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# Innovative Technologies for Extraction and Microencapsulation of Bioactives from Plant-Based Food Waste and Their Applications in Functional Food Development

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**Abstract:** The by-products generated from the processing of fruits and vegetables (F&V) largely are underutilized and discarded as organic waste. These organic wastes that include seeds, pulp, skin, rinds, etc., are potential sources of bioactive compounds that have health imparting benefits. The recovery of bioactive compounds from agro-waste by recycling them to generate functional food products is of increasing interest. However, the sensitivity of these compounds to external factors restricts their utility and bioavailability. In this regard, the current review analyses various emerging technologies for the extraction of bioactives from organic wastes. The review mainly aims to discuss the basic principle of extraction for extraction techniques viz. supercritical fluid extraction, subcritical water extraction, ultrasonic-assisted extraction, microwave-assisted extraction, and pulsed electric field extraction. It provides insights into the strengths of microencapsulation techniques adopted for protecting sensitive compounds. Additionally, it outlines the possible functional food products that could be developed by utilizing components of agricultural by-products. The valorization of wastes can be an effective driver for accomplishing food security goals.

**Keywords:** agro-waste; bioactive compounds; therapeutic; encapsulation; functional food

## 1. Introduction

Fruits and vegetables (F&V) are a significant part of the human diet. Besides containing many nutrients, they are rich in phytochemicals which play a protective role in several chronic diseases [1–3]. Nowadays the consumption of F&V has been incorporated into many products such as ready-to-serve beverages, sauces, frozen F&V, fruit juices, nectars, dehydrated pulps, and so on. During the production of these food products, substantial amounts of waste are generated [4]. F&V processing in India, USA, the Philippines, and China produces approximately 1.81, 15.0, 6.53, and 32.0 million tons, respectively, of F&V wastes annually [5]. Major organic by-products from food production include seeds, peels, bracts, leaves, roots, bark, and midribs. These wastes are a potential source for many bioactive compounds (phytochemicals, antioxidants, coloring pigments, and nutrients) having nutritional and functional values. Moreover, proper management of organic by-products can furnish environmental and economic benefits by reducing food loss.

Numerous efforts have been made to utilize bioactive compounds embedded in F&V wastes [6,7]. The bioactive compounds are extracted from the wastes through different extraction techniques [8–11]. Depending upon the nature of the raw material and the type of bioactive to be extracted, different extraction methods are selected [12]. The recovered bioactive compounds can be used as ingredients to fortify food products, in the pharmaceutical or cosmetics industries [13]. However, there is a high risk of degradation during functional food development. To protect extracted bioactive compounds from severe processing conditions and environmental factors, they can be encapsulated within a coating material [14–17]. The selection of coating material is dependent on the ratio of the enclosed material (core), which plays a major role in producing uniform spherical microcapsules with high encapsulation efficiency. Contrarily, there are minimal studies that encompass all the fundamental aspects of waste valorization beginning from extraction to functional products via encapsulation. The encapsulated bioactive compounds can be utilized for the development of functional food products that may have many health benefits [18]. These by-products in some forms are added to various food products like meat, sausages, cheese, yogurt, curd, butter, ice-cream, juices, fruit purees, bakery products, and candies [19–21].

The present paper provides a comprehensive review of different sources of bioactive compounds generated from F&V wastes and their functional properties. Furthermore, it summarizes some recent advances in the extraction techniques of bioactive compounds. The review paper also explores the effects of operating conditions on the microencapsulation of these compounds. Lastly, it gives a concise overview of the development of functional food products by incorporating microencapsulated compounds.

## 2. Sources of Bioactive Compounds

Food wastes, particularly from fruits and vegetables, are rich sources of bioactive compounds. Bioactive components have elicited nutraceutical effects which are utilized to produce functional foods [8,22]. There have been numerous attempts to recycle these wastes into functional foods to get therapeutic and nutritional benefits. Figure 1 shows a schematic representation of the utilization of food wastes generated from industrial processing. Fruits and vegetables contain bioactive molecules both as primary and secondary metabolites such as lipids, amino acids, fatty acids, polyphenols including hydrolyzable tannins, glycosides, anthocyanin, alkaloids, and flavonoids [23,24]. Antioxidants directly act on quenching of free radicals, slowing down cell damage [25]. Generally, seeds have a pool of polyphenols and other antioxidant compounds while peels are a major resource for dietary fibers [26]. Apart from being an excellent reservoir of bioactive components, the agricultural wastes are also endowed with abundant cellulose, hemicellulose, lignin substances contained in peels, seed coats, or pomace [27,28].

Carotenoids are fat-soluble pigments commonly found in plant tissues that have a good antioxidant activity [29,30]. The predominant forms of carotenoids include lutein, $\gamma$, β-carotene, lycopene, zeaxanthin, violaxanthin, antheraxanthin, neoxanthin, and β-cryptoxanthin [31]. There are two classes of carotenoids, (i) xanthophyll which contains oxygen and confers a yellow color; (ii) carotenes that contain no oxygen but only linear hydrocarbons, which can be cyclized at both ends of the molecule, and which confer an orange color. For light absorption in carotenoids, a chromophore group exhibited by conjugated double bonds is responsible. Carotenoids are used in the food industry to replenish color lost due to thermal processing. Islamian and Mehrali [32] suggested that carotenoids have excellent free radical and singlet oxygen quenching capacity. This phenomenon is associated with the inhibition of many free radical influenced diseases namely, atherosclerosis-related cardiovascular diseases [33], multiple sclerosis [34], degenerative diseases [35], and macular degeneration [36]. Graff et al. [37] showed a positive relationship between the consumption of tomato sauce and lycopene and the reduction of prostate cancer. Mezzomo and Ferreira reported a protective action of these compounds for the human immune system along with the enhancement of intracellular communication through gap junctions by second messengers, ions, or metabolites [31]. Carotenes are most bioavailable in their natural trans-form [38,39]. However, isomerization of carotenoids from their trans-form to cis-form occurs in presence of light, heat, metals, or pro-oxidants, resulting in loss of pro-vitamin activity and color [40]. Furthermore, the bioavailability of pro-vitamin A compounds in fruits are greater than in vegetables due to the complex structures of protein in the chloroplast [39]. These compounds after extraction are widely used in the food industry for imparting color (natural colorant), promoting healthy antioxidants, and supplements.

