecture of Messinia is the dominant olive-growing area of Peloponnese with the Koroneiki cultivar (*Olea europeae* var. *Microcarpa alba*) representing the indigenous variety in the area. 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 Three-Phase Olive Mills

Olive processing is carried out in three phases through a technology adapted in the 1970s and 1980s in which a centrifugal decanter separates olive oil, pomace, and vegetable waste water, with the addition of lukewarm water [3–5]. This causes a reduction of the natural antioxidants of oil along with a high volume of vegetable waste water.

At the beginning of the 1990s, two-phase technology was introduced with a new models of decanters (having two exits producing oil and pomace) into the market. This did not require the addition of lukewarm water and did not produce waste [6,7].

3. Quality and Safety Aspects

3.1. Quality-Polyphenols and Other Compounds

Some of the EVOO polyphenols are unique due to their sensory properties possessing a very distinct bitter and pungent taste. Oleacein and oleocanthal, two secoiridoids that are naturally formed during the production of EVOO, are amongst them. These molecules, along with the hydroxytyrosol found in urine, possess anti-inflammatory properties after the consumption of EVOO [8]. Oleuropein, another polyphenol, and some triterpenes, such as squalene and oleanolic and maslinic acids, are other bioactive compounds. The antioxidant and anti-inflammatory effects of EVOO have been evaluated after the enrichment of EVOO with these bioactive compounds [9]. The enrichment of EVOO with phenolic compounds, tocopherols, phytosterols, carotenoids, luteolin, and triterpenic acids contribute to its high significance. Moreover, a key health role is attributed to oleic acid content.

3.2. Safety Aspects—The integration of HACCP into ISO22000:2018

Hazard analysis critical point control (HACCP) is associated with the analysis of critical control points and the identification of hazards and their control along with risk assessment (likelihood of occurrence and severity) within a food production process or practice.

The well-known seven basic principles of HACCP should include hazard analysis and assessment, identification of critical control points (CCPs) and their critical limits or operational prerequisite programs (oPrPs) and their measurable criteria. Of course if CCPs are detected corrective actions should be undertaken, but more specifically preventative actions should be carried out. All these data gathered need to be recorded and checked. The monitoring of CCPs is critical and this happens with quality control analysis. Finally, progress is maintained by validation and verification (internal audits that the HACCP system is working). ISO 22000 is a food safety management system and its umbrella comprises all players in the food chain, from farmers to supermarkets including equipment manufactures for foods or manufactures of packaging materials. A new version of ISO 22000 was adopted in 2018 replacing the older version from 2005. It is based on CCPs and oPrPs, as stated previously, but also incorporates Deming's PDCA circle in all paragraphs of ISO20000.

Table 1 shows a tree diagram with questions for CCP and oPrP detection in extra virgin olive oil processing with examples of two processing steps according to the decisions of EC 2016/C278/01.

Table S1 depicts a HACCP plan for the filtration of olive oil (CCP 1, P), whereas Table S2 shows an OPrP plan for the 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 the tree diagram for CCP and OPRP detection in extra virgin olive oil processing with examples of two 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 hazards to an acceptable level?	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?	Is this step a critical control point? (Yes/No)

		(Yes/No)		(Yes/No)	
Receiving of olive fruits	Y	N	Y	N	OPRP
Filtration	Y	Y			CCP1 (P)

3.2.1. FMEA

In failure mode and effect analysis (FMEA), the risk priority number (RPN) is defined as follows to determine the risk of contamination and its presence as related to hazards in the final product (EVOO):

$$RPN = S \times O \times D$$

where S = severity of contamination risk, O = occurrence of contaminated ingredient, and D = detection probability of contaminated ingredient.

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

According to the RPN assessment, the classification of hazards (physical, chemical, microbiological) occurs as shown Table 2 and corrective actions should be proposed if the RPN >130. Following the calculation of the new RPN (RPN′ after undertaking corrective actions), a new classification of hazards takes place. Here it was not necessary since the RPN is 112 which is less than 130.

