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Editorial

Special Issue on "Phenolic Compounds: Extraction, Optimization, Identification and Applications in Food Industry"

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Interest has grown regarding natural plant extracts in food and beverage applications, their vital role in food quality and technology, and their therapeutic use in inhibiting several diseases. The protective properties of healthy diets rich in fruits, vegetables, and whole grains are due not only to fiber, vitamins, and minerals, but also to a variety of plant secondary metabolites, particularly phenolic compounds, which are considered among the most important classes originating in plant-derived secondary metabolites. Phenolic compounds or phenolics are well-renowned for their possession of a wide array of remarkable biochemical and pharmacological properties, namely, antioxidant, antiviral, anticancer, and anti-inflammatory activities, etc. Therefore, these compounds can be functional in the prevention of many diseases and in health maintenance, in addition to phenolic-varied applications in the food, nutraceutical, and pharmaceutical industries, and due to their importance in the pharma- and nutraceutical arenas. This Special Issue (SI) aims to gather the most recent contributions concerning their chemistry, extraction methods, and analytical techniques, along with their biological activities. The interpretation of phenolic bioactivities on a molecular basis by means of both well-established and advanced bio-analytical techniques is also covered in this SI.

This Special Issue of *Processes*, entitled "Phenolic Compounds: Extraction, Optimization, Identification and Applications in Food Industry" (https://www.mdpi.com/journal/processes/special_issues/Phenolic_Compounds_Industry, accessed on 23 December 2021), gathers the recent work of leading researchers in a single collection, and the content covers a variety of theoretical studies and experimental applications, focusing on the phenolic compounds extraction, identification, and applications in industry. We think that the advances described by the contributors in this SI have significantly helped accomplish this target. Aside from the research articles, the Special Issue features two reviews, covering a range of topics, which highlight the versatility of the area.

The topics covered in this SI include: advanced analytical methodologies for the isolation, purification, and analysis of phenolics from food, food wastes, and medicinal plants; phenolic compounds and metabolites in plants, food, and biological samples; biological activities and mechanisms of action; health benefits, in vivo evaluation; development of novel antioxidants and phenolics-based nutraceuticals and functional ingredients.

For instance, Campos et al., [1] discuss the drying impact on the phenolic composition of pollens of *Eucalyptus globulus* and *Salix atrocinerea* plant models by using infrared irradiation technology. This technique is used to determine the moisture content in pollens. Moreover, the influence of the IR radiation over the phenolic and flavonoid profiles has also been examined by HPLC/DAD profiling and radical scavenging ability by the DPPH assay. The IR-based method shows good reproducibility and, furthermore, it reduces drying time and energy consumption, thus having a low environmental impact, and it is suitable for

Citation: Abu-Reidah, I.M.; Taamalli, A. Special Issue on "Phenolic Compounds: Extraction, Optimization, Identification and Applications in Food Industry". *Processes* **2022**, *10*, 128. https://doi.org/10.3390/pr10010128

Received: 23 December 2021
Accepted: 24 December 2021
Published: 9 January 2022

industrial scaling-up once no more degradation is found to occur during the radiation process.

Potter and Jones [2] studied the (poly)phenolic profiles of green waste determined by UPLC-HDMSE separation and detection techniques to identify the main phenolics present in four contrasting green waste feedstocks, viz. *Smyrnium olusatrum*, *Ulex europaeus*, *Allium ursinum*, and *Urtica dioica*. In this work, over 70 phenolic compounds with reported benefits to human health were identified, where *U. europaeus* was the most abundant in these compounds. Important components identified include among others procyanidins, naringenin, (−)-epigallocatechin, eriodictyol, naringenin, eriodictyol, iso-liquiritigenin and eriodictyol, plus several phytoestrogens, which highlights the importance of food waste through the formation of nutritional supplements.

Vukojaet al. [3] formulated raspberry juice phenolics and freeze-dried cellulose/ raspberry encapsulates by using cellulose as carrier and studied the influence of cellulose amount and time on the complexation of cellulose and raspberry juice. An increase in the amount of cellulose during formulation resulted in the decrease in the content of total phenolics and anthocyanins. Encapsulates with 2.5% of cellulose had the highest and those with 10% of cellulose the lowest capability for inhibition of α-amylase. They concluded that cellulose in low proportions could be used as a good encapsulation material for delivering bioactives as well as for the formulation of encapsulates.