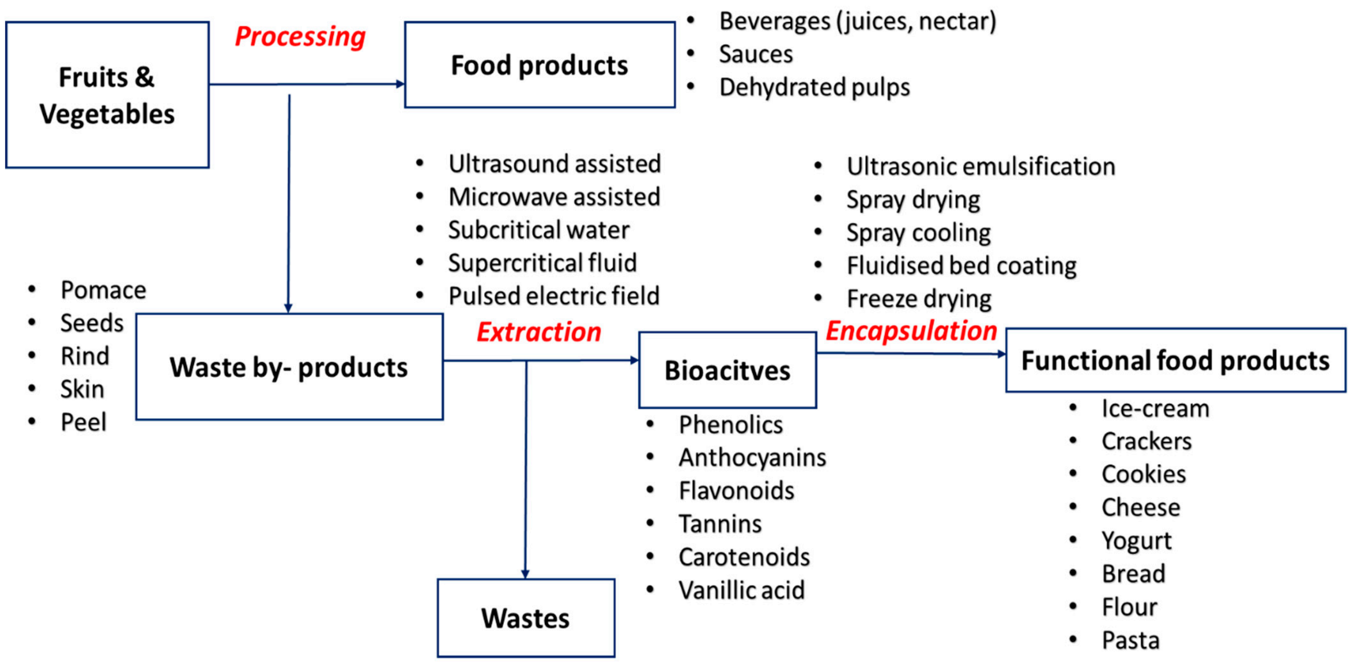


**Figure 1.** Overview of the utilization of the fruit and vegetables (F&V) by-products from the extraction of bioactive components to food product development.

On the other hand, phenolic compounds are characterized by an aromatic ring consisting of one or more hydroxyl substituents. They might involve simple or highly polymerized molecules. There are two classes of compounds; flavonoids and non-flavonoids. The flavonoids encompass subclasses such as flavonols, flavones, flavan-3-ols, anthocyanins, and chalcones while non-flavonoids include stilbenes, phenolic acids (hydroxybenzoic acids and hydroxycinnamic acids), tannins, neolignans, and coumarins [41]. Different phenolic compounds found in peel, pomace, and seeds of fruits and vegetables are summarized in Table 1. Flavonols contain a carbonyl group in their molecular structure. The abundant forms of flavonols found are quercetin and its derivatives, kaempferol 3-O-glucoside, and myricetin. However, phenolic acids with a single phenolic ring are categorized into hydroxycinnamic acids and hydroxybenzoic acids. The hydroxycinnamic acids mainly constitute a three-carbon side chain (C6–C3) in their molecular structure; some of its examples are caffeic, sinapic acids, ferulic, and *p*-coumaric; while the hydroxybenzoic acids group comprises a C6–C1 structure; it covers gallic acid, vanillic acid, *p*-hydroxybenzoic, syringic acids, and protocatechuic [42]. Besides having antioxidant potential, phenolic compounds have received a good amount of attention due to their ability to lower the risk of many chronic diseases such as cancer [43,44], cardiovascular diseases [45–47], diabetes [48], neurological disease [49,50], cataract [51], and some disorders of the cognitive function [52,53].

