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Editorial

Innovations and New Processes in the Olive Oil Industry

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The olive oil industry, one of the largest industries in the Mediterranean basin and in other countries around the world, is fundamentally composed of olive groves, olive oil mills, pomace oil extraction plants, and oil refineries. Additionally, there are other types of closely related industries, such as those producing table olives and margarine and the industries based on physicochemical transformation to obtain high value-added products for the pharmaceutical, cosmetic, nutritional, and dietary sectors [1].

Innovative processes and new technologies have been implemented in olive oil mills, oil refineries, and transformation industries in the last decade to improve the olive oil extraction and its quality, as well as to minimise and valorise the generated wastes. In this sense, biofuels (bioethanol, biodiesel, biogas, synthetic gas . . .) and high value-added products (tyrosol, hydroxytyrosol, squalene, oleuropein, tocopherols and others) can be obtained from byproducts and residues from the olive oil and pomace oil extraction processes.

This Special Issue "Innovations and New Processes in the Olive Oil Industry" brings together high-quality research studies addressing challenges faced in the olive oil industry and related industries, along with comprehensive overviews and in-depth technical research papers addressing recent progress in olive oils and table olives production and the management of the different olive oil industry wastes.

With regard to the management of olive oil mill wastes, Kurtz et al. studied the benefits and drawbacks of applying olive mill wastewater (vegetation water, tissues of olive fruits, and process water used in different stages of the olive oil extraction) in irrigated olive orchards [2]. Used in semi-arid areas with sandy loam soils, olive mill wastewater brings some benefits to soils (accumulation of K+, Ca^{2+}, PO_4^{3-}, organic carbon and increased biological activity and diversity). Notwithstanding, it has also negative effects (accumulation of phenolic compounds, increased soil hydrophobicity, and salinity). Most of these effects depend on the dose of wastewater applied, mainly in the topsoil.

In relation to olive oil quality, the control of temperature and time during olive oil production is of major importance since olive oil quality is strongly dependent on it [3]. In this sense, Plasquy et al. discuss the advantages of the cold storage of olive fruit before the olive oil extraction process [4]. Cold storage is not just a method to prolong the quality of the harvested olives, but it is also a temperature management procedure. These authors highlight the most important factors during cold storage and their influence on both fruit and oil produced. The same authors also studied the adjustment of the temperature of the intact fruit of three different olive varieties ('Arbequina', 'Cobrançosa' and 'Gordal') before grinding at both the laboratory level and a pilot plant [5]. In their work, Plasquy et al. demonstrated the feasibility of bringing the fruit to the ideal temperature for malaxing without applying excessive heat and within a period according to the characteristics of an industrial washing equipment.

During the malaxation stage, certain olive varieties, such as 'Hojiblanca' and 'Picual', give rise to pastes from which it is difficult to separate the oil, leading to low extraction yields. To improve oil extraction in these pastes, one alternative is the addition of natural

Citation: Sánchez Villasclaras, S.; García Martín, J.F. Innovations and New Processes in the Olive Oil Industry. *Processes* **2024**, *12*, 1570. https://doi.org/10.3390/pr12081570

Received: 19 July 2024
Accepted: 23 July 2024
Published: 26 July 2024

microtalcs. In their work, Sánchez et al. added a natural microtalc of great purity ($CaCO_3$ concentration less than 6 wt.%) and small average particle size ($\phi \leq 2.1$ μm) in the malaxation stage during the production of virgin olive oils from the two aforementioned olive varieties on an industrial scale at two olive mills [6]. The high-purity natural microtalc not only increased the extraction yields but also improved the virgin olive oil quality, especially in relation to antioxidant compounds. To be specific, Sánchez et al. found increases of 10.4% in phenolic compounds and of 21.5% in the tocopherols when adding the natural microtalc into the malaxer, which enhance the oxidative stability of the virgin olive oils. In relation to the increases in industrial yield in the extraction process, these results agree with those obtained by Caponio et al. [7,8].