Ivić et al. [4] studied the influence of processing parameters on phenolics and color of red wine concentrates attained by reverse osmosis and nanofiltration under different pressures and membrane conditions, in order to obtain highly enriched concentrates of phenolics. It was shown that the higher the pressure applied, the greater was the drop in retentates' temperature, as a favorable technique for higher phenolics retention. Several factors can affect the retention of individual compounds such as the operating conditions, membrane properties, chemical structure, and membrane fouling. Out of the two membrane types used, the highest concentrations of phenolics were detected in retentates obtained at around 50 bars, involving a cooling process.

The work of Wang et al. [5] involved the evaluation of phenolic compounds from potato peels and by-products by using direct ultrasound-assisted extraction system. In their study, they estimated the efficiency of various ultrasound-assisted extraction techniques, namely, direct ultrasound-assisted extraction (DUAE), indirect ultrasound-assisted extraction (IUAE), and conventional shaking extraction (CSE) in recovering antioxidants from potato peels. It was found that DUAE was more effective in extracting phenolic compounds than IUAE and CSE. Temperature, time, acoustic power, ratio of solvent to solids, and size of PPs particles were found to affect the yield of total phenolic compounds (TPC) in DUAE. DUAE was found with a higher yield TP comparable to commercial synthetic antioxidants, and the extraction rate was faster than IUAE and CSE. Furthermore, TPC yield was strongly correlated to the temperature of the mixture of the potato peels suspension. The study concluded that DUAE has the potential to transform potato peels from agricultural waste to functional ingredients.

In the work of Pușcaș et al. [6], phenolics dynamics and infrared fingerprints during the storage of pumpkin seed oil, and oleogel thereof, have been established. The work aimed to assess individual phenolics' dynamics and infrared fingerprints during the ambient storage of pumpkin seed oil, and oleogel thereof. Several phenolics including isolariciresinol, vanillin, caffeic and syringic acids were quantified. The main changes were determined for isolariciresinol, which decreased in liquid pumpkin seed oil samples from 0.77 to 0.13 mg/100 g, whereas for oleogel samples, it decreased from 0.64 to 0.12 mg/100 g. However, during the storage at room temperature, it was concluded that the oleogelation technique might display potential protection of specific phenolic compounds such as syringic acid and vanillin after 8 months of storage. For isolariciresinol, higher amounts are registered in the oleogel than in the oil after 5 months of ambient temperature storage, which may be due oxidation processes occurred after 5 months storage for both oil and oleogel samples.

Profiling of polyphenolics of several agro-forestry by-products by using UPLC-HDMSE was reported by Potter and Jones [7]. They used UPLC-HDMSE tool to profile ethanol extracts of three common tree barks (*Pinus contorta, Pinus sylvestris, Quercus robur*). About 35 high scoring components with reported significance to health were tentatively characterized across the three bark extracts. Scots Pine showed generally higher compound abundances than the other two extracts. Although Oak bark extract had the lowest abundances, it exhibited higher amounts of naringenin and 3-O-methylrosmarinic acid. The study concluded that forestry bark waste can provide a rich source of extractable polyphenols suitable for use in food supplements.

In their study, Banica et al. [8] used a newly sensitive invented glassy carbon sensitive electrodes with carbon nanotubes to assess the total polyphenols content and antioxidant activity of *Echinacea purpurea* extracts. In this investigation, three glassy carbon electrodes (GCE) were used; three different pharmaceutical forms (capsules, tablets, and tincture) were assessed, which contain aerial or root parts of *E. pururea* extracts. The modified [1 mg/mL CNTs/CS 5%/GCE] electrode has superior properties compared with the other two (the unmodified and (20 mg/mL CNTs/CS 0.5%/GCE-modified)) electrodes used in the study. Echinacea tincture had the highest antioxidant capacity and total amount of polyphenols, whereas capsules and tablets had the lowest antioxidant capacity and the lowest total amount of polyphenols. Pulse-differential cyclic voltammetry represents a rapid, simple, and sensitive technique to establish the entire polyphenolic amount and the antioxidant activity of the *E. purpurea* extracts.

The storage stability of microencapsulated extract of *Moringa oleifera* was studied by Castro-López et al. [9], by assessing its in vitro-simulated digestion and cytotoxicity assessment. The extract was processed by spray-drying technique using tragacanth gum (MorTG) to improve its stability. The results of the study showed that TPC was as follows—oral (9.7%), gastric (35.2%), and intestinal (57.6%). The in vitro antioxidant activity in digestion was 300% higher than the initial value. Moreover, microencapsulated moringa extract presented a half-life up to 45 days of storage, where the noticeable change was observed at 35 °C and 52.9% relative humidity. Caco-2 cells' viability demonstrated non-cytotoxicity, which supports the safety of the proposed formulation and potential use within the food field.