Additionally, the peels of citrus fruits namely lemon, orange, grapes contain distinct compounds likely exo/mesocarp have an excellent amount of flavone and furano derivatives, on the other hand, particularly exocarp is richer in oxygenated monoterpenes [54]. However, a substantial quantity of essential oils is also embedded in the peels (exo and mesocarp), seeds, and other wastes. Lemon essential oils are richer in γ-terpinene and β-pinene, while orange oils have β-myrcene. Grapes and oranges have citral isomers in higher content, whereas lemons contain more valuable essential oils with a greater content of oxygenated compounds [54]. Despite being less explored, the by-products of sapodilla plum (Achras sapota) contain a good amount of saponins and triterpenoids which are widely utilized in folk medicine [55]. These compounds exhibit antimicrobial, spermicidal, anti-inflammatory, and analgesic activities [56–58]. Different parts of the plant are inherent with other chemical compounds such as gallic acid, flavonoids, and other phenolic compounds. Interestingly, it has been reported that the introduction of compounds from sapota fruit in the diet can avert the outset of cancer or alleviate the progression of cancer [59].

There are several factors that influence the extraction efficiency of bioactive compounds as well as essential oils, such as the extraction time and technique used, solvent to the amount of sample ratio, and sample matrix (particle size, protein content, oligosaccharide content) [60–63]. Lafarga et al. [61] reported a reduction in total phenolic content in Brassica vegetables on thermal processing (boiling, steaming), due to the leaching loss of water-soluble phenolics. Contrarily, Su et al. [64] claimed a significant rise in total phenolic content after thermal processing, which can be explained by the rupture of complexes/matrices between phenolic compounds and protein molecules, positively influencing its availability during extraction. Bioactive compounds found in several fruits and vegetable wastes are summarized in Table 1.

## 3. Extraction Methods for Bioactive Compounds

There are various techniques for the extraction of bioactive compounds from fruit and vegetable wastes depending on their source, chemical properties, functionality, and end-use. The severity of the extraction methods in terms of temperature, pH, frequency, or electromagnetic waves might have an adverse impact on the extracted compounds. The major extraction methods discussed in this section are listed with key summary information in Table 2. Moreover, the schematic illustration of the extraction techniques are shown in Figure 2.

**Table 1.** Different sources of bioactive compounds from plant products and their key functional properties.

| Bioactive Compounds | Functionality for Processed Foods | Claimed Health Benefits | Parts | Sources |
|---|---|---|---|---|
| Lycopene | Antioxidants, food colorant | Radio protectant [65], anti-cancer agent [66], inhibit neurodegenerative diseases [35], promoter of heart health [67] | Peel- 611.10 mg/100 g DW [68]; Pomace- 28.64 mg/100 g DW [69] | Tomato |
| Polyphenols (gallic, chlorogenic, caffeic, ferulic, syringic, and *p* coumaric acids); and steroidal alkaloids (α-solanine, α-chaconine, aglycone solanidine) | Antioxidants, thickener | Anti-pathogenic [70], anti-inflammatory [71], anti-carcinogenic activities [71,72], neuroprotective activities [73] | Peel- alkaloids 84–2226 mg/kg [74]; polyphenols 32.87 mg/g DW [75] | Potato |
| Phenols, β-carotene | Antioxidants, pro-vitamin | Anti-inflammatory [76], anti-cancer agent [77], anti-microbial [78] | Peel: β-carotene 20.4 mg GAE/g DW; polyphenols 1371 mg GAE/g DW [79] | Carrot |
| Chlorophyll, caryophyllene, phellandrene, pheophytin | Antioxidants | Antimicrobial [80], antidiabetic [81] | Peel: chlorophyll 3.46 mg/g, caryophyllene 1.49 mg/g, phellandrene 1.21 mg/g, pheophytin 1.95 mg/g [82] | Cucumber |
| *p*-hydroxybenzoic acid, *trans*-*p*-coumaric acid, *p*-hydroxybenzaldehyde, caffeic acid | Antioxidants, fiber-rich component | Antimicrobial [83], treatment for diabetes mellitus [84] | Seeds: polyphenols 2.34–6.12 mg GAE/g DW; Shells: polyphenols 7.41–10.69 mg GAE/g DW [85] | Pumpkin |
| Anthocyanins, cinnamic acid, dihydrochalcones (phloretin), flavan-3-ol (epicatechin), flavonol (quercitin glycosides) | Antioxidant activity (ROS and RNS), food additive (natural alternative to synthetic antioxidants and anti-microbials) | Reduction of oxidative stress and inflammation properties [86,87], modifications of plasma lipids and lipoprotein levels [88,89], and anti-cancer activity [90] | Wastes (pomace, peel)- Anthocyanins 2.83 g/100 g DW; cinnamic acid 1.06 g/100 g DW; phloretic 569 mg/100 g DW; epicatechin 291 mg/100 g DW; flavonol 768 mg/100 g DW [91] | Apple |
| malvidin-3-O-glucoside, peonidin-3-O-glucoside, gallic acid, *p*-hydroxybenzoic acid, cinnamic acid, vanillic acid, proanthocyanidins, coumaric acid, chlorogenic acid, engeletin, quercetin, astilbin, resveratrol | Antioxidants (ROS/RNS), natural additive | Cardioprotective effect [92], prevention of metabolic syndrome [93], management of diabetes [94], anti-proliferative [95], anti-microbial/bacterial potential [96,97] | Pomace: anthocyanins 1246.85–2092.93 mg/100 g, total phenolic content 3014.55–5101.82 mg GAE/100 g, total flavonoids 1648.28 to 2983.91 mg CE/100 g, Total anthocyanin 1246.85–2092.93 mg/100 g [98] | Grapes |
| Gallic acid, delphinidin-3,5-diglucoside, cyaniding diglucoside, sinapic acid, α –punicalagin, β –Punicalagin, ellagic acid, hesperidine, quercetrin | Antioxidants, dietary fibers, single-cell protein, industrial enzymes, functional food ingredients, food additives, food lipid stabilizer, and artificial sweetener | Alleviates hypercholesterolemia [99], hyperpigmentation treatment [100], anti-cancer activity [43], dietary supplements | Peels- polyphenols 249.4 mg/g, flavonoids 59.1 mg/g, proanthocyanidins 10.9 mg/g [101] | Pomegranate |
| Naringin, eriocitrin, hesperidin, narirutin, limonin | Thickening and gelling agent, stabilizer, food additive | Mucoprotective agent [102], anti-carcinogenic [103], cytoprotective effect [104], prevention of neurodegenerative diseases [49] | Peel: Total phenolic content- 1259 mg GAE/100 g (orange), 1812 mg GAE/100 g (lemon), 793 mg GAE/100 g (mandarin) [105]; Total Flavonoids: 4.52 mg CE/100 g lemon peel [106], TF: 2539.82 mg QE/100 g mandarin peel [107]; lemon seeds- limonin 8.95 mg/g DW; Valencia orange seeds- limonin 10 mg/g DW [108] | Citrus fruits |
| Gallic acid, anthocyanins, ellagic acid, quercetin, tannins, xanthones, mangiferin and its related compounds, kaempferol | Antioxidants, micronutrient, protein-rich food source, | Modulation of diabetes and dyslipidemia [109], heart-protective effects [46,110], anti-cancer [111,112], anti-inflammatory [113] | Peel- Total polyphenolic content: Raw—90 to 110 mg/g, ripe- 55 to 100 mg/g [114] | Mango |