Table 2. 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 environmental matter.	Pathogens, chemical residues	Wrong handling	7	4	4	112	Not required	-	-	-	-

3.2.2. Cause and Effect Diagrams/Ishikawa or fishbone diagrams

Ishikawa diagrams invented by Dr. Kaoru Ishikawa [10] are analysis tools providing a specific methodology to incorporate causes and effects (Figure S2) (Supplementary Material). Here, this involves four “Ms” (materials, methods, machinery, and men) and one “E” (environment).

4. Different Authenticity Methodologies for Detection of Adulteration

The adulteration of olive oil with other less expensive vegetable oils such as olive pomace oil, corn oil, peanut oil, cottonseed oil, sunflower oil, soybean oil, and poppy seed oil is of major concern nowadays [11,12]. Different physiochemical methods are involved in the detection of the adulteration of olive oil by seed oils, and these include: sterol analysis (presence of stigmasterol, β-sitosterol), alkane analysis (C_{27}, C_{29} and C_{31}), wax and aliphatic alcohol analysis, and the detection of fatty acids, trans-fatty acids, and triacylglycerols with HPLC.

Producers, importers, and consumers need to be aware of the classification of virgin olive oils according to their variety and/or geographical origin because only in this context can they be certain of the non-adulteration of this product. In this direction multivariate statistical procedures can be employed including cluster analysis, factor analysis, multidimensional scaling, and others. Artificial intelligence has also been applied lately along with neural networks and expert systems [13].

Different analytical approaches have also been employed for detecting the adulteration of olive oil including capillary column gas chromatography-mass spectrometry (GC/MS), compound-specific isotope analysis (CSIA), and isotope ratio mass spectrometry (IRMS). Finally, principal component analysis and classification can be used for the differentiation of olive oil from other plant oils [14].

5. Health Aspects

It is well known that the Mediterranean diet is beneficial, helping to prevent cardiovascular disease [15] and aiding in the reduction of overall mortality [16]. In order to prevent cardiovascular disease and other conditions we need to adhere to the "Mediterranean diet model" (incorporating extra virgin olive oil) [17]. The benefits of the Mediterranean diet have been attributed, in part, to the antioxidant nature of polyphenolic compounds such as hydroxytyrosol (HT) and hydroxytyrosol acetate (HT-AC) [18].

5.1. Heart Disease and Stroke

Heart disease and stroke can be reduced if a diet high in monounsaturated fat (olive oil) is followed [19]. Blood pressure, cholesterol levels, and blood glucose can be diminished if this diet is followed.

5.2. Type II Diabetes

A large analysis has shown that the incorporation of olive oil in the diet might reduce the risk of type 2 diabetes by 13%. This has to do with the phenolic antioxidant compounds in EVOO which improve the effectiveness of insulin (reduced in patients suffering with type II diabetes). Moreover, blood glucose levels in patients suffering with type 2 diabetes may go back to normal if they follow a diet enriched in olive oil [20].

5.3. Cancer

It has been already reported that nutrition affects cancer risk. Observational studies have shown that high olive oil consumption could lead to a lower incidence of some cancers [21]. Phenols (tyrosol, hydroxytyrosol, or 3,4-dihydroxyphenylethanol), phenolic acids (caffeic acid), and flavonoids (quercetin) of EVOO possess recognized antitumor properties.

5.4. 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 consumption through food 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 its beneficial attributes in the oral cavity [22,23].

Olive oil offers protection against enamel and dentin erosion when applied as a 2% emulsion or 2% olive-oil-containing mouth rinse, but its effects are not protective when applied as pure olive oil (100%). However, the acidic 13.2 mol·L^{-1} fluoride solution is more effective than the 2% olive oil emulsion [24].

6. Conclusions

Extra virgin olive oil is gaining much attention because of its sensory, nutritive qualities, and health-promoting effects.

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

Supplementary Materials: The following are available online at https://www.mdpi.com/2504-3900/70/1/107/s1, Figure S1: Flow diagram of EVOO processing, Figure S2: Ishikawa diagram, Table S1: HACCP plan for the filtration of olive oil (CCP 1, P), Table S2: OPrP Plan for the storage of packaged olive oil.

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