A preliminary testing of ultrasound/microwave-assisted extraction (u/m-ae) for the isolation of geraniin from *Nephelium lappaceum* l. peel was reported by Hernández-Hernández et al. [10]. Five extractions were performed using different (mass/volume) and ethanol/water ratios. Condition 1:16-0 was defined as the best extraction condition (only water). The major compound isolated in the two separations was geraniin, according to HPLC/ESI/MS analysis.

Jebabli et al. [11] designed an industrial-scale study of the chemical composition of olive oil process-derived matrices to investigate the effect of the industrial process and collecting period on produced olive oil and by-products was evaluated. The obtained results showed significant variations for most quality indices before and after vertical centrifugation between all samples from the three collecting periods. All the tested samples were enriched in monounsaturated fatty acid: Oleic acid (C18:1) with a maximum of 69.95%. The total polyphenols and individual phenolic compounds varied significantly through the extraction process, with a significant variation between olive oil and by-products. Remarkably, the percentage of secoiridoids and their derivatives was significant in paste and olive oil, emphasizing the activity of many enzymes released during the different extraction steps. Regarding antioxidant capacity, the most remarkable result was detected in olive oil and olive mill wastewater samples.

Nguyen et al. [12] investigated Vietnamese Dalbergia species for their fresh seeds and oil composition of fatty acids, tocopherols, and phytosterol, phenolic compounds and antioxidant activity. Among the examined samples, *D. tonkinensis* seed oils showed high contents of linoleic acid, whereas in *D. mammosa*, oleic acid was predominant. Moreover, α- and γ-tocopherol and β-sitosterol were major ingredients in the seed oils, whereas ferulic

acid and rosmarinic acid are usually predominant in the seeds of these species. Concerning sterol composition, the *D. entadoides* seed oil figured for remarkably high content of Δ7-stigmastenol and Δ5,23-stigmastadienol. Moreover, extracts with methanol/water of seeds displayed significant in vitro antioxidant activity which was determined by DPPH free radical scavenging assay.

In his study, Nasser et al. [13] explored the phytochemical profile, biological properties of green grape verjuice. Antioxidant and antitumor activities have been assessed and various conventional methods were used to quantify the alkaloids and tannins. Results show that the verjuice extract contains alkaloids, tannins, and a high quantity of total flavonoids and total phenols. Aside from its antioxidant activity, verjuice significantly repressed human pulmonary adenocarcinoma (A549) cells' viability in both time- and dose-dependent manners. Furthermore, verjuice extract significantly enhanced the anticancer potential of cisplatin. This study suggests a potential use of verjuice as a natural antitumor therapy.

The review of Wang et al. [14] reported an overview of natural products and their derivatives, the traditional medicine products, already described in the literature with potential to inhibit and manage SARS-CoV-2 in vitro, in vivo, or in clinical reports or trials. The study proposed that randomized, double-blind, and placebo-controlled large clinical trials are necessary to deliver solid evidence for the potential effective treatment. In addition, they suggested that carefully combined cocktails need to be assessed for preventing the COVID-19 pandemic and the resulting global health concerns thereof.

The review of Chávez-González et al. [15] entailed a comparison between the conventional and emerging extraction processes of flavonoids, which are found in plant-based foods and beverages as anon-energetic components. In this study, they examine, analyze, and discuss recent methodologies for biotechnological recovery/extraction of flavonoids from agro-industrial residues, describing the challenges and advances in the topic.

We would thank all the contributors and the Editor-in-Chief, Giancarlo Cravotto, for their enthusiastic support of the Special Issue, as well as the editorial staff of *Processes* for their efforts, and the SI manger, Ella Qiao.

Author Contributions: Conceptualization, I.M.A.-R. and A.T.; methodology, I.M.A.-R. and A.T.; software, I.M.A.-R. and A.T.; validation, I.M.A.-R. and A.T.; investigation, I.M.A.-R. and A.T.; data curation, I.M.A.-R. and A.T.; writing—original draft preparation, I.M.A.-R. and A.T.; writing—review and editing, I.M.A.-R. and A.T.; project administration, I.M.A.-R. and A.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