Another alternative to improve the malaxation stage is the use of a sono-heat-exchanger. Clodoveo et al. presents it as a suitable solution to respond to the needs mapped in the community of millers because the sono-heat-exchanger is a continuous system and a potential substitute for the current malaxers [9]. It is based on ultrasonic waves, which induce cavitation (the phenomenon responsible for the mechanical action of ultrasound) and penetrate the entire thickness of the olive paste, all without representing a decrease in or elimination of the minor components in the olive oils. This ultrasonic device aims at favouring the extraction yield and increasing virgin olive oil quality by enhancing its content of phenolic compounds without causing undesired sensorial defects, thus effectively eliminating the bottleneck represented by the traditional malaxer. This conclusion was also obtained and supported by other research groups [10,11].

With regard to the olive oil itself, there is a current demand for innovative and specialised products of high nutritional quality and with various sensory characteristics, such as flavoured oils (which correct technical name is food seasoning). Following this, Chéu-Guedes et al. flavoured extra virgin olive oils of the 'Madural' variety from Trasos Montes region of Portugal with different aromatics herbs and condiments (flower of salt and bay leaf, garlic, rosemary, and dehydrated lemon peel), with the aim of studying the influence of these aromatic herbs and condiments on the physicochemical parameters of the oils [12]. The authors concluded that the flavourings did not affect the fatty acid profile of the extra virgin olive oils, while the impact on quality, purity, oxidative stability and microbiological spoilage was complex. In this work, it is worth highlighting the excellent study carried out on the composition profile of the fractions of phenolic compounds, tocopherols and sterols in flavoured olive oils. Concerning total phenolic compounds, an increase can be observed with respect to the monovarietal oil, perhaps due to the contribution of the phenolic compounds present in the composition of bay leaves, rosemary and garlic. These results agree with what different research groups indicated for garlic and rosemary [13,14].

Studies of advanced techniques and methods for high value-added product and bioenergy production within the olive oil industry are also included in this Special Issue. With regard to the former, Lozano et al. studied the use of the pomace obtained with two-outlet decanters within a biorefinery scheme to produce value-added products along with solids that can be used for energy or adsorbent production [15]. The aim was to develop a novel, efficient and environmentally friendly extraction process based on a combination of hydrothermal treatments with liquid/liquid extractions. Under mild extraction conditions (30 °C and 30 min), significant amounts of bioactive polyols (1126 mg/L inositol), saccharides (15,960 mg/L D-glucose, 385 mg/L D-xylose, 5550 mg/L D-fructose, 165 mg/L lactose, and 248 mg/L sucrose) and phenolic compounds (4792 mg/L) were extracted. Furthermore, Fainassi et al. studied the surface-active and emulsifying properties of various aqueous ethanolic extracts from the pomace obtained in the process with a two-outlet decanter [16]. The objective was to produce stable oil-in-water emulsions with smaller droplet sizes and for an extended period of storage using these extracts as sole emulsifiers.

Concerning bioenergy production, Cubero-Cardoso et al. [17] and Fernández-Rodríguez et al. [18] studied the production of methane from olive mill byproducts by anaerobic digestion. Cubero Cardoso et al. broaden the knowledge behind the processes of anaerobic degradation of olive oil solid waste under mesophyll conditions operating in a semicontinuous regime. These authors assess the instability of the degradation of this complex biomass and determine the relationship between the decrease in methane production and the microbial population present in the waste [17]. On the other hand, Fernández-Rodríguez et al. study the anaerobic digestion bioprocess of the waste generated in the extraction process for cold-pressed olive (a mixture of wastewater and solid waste). In order to assess the potential influence of the ripening level of the olives on the performance of the anaerobic digestion of the produced waste, the authors collected olives of the 'Picual' variety at two stages; i.e., green olives and olives in veraison. The highest methane yield and energy output result were detected in the waste from cold-pressed green olives [18]. On the other hand, this work concludes that the use of microwaves as pretreatment improved the solubilisation of organic compounds and the hydrolysis of proteins to NH^{4+}-N, and also increased the methane yield and the maximum methane production rate during the co-digestion process, a result consistent with what can be found in the available literature for other wastes [19].