**Table 1.** *Cont.*

| Bioactive Compounds | Functionality for Processed Foods | Claimed Health Benefits | Parts | Sources |
|---|---|---|---|---|
| Epicatechin-3-gallate, malvidin-3-glucoside, procyanidin B2, gallic acid, procyanidin B4, anthocyanins, naringin, isoscopoletin, coumaric acid | Antioxidant, Food colorant, food additives | Pain reliever & Anti-cancer agent [115,116], tyrosinase inhibitory [117,118], anti-inflammatory [119], immunomodulatory, anti-glycated, anti-diabetics [120], metalloproteinase activity [121] | Seeds: phenolic compounds 80.9 g/kg DW [122], Pericarp: phenolic content 57.8 mg GAE/g DW [123] | Logan/Litchi |
| Gallocatechin, catecholamine, anthocyanins, delphinidin, cyanide, ferulic acid, cinnamic acid, Epicatechin, Procyanidin | Antioxidant, thickening agent, natural bio-colorant, bio-flavors, source of macro & micro-nutrients | Anticancer [44,124], anti-bacterial [125], lower plasma oxidative stress [126], treatment of diarrhea [127] | Peel: phenolic content 29.2 mg GAE/g DW [128] | Banana |
| Ferulic acid, *p*-coumaric acid, Caffeic acid, bromelain | Prebiotic, single-cell protein, anti-browning agent, texture improver | Manage hyperlipidemia [129], analgesic and anti-inflammatory effects [130], blood coagulation [131], anticancer agent for malignant peritoneal mesothelioma [132] | Peel: phenolics 222–428 mg GAE/100 g DW [133] | Pineapple |
| Carpaine, glucotropacolin, benzylisothiocynate, bemzylthiourea, benzylglucosinolate, sitosterol, hentriacontane, papain, caffeic acid, chlorogenic acid, *p*-coumaric acid, ferulic acid, and vanillic acid | Rich in digestive enzymes | Antimalarial [134], Antimicrobial/Antifungal [135], abortifacient [136], wound healing [137], treatment of psoriasis & jaundice [138] | Seeds: total phenolic content 0.31–0.77 mg/g [139], Leaf/peel: total polyphenols 28.61–63.59 mg GAE/g, flavonoids 8.36–23.45 mg CE/g, Proanthocyanidins 3–8.89 mg CE/g [140] | Papaya |

GAE: gallic acid equivalent; CE: catechin equivalent; DW: dry weight.

**Table 2.** Different techniques for extraction of bioactive compounds and their operating conditions.

| Extraction Techniques | Sources | Compounds | Operating Conditions | | | | | | Solvent/Co-solvent | Extraction Efficiency, EE (%)/Yield, EY (g/100 g) | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Temperature (°C)/MW Power (W) | Pressure (bar)/Flow Rate of Solvent (ml/min) | Frequency (kHz) | Amplitude (%)/Applied Voltage (kV/cm) | Time (min) | Solid: Solvent | | | |
| SE | Pomegranate peels | Carotenoids; Punicalagins and ellagic acids | 35; 100 | - | - | - | -;5 | 1:5; 1:5 | Hexane, Isopropanol; Water | EE:85.7; 80.3 & 19.7 | [141,142] |
| | Pouteria sapota seeds | Oil | 70 | - | - | - | 360 | 1:7 | Hexane | EE:40 | [143] |
| UAE | Tobacco waste (midrib, dust, scrap) | Chlorogenic | 50/50 | - | 37 | - | 30 | 1:10 | Ethanol-water | EY:0.35 | [144] |
| | *Citrus latifolia* waste | Catechin and diosmin | 50/130 | - | 20 | 89 | 12.5 | 1:50 | Ethanol | EE:93, 89 | [145] |
| | Pomegranate peels | Carotenoids | 51.5 | - | 20 | 40% | 30 | 1:10 | Vegetable oil | EE:93.8 | [142] |
| | *Artocarpus heterophyllus* (Jackfruit) peel | Pectin | 60, pH 1.6 | - | - | - | 24 | 1:15 | Water | EE:14.5 | [146] |