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

References

1. Campos, M.G.; Frigerio, C.; Bobiş, O.; Urcan, A.C.; Gomes, N.G.M. Infrared Irradiation Drying Impact on Bee Pollen: Case Study on the Phenolic Composition of *Eucalyptus globulus* Labill and *Salix atrocinerea* Brot. Pollens. *Processes* **2021**, *9*, 890. [CrossRef]
2. Potter, C.; Jones, D. Polyphenolic Profiling of Green Waste Determined by UPLC-HDMSE. *Processes* **2021**, *9*, 824. [CrossRef]
3. Vukoja, J.; Buljeta, I.; Pichler, A.; Šimunović, J.; Kopjar, M. Formulation and Stability of Cellulose-Based Delivery Systems of Raspberry Phenolics. *Processes* **2021**, *9*, 90. [CrossRef]
4. Ivić, I.; Kopjar, M.; Jakobek, L.; Jukić, V.; Korbar, S.; Marić, B.; Mesić, J.; Pichler, A. Influence of Processing Parameters on Phenolic Compounds and Color of Cabernet Sauvignon Red Wine Concentrates Obtained by Reverse Osmosis and Nanofiltration. *Processes* **2021**, *9*, 89. [CrossRef]
5. Wang, S.; Lin, A.; Han, Q.; Xu, Q. Evaluation of Direct Ultrasound-Assisted Extraction of Phenolic Compounds from Potato Peels. *Processes* **2020**, *8*, 1665. [CrossRef]
6. Pușcaș, A.; Mureșan, A.; Ranga, F.; Fetea, F.; Muste, S.; Socaciu, C.; Mureșan, V. Phenolics Dynamics and Infrared Fingerprints during the Storage of Pumpkin Seed Oil and Thereof Oleogel. *Processes* **2020**, *8*, 1412. [CrossRef]
7. Potter, C.; Jones, D. Polyphenolic Profiling of Forestry Waste by UPLC-HDMSE. *Processes* **2020**, *8*, 1411. [CrossRef]
8. Banica, F.; Bungau, S.; Tit, D.; Behl, T.; Otrisal, P.; Nechifor, A.; Gitea, D.; Pavel, F.M.; Nemeth, S. Determination of the Total Polyphenols Content and Antioxidant Activity of Echinacea Purpurea Extracts Using Newly Manufactured Glassy Carbon Electrodes Modified with Carbon Nanotubes. *Processes* **2020**, *8*, 833. [CrossRef]

9. Castro-López, C.; Gonçalves, C.; Ventura-Sobrevilla, J.; Pastrana, L.; Aguilar-González, C.; Martínez-Ávila, G. Moringa oleifera—Storage Stability, In Vitro-Simulated Digestion and Cytotoxicity Assessment of Microencapsulated Extract. *Processes* **2020**, *8*, 770. [CrossRef]
10. Hernández-Hernández, C.; Aguilar, C.; Flores-Gallegos, A.; Sepúlveda, L.; Rodríguez-Herrera, R.; Morlett-Chávez, J.; Govea-Salas, M.; Ascacio-Valdés, J. Preliminary Testing of Ultrasound/Microwave-Assisted Extraction (U/M-AE) for the Isolation of Geraniin from Nephelium lappaceum L. (Mexican Variety) Peel. *Processes* **2020**, *8*, 572. [CrossRef]
11. Jebabli, H.; Nsir, H.; Taamalli, A.; Abu-Reidah, I.; Álvarez-Martínez, F.J.; Losada-Echeberria, M.; Barrajón Catalán, E.; Mhamdi, R. Industrial-Scale Study of the Chemical Composition of Olive Oil Process-Derived Matrices. *Processes* **2020**, *8*, 701. [CrossRef]
12. Nguyen, T.T.; Doan, L.P.; Trinh Thi, T.H.; Tran, H.H.; Pham, Q.L.; Pham Thi, H.H.; Bach, L.G.; Matthäus, B.; Tran, Q.T. Fatty Acids, Tocopherols, and Phytosterol Composition of Seed Oil and Phenolic Compounds and Antioxidant Activity of Fresh Seeds from Three Dalbergia Species Grown in Vietnam. *Processes* **2020**, *8*, 542. [CrossRef]
13. Nasser, M.; Cheikh-Ali, H.; Hijazi, A.; Merah, O.; Al-Rekaby, A.; Awada, R. Phytochemical Profile, Antioxidant and Antitumor Activities of Green Grape Juice. *Processes* **2020**, *8*, 507. [CrossRef]
14. Wang, D.; Huang, J.; Yeung, A.W.K.; Tzvetkov, N.T.; Horbańczuk, J.O.; Willschke, H.; Gai, Z.; Atanasov, A.G. The Significance of Natural Product Derivatives and Traditional Medicine for COVID-19. *Processes* **2020**, *8*, 937. [CrossRef]
15. Chávez-González, M.; Sepúlveda, L.; Verma, D.; Luna-García, H.; Rodríguez-Durán, L.; Ilina, A.; Aguilar, C. Conventional and Emerging Extraction Processes of Flavonoids. *Processes* **2020**, *8*, 434. [CrossRef]