Finally, in relation to closely related industries, Demir et al. assess the effect of growing regions and processing methods on the phenolic compound profile in table olives of the 'Gemlik' variety (very extended in Türkiye), concluding that both regions and processing methods have statistical significant effects on the phenolic composition of table olives [20], which is in agreement with the results of Pistarino et al., who also considered the olive-growing region as a key factor [21]. In this study, six regions of Türkiye were considered. The main phenolic compounds found were 3-hydroxytyrosol (from 4.58 to 168.21 mg/kg), 4-hydroxyphenyl (from 0.76 to 97.58 mg/kg), luteolin 7-glucoside (from 0.32 to 58.64 mg/kg), tyrosol (from 1.57 to 47.24 mg/kg) and luteolin (from 0.17 to 53.56 mg/kg). The results in hydroxytyrosol and tyrosol are quite similar to those obtained by Malheiro et al. [22].

Funding: This research received no external funding.

Acknowledgments: The Guest Editors are grateful to all the authors that have contributed to this Special Issue, all the reviewers for their excellent work in evaluating the submitted manuscripts and the editorial staff of *Processes*.

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

References

1. *IOC/T.15/NC No 3/Rev.17/2021*; Trade Standard Applying to Olive Oils and Olive Pomace Oils. International Olive Council: Madrid, Spain, 2021; pp. 1–17.
2. Kurtz, M.P.; Dag, A.; Zipori, I.; Laor, Y.; Buchmann, C.; Saadi, I.; Medina, S.; Raviv, M.; Zchori-Fein, E.; Schaumann, G.E.; et al. Toward balancing the pros and cons of spreading olive mill wastewater in irrigated olive orchards. *Processes* **2021**, *9*, 780. [CrossRef]
3. García, J.M.; Streif, J. The effect of controlled atmosphere storage on fruit and oil quality of 'Gordal' olives. *Gartenbauwissenschaft* **1991**, *56*, 233–238.
4. Plasquy, E.; García Martos, J.M.; Florido, M.d.C.; Sola-Guirado, R.R.; García Martín, J.F. Cold storage and temperature management of olive fruit: The impact on fruit physiology and olive oil quality—A review. *Processes* **2021**, *9*, 1543. [CrossRef]
5. Plasquy, E.; García Martos, J.M.; Florido Fernández, M.D.C.; Sola-Guirado, R.R.; García Martín, J.F. Adjustment of olive fruit temperature before grinding for olive oil extraction. Experimental study and pilot plant trials. *Processes* **2021**, *9*, 586. [CrossRef]
6. Sánchez, S.; Olivares, I.; Puentes, J.G.; Órpez, R.; La Rubia, M.D.; Pacheco, R.; García Martín, J.F. Use of natural microtalcs during the virgin olive oil production process to increase its content in antioxidant compounds. *Processes* **2022**, *10*, 950. [CrossRef]
7. Caponio, F.; Squeo, G.; Difonzo, G.; Pasqualone, A.; Summo, C.; Paradiso, V.M. Has the use of talc an effect on yield and extra virgin olive oil quality? *J. Sci. Food Agric.* **2016**, *96*, 3292–3299. [CrossRef] [PubMed]
8. Caponio, F.; Monteleone, J.I.; Martellini, G.; Summo, C.; Paradiso, V.M.; Pasqualone, A. Effect of talc addition on the extraction yield and quality of extra virgin olive oils from 'Coratina' cultivar after production and during storage. *J. Oleo Sci.* **2014**, *63*, 1125–1132. [CrossRef] [PubMed]
9. Clodoveo, M.L.; Crupi, P.; Corbo, F. Olive sound: A sustainable radical innovation. *Processes* **2021**, *9*, 1579. [CrossRef]
10. Jiménez, A.; Beltrán, G.; Uceda, M. High-power ultrasound in olive paste pretreatment. Effect on process yield and virgin olive oil characteristics. *Ultrason. Sonochem.* **2007**, *14*, 725–731. [CrossRef]
11. Bejaoui, M.A.; Beltran, G.; Aguilera, M.P.; Jimenez, A. Continuous conditioning of olive paste by high power ultrasounds: Response surface methodology to predict temperature and its effect on oil yield and virgin olive oil characteristics. *LWT Food Sci. Technol.* **2016**, *69*, 175–184. [CrossRef]