**Table 2.** *Cont.*

| Extraction Techniques | Sources | Compounds | Operating Conditions | | | | | | Solvent/Co-solvent | Extraction Efficiency, EE (%)/Yield, EY (g/100 g) | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Temperature (°C)/MW Power (W) | Pressure (bar)/Flow Rate of Solvent (ml/min) | Frequency (kHz) | Amplitude (%)/Applied Voltage (kV/cm) | Time (min) | Solid: Solvent | | | |
| UAE + PLE | Blackberry, blueberry, and grumixama wastes | Anthocyanin | 80/580 | 100 | 37 | - | 30 | 1:18 | Ethanol/water | EY:9.62–11.66 | [10] |
| SCFE | Vegetable peel wastes (sweet potato, tomato, apricot, peach) | Carotenoids | 59 | 350/15 | - | - | 30 | 1:15.5 | $CO_2$, Ethanol | EE > 90 | [147] |
| | Apple pomace | Total phenolic content | 45 | 300/33.3 | - | - | 120 | - | $CO_2$, Ethanol | EY:5.78 | [148] |
| | Citrus peels and seeds | Carotenoids | 41–45 | 250–300/27 | - | - | 120 | 1.5–2.25 | $CO_2$, seed oil | EY:0.198 | [149] |
| SCWE | Pistachio hulls | Gallotannin & flavonols | 110–190 | 69/4 | - | - | 30–50 | 1:25 | Water | EE > 96 | [150] |
| | Mandarin peel | Flavonoids | 130 | 30/1000 | - | - | 15 | 1:34 | Water | EE-96.3 | [151] |
| MAE | Vine prune residues | Total phenolic content | 120 | - | - | - | 5 | 1:40 | Ethanol -water | EY:2.4 | [152] |
| | *Ocimum basilicum* | Polyphenols | -/442 | - | - | - | 15 | 1:10 | Ethanol | EY:4.3 | [153] |
| | *Mangifera indica* leaves | Mangiferin | -/272 | - | - | - | 5 | 1:20 | Water | EY:5.5 | [154] |
| | Red grape pomace | Phenolics | 50/200 | - | - | - | 60 | 1:50 | Water-ethanol | EY:23 | [155] |
| | Cabbage leaves | Phenolic content | ~50/100 | - | - | - | 2 | 1:10 | Ethanol | EY:0.86 | [156] |
| PEF + SLE | Potato peel | Steroidal alkaloids | 15–23 | - | 0.01 | -/0.75 | 200 pulses@ 3 µs, 60 min | 1:5 | Methanol | EY:0.158 | [157] |
| PEF + SE | Blueberry press cake | Total phenolics, anthocyannin | 23 | - | 0.01 | -/1–5 | Pulse width- 1–23 µs, 24 h | 1:6 | Ethanol | EE: >63, >78 | [158] |
| PEF + UAE | Defatted canola seed cake | Polyphenols | 70/200 | - | 0.03 | | 900 pulses@ 20 µs, 20 min | 1:10 | Ethanol | EY:2.6 | [159] |

SE: solvent extraction, UAE: ultrasound-assisted extraction, MAE: microwave-assisted extraction, PLE: pressurized liquid extraction, SCFE: supercritical fluid extraction, SCWE: sub-critical water extraction, PEF: pulsed electric field extraction, SLE: solid-liquid extraction.