12. Chéu-Guedes, M.H.; La Rubia, M.D.; Sánchez, S.; Ramos, N.; Pacheco, R. Characterization of flavoured olive oils of 'Madural' variety. *Processes* **2023**, *11*, 205. [CrossRef]
13. Gambacorta, G.; Faccia, M.; Pati, S.; Lamacchia, C.; Baiano, A.; La Notte, E. Changes in the chemical and sensorial profile of extra virgin olive oils flavored with herbs and spices during storage. *J. Food Lipids* **2007**, *14*, 202–215. [CrossRef]
14. Soares, V.P.; Fagundes, M.B.; Guerra, D.R.; Leães, Y.S.V.; Speroni, C.S.; Robalo, S.S.; Emanuelli, T.; Cichoski, A.J.; Wagner, R.; Barin, J.S.; et al. Ultrasound assisted maceration for improving the aromatization of extra-virgin olive oil with rosemary and basil. *Food Res. Int.* **2020**, *135*, 109305. [CrossRef] [PubMed]
15. Lozano, E.J.; Blázquez, G.; Calero, M.; Martín-Lara, M.Á.; Pérez-Huertas, S.; Pérez, A. Optimizing the extraction process of value-added products from olive cake using neuro-fuzzy models. *Processes* **2024**, *12*, 317. [CrossRef]
16. Fainassi, F.; Taarji, N.; Benkhalti, F.; Hafidi, A.; Neves, M.A.; Isoda, H.; Nakajima, M. Emulsion formation and stabilizing properties of olive oil cake crude extracts. *Processes* **2021**, *9*, 633. [CrossRef]
17. Cubero-Cardoso, J.; Fernández-Prior, Á.; Ramiro-Garcia, J.; Trujillo-Reyes, A.; Caballero-Guerrero, B.; Rodríguez-Gutiérrez, G.; Fermoso, F.G. Microbial population dynamics during unstable operation of a semicontinuous anaerobic digester fed with a mild-treated olive mill solid waste. *Processes* **2023**, *11*, 2724. [CrossRef]
18. Fernández-Rodríguez, M.J.; Cubero-Cardoso, J.; de la Lama-Calvente, D.; Fernández-Prior, Á.; Rodríguez-Gutiérrez, G.; Borja, R. Anaerobic digestion of the residue (combination of wastewater and solid waste) from a new olive-oil manufacturing process based on an olive cold-pressing system: Kinetic approach and process performance. *Processes* **2022**, *10*, 2552. [CrossRef]
19. Liu, J.; Zhao, M.; Lv, C.; Yue, P. The effect of microwave pretreatment on anaerobic co-digestion of sludge and food waste: Performance, kinetics and energy recovery. *Environ. Res.* **2020**, *189*, 109856. [CrossRef]
20. Demir, C.; Yildiz, E.; Gurbuz, O. Profile phenolic compounds in Spanish-style and traditional brine black olives ('Gemlik' cv.) provided from different regions of Türkiye. *Processes* **2023**, *11*, 2412. [CrossRef]
21. Pistarino, E.; Aliakbarian, B.; Casazza, A.A.; Paini, M.; Cosulich, M.E.; Perego, P. Combined effect of starter culture and temperature on phenolic compounds during fermentation of 'Taggiasca' black olives. *Food Chem.* **2013**, *138*, 2043–2049. [CrossRef]
22. Malheiro, R.; Sousa, A.; Casal, S.; Bento, A.; Pereira, J.A. Cultivar effect on the phenolic composition and antioxidant potential of stoned table olives. *Food Chem. Toxicol.* **2011**, *49*, 450–457. [CrossRef] [PubMed]