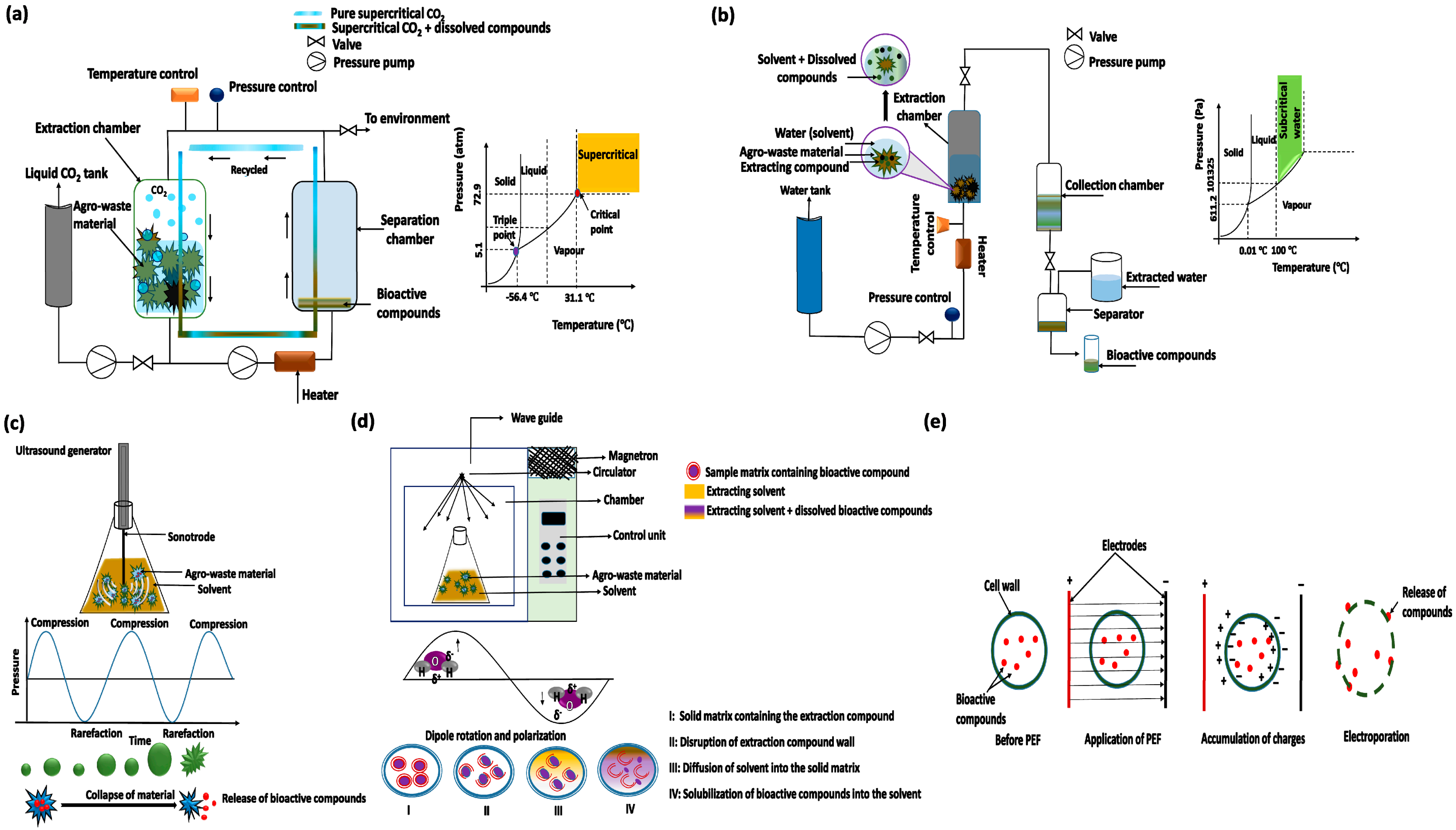


**Figure 2.** Schematic illustration of extraction techniques, (**a**) supercritical fluid extraction; (**b**) subcritical water extraction; (**c**) ultrasonic assisted extraction; (**d**) microwave assisted extraction; (**e**) pulsed electric field extraction.

*3.1. Supercritical Fluid Extraction*

Supercritical fluid extraction (SCFE) using supercritical $CO_2$ has been widely used for high-value food applications. Importantly, $CO_2$ is non-toxic, better extraction of nonpolar or partially polar compounds in supercritical $CO_2$, high solubility of oxygenated organic compounds of medium molecular weight, and non-explosive, in contrast to many organic solvents [160]. It is preferred for the extraction of bioactives from plants or food by-products because of its easy removal from the extracted final product [161].

For extraction, the raw material is initially placed in an extraction container with temperature and pressure controllers, thereafter it is pressurized with the fluid by a pump regulating the temperature conditions. The compounds dissolved in the fluid are conveyed to the separators where the compounds are collected at the bottom and the fluid is either recycled or released to the environment [162]. The critical point of any fluid is marked by its ability to neither behave like gas nor liquid above a critical temperature (CT) and pressure (CP), thus it can easily diffuse into a solid matrix like a gas while also having a high capacity to dissolve compounds like a liquid. Thus, SCFs have an advantage in terms of diffusivity, solute capacity, and low viscosity over other solvents. These characteristics are responsible for better extraction yields and shorter extraction times [163]. $CO_2$ with CT 31 °C and CP 74 bar is the most commonly utilized SCF for food application. However, due to its low polarity, the solvation power of supercritical $CO_2$ to dissolve the bioactives from a solid matrix gets reduced. Therefore, it is often used in conjunction with a co-solvent or a modifier. Da Porto et al. [164] combined water and ethanol with $CO_2$ as co-solvents to extract phenols from grape marc. They indicated that the solubility of the phenols in the supercritical phase reduced at a higher temperature (313.15 to 333.15 K) mainly due to the pre-dominant density effect of SC-$CO_2$ + water on the vapor pressure of the extracted compounds, conversely, a predominant effect of vapor pressure over density was observed for SC-$CO_2$ + ethanol. However, the extraction yield improved after extracting with SC-$CO_2$ + water followed by SC-$CO_2$ + ethanol because of the varying polarity of the phenols. The selective extraction of bioactive compounds or co-precipitation of heat-sensitive natural antioxidants can be achieved by micronization through the supercritical anti-solvent (SAS) process where supercritical $CO_2$ is used as anti-solvent to precipitate the compounds [165,166].

The steps for extraction of bioactives by SAS process [167,168] are: (1) The solute containing bioactive compounds are dissolved in an organic solvent; (2) $CO_2$ continuously flows into the extraction system under a regulated pressure and temperature condition; (3) The solute-organic solvent mixture is then sprayed into SC-$CO_2$ where the organic solvent is extracted out of the atomized solute droplet by $CO_2$; (4) Due to high miscibility of organic solvent in SC-$CO_2$ at super-critical conditions, an instant mutual diffusion occurs at the interface of the solute and SC-$CO_2$, this phenomenon induces saturation and phase separation of solute in SC-$CO_2$, thus, results in nucleation and precipitation of target bioactive compounds. Zabot and Meireles [169] in their study highlighted the positive effect of the SAS process on the quercetin yield from onion peels. They demonstrated minimum degradation of quercetin because of less exposure to light and oxygen and direct flow of solute organic solvent (ethanol) mixture into the precipitation vessel. According to Czaikoski et al. [170], when propane was utilized as an alternative SCF, both pressure and temperature had a positive impact on the yield. The influence of pressure and temperature on extraction performance vary according to the material type, its origin, and the target compound. For instance, Espinosa-Pardo et al. [171] reported a 24.7% increase in carotenoid yield from peach palm pulp at high pressure and temperature caused by the predominant vapor pressure effect of solute over the density of solvent. The major limitation of SCFE is the slow extraction kinetics [172]. Henceforth, in order to improve the extraction efficiency, it is advisable to couple with other methods like ultrasound or enzyme with SCFE to intensify the mass transfer process by disrupting vegetal matrices.

### *3.2. Subcritical Water Extraction*

Subcritical water extraction (SCWE) is another promising environmentally friendly and low toxicity extraction method that can be used as an alternative to traditional techniques. The basic principle of extraction by this technique involves heating water to a temperature between 100–320 °C at a pressure (~20–150 bar). At these given conditions, water remains in its liquid state, however, the dielectric constant of water is altered (i.e., 80 at room temperature to ~27 at 250 °C) [173]. The dielectric constant of water becomes comparable to that of methanol and ethanol which are 33 and 24, respectively at 25 °C. Due to the low dielectric constant of water, the polarity, viscosity, and surface tension are reduced, consequently, the dissolution of non-polar molecules is improved [174]. Based on this unique property, the SCWE method has gained immense popularity for fractionation and extraction of a wide range of compounds with a high degree of specificity. Munir et al. [175] explored the extraction of phenolic compounds from onion skin by employing SCWE for 0.5 h and ethanol extraction for 3 h. They asserted that SCWE produced higher extracts of phenolic compounds than ethanol extraction (200 vs. 70 mg gallic acid equivalent/g) and flavonoids (90 vs. 24 mg quercetin equivalent/g) concentration because of effective disruption of hydrogen bonds, van der Waals forces between analyte and sample matrix and low viscosity of water caused by high temperature and pressure. Similarly, Yan et al. [176] in their studies found that polyphenol extracts of lotus seed epicarp from SCWE exhibited greater radical scavenging ability than hot water extraction (88.72 vs. 30.07 mg gallic acid equivalent/g). To accelerate extraction and to reduce the time of heat-sensitive compounds that are exposed to high temperatures, the raw material can be pre-treated using microwaves, ultra-sonication, or gas hydrolysis ($N_2$ or $CO_2$). Pre-treatments like microwave and ultrasonication facilitates the diffusion of bioactive compounds into the solvent through sample matrix disruption. On the other hand, $N_2$ replaces oxygen in the water and has a shielding effect on the reaction atmosphere that favors the extraction of bioactive compounds [177]. Getachew and Chun [178] reported that amongst all the pre-treatments, microwaves helped in extracting the highest content of bioactive compounds from the spent ground coffee. Some limitations of SCWE include corrosiveness and high reactivity of water at a subcritical state that needs to be considered while designing SCWE equipment [179]. Todd and Baroutian [180] in their study have estimated the cost of manufacture of SCWE unit = NZ$ 89.6/kg product for grape marc.

### *3.3. Ultrasound-Assisted Extraction*

Sound at frequencies over 20 kHz, which cannot be detected by humans, is referred to as the ultrasonic region. Ultrasound-assisted extraction (UAE) is one of the promising techniques used for the extraction of bioactive compounds via acoustic cavitation, vibration, and mixing effect generated in liquid media. Generally, the frequency ranges from 20 kHz to 100 kHz and is used for effective extraction of functional compounds from plant materials [181]. UAE efficiency strongly depends upon the physical forces generated by acoustic cavitation, and the 20 kHz to 100 kHz frequency range is known to generate strong physical forces. Acoustic cavitation can result in cell wall destruction which facilitates extraction [182]. The propagation of ultrasound waves in liquid media induces cavitation bubbles to grow and collapse, generating various physical effects that include microjets, shockwaves, and turbulence. These physical forces cause cell wall breakdown, cell surface holes, and exudation of nutrients from the cellular plant matter into the solvent [183]. Additionally, the ultrasonic waves passing through the liquid medium create regions of higher and lower pressure variations known as acoustic pressure. The cavities created by microbubbles on exposure to the acoustic field is dependent on the number of acoustic cycles. The bubble oscillation is accompanied by its expansion during the negative pressure cycle and contraction during the positive pressure cycle [184]. Moreover, the expansion and contraction are followed by the diffusion of vapor in and out of the bubble. This diffusion process causes accumulation of mass in the bubble over time, resulting in net bubble growth known as rectified diffusion. Net bubble growth might also be due to the coalescence of multiple bubbles present in the acoustic sound field. In both ways, the bubbles collapse after growing up to a certain size, which is called resonance or critical size and is inversely related to applied frequency. The low-frequency range (16–100 kHz) is also known as the power ultrasound region where strong physical effects like localized shear and high temperatures occur from the high-intensity collapse of large resonance size bubbles [185]. The cavitation phenomenon intensifies the mass transfer and movement of solvent into the cell matrix. Mostly, water is preferred for UAE, but other solvents namely ethanol, methanol, and hexane are also used. Kaderides et al. [186], observed an increased extraction yield of phenolic compounds from pomegranate peel on increasing the amplitude level up to 40% due to greater contact surface area between the solid matrix and the solvent surface that enhanced the mechanical and cavitation effect of ultrasounds. This increased amplitude caused more violent bubble collapse in the short time since the resonant bubble size is influenced by the amplitude of the ultrasound waves. The generated high-speed jet accelerated the penetration of the solvent into the matrix and the release of phenolic compounds into the solvent by cell wall disruption. González-Centeno et al. [187] found that at 40 kHz, 150 W/L power density and 25 min of extraction time were adequate for extraction of phenolic compounds and flavonols from grape pomace. Cavitation is also influenced by extraction temperature. Sometimes, high temperature improves the solvent diffusion rate by disrupting intermolecular bonds between solvent and matrix. Ahmed et al. [188] investigated the ultrasonic extraction of bioactive compounds from Amaranth extract by varying solution temperature (30–70 °C). They observed the highest phenol and flavonoid contents at 70 °C due to the release of bound polyphenols upon disruption from cell-matrix at a high temperature. Analogous results at 80 °C were also claimed by Das and Eun [189]. Similarly, sample matrix size, state of raw material (powder or leaves), and extraction time were found to influence the overall extraction yield [190,191]. Longer extraction times generated some undesirable changes in the extracted solution, while the small sample matrix size enhanced the contact between the exposed surface and solvent favoring cell pore destruction followed by increased internal diffusion of solute into the solvent. It was found that the particle size of samples varying from 0.54–1.5 mm had the highest oil yield when extracted from date seeds [192]. A comparative study was conducted by Drosou et al. [155] and Safdar et al. [193] utilizing soxhlet extraction and UAE, where UAE ethanol: water (1:1) extracts exhibited the highest phenolic compounds and antiradical activity. Therefore, UAE has an advantage of a shorter time, increased extraction rate, and higher yield over conventional extraction techniques.

### 3.4. Microwave-Assisted Extraction

Microwave-assisted extraction (MAE) is another technique that can be employed in combination with classical solvent extraction. This method is advantageous over traditional extraction methods due to the high extraction rate, less use of solvents, and shorter extraction time [9,194]. The electromagnetic field of microwaves generally ranges from 300 MHz to 300 GHz. Microwave energy is absorbed by the polar materials which are then transformed into heat by ionic conduction and dipole rotation known as dielectric heating. Generally, the solvent with a high dielectric constant is selected for extraction of bioactives from plant matrices for maximum absorption of microwave waves that convert into kinetic energy. The molecules with high kinetic energy thus diffuse into the plant materials resulting in the effective mass transfer of solute into the solvent [195]. However, in certain cases, the plant matrix is directly exposed to microwave heating allowing the solutes to be released into the cold solvent [196,197]. The mechanism of MAE includes 3 basic steps [198]. Firstly, the selective absorption of microwave energy by the water glands inside the sample matrix favors localized heating above or near the boiling point of water causing expansion and rupture of cell walls by disrupting the interaction between the solute and active site of the matrix through the splitting of hydrogen bonds, van der Waals force, and dipole attraction. Second, the disrupted cell promotes the mass transfer of the solvent into the sample matrix and bioactive compounds into the solvent. Third, extracted bioactive compounds then dissolve into the surrounding solvent. Kulkarni and Rathod [154] exploited MAE for extraction of mangiferin from Mangifera indica leaves with water as a solvent. They obtained maximum yield (55 mg/g) at 20:1 solvent to solid ratio and 272 W in 5 min, while Soxhlet extraction produced 57 mg/g in 5 h. The optimum microwave conditions and solvent concentration are the main parameters that vary with the source of raw materials, permeability of the matrix, and the targeted compound. Several researchers extracted bioactive compounds by different extraction techniques to examine their comparative studies on its extraction effectiveness. For instance, Zhang et al. [199] compared a few extraction methods like maceration, percolation, UAE, and MAE for recovery of alkaloids from Macleaya cordata, and MAE had the highest yield of alkaloids (17.10 mg/g sanguinarine, 7.04 mg/g chelerythrine) with the shortest extraction time. MAE is rapid and exploits the advantage of the reduced amount of organic solvent (5 to 10-fold) in contrast to conventional methods with high sample throughput by overcoming the resistance offered by the sample matrix [200]. Conversely, there might be an issue of solute degradation at increased temperatures. Due to the risk of explosions generated by high pressure, special precautions involving the material of construction need to be taken while designing the closed vessel MAE equipment. The industrial scale-up process is achieved with appropriate designing of the reaction vessel, the frequency of electromagnetic radiation, and sample thickness [201].

### *3.5. Pulsed Electric Field Extraction*

Pulsed electric field extraction (PEF-E) is an emerging technology used for the extraction of bioactive compounds. It is a non-thermal method that induces cell destruction through the application of electric pulses. These electric pulses are applied in a short duration (usually ranging from milli to nanoseconds) at moderate electric field strength (EFS) [202]. The cells or the sample matrix exposed to these electric fields accumulate charges on either side of the membrane surface, thereby generating transmembrane potential on the cell surface. When the transmembrane potential exceeds a certain critical limit, the weaker sections of the cell membrane create pores otherwise known as cell electroporation [203]. It promotes a substantial increase in permeation across the cell membrane, facilitating the release of intracellular compounds. Therefore, it is known to increase the extraction yield and rates at reduced energy consumption and low environmental impact [204,205]. Furthermore, PEF-E is useful for the effective extraction of heat-sensitive compounds from the sample matrix [206]. As the raw material is placed in between two electrodes inside the treatment chamber, the optimization of the process parameters, including pulse number, electric field strength, treatment temperature, and specific energy input is essential [207]. Fincan et al. [208] subjected beetroots to 270 monopolar rectangular pulses at 10 μs, 1 kV/cm field strength with an energy consumption of 7 kJ/kg for the extraction of betanin. They found that the samples had the highest release about 90% of total betanin in contrast to freezing and mechanical pressing following 1 h aqueous extraction. On comparing with the untreated sample, PEF treated orange peels showed an increase in total phenols from 11.76 to 14.14, 26.92, 29.81, 34.80 mg Gallic acid equivalent/100 g at 1, 3, 5, 7 kV/cm, respectively [209]. Similarly, Delsart et al. [210] reported that moderate electric field treatment and shorter duration (40–100 ms) accelerated the release of phenolic compounds and anthocyanins across the cell membrane. PEF-E showed better selectivity in terms of anthocyanin extraction from grape pomace, other than high voltage electric discharge [211]. This non-thermal treatment can be utilized for selective extraction (temperature <5 °C) by preserving sensitive compounds. PEF-E can also be applied prior to a classical extraction process to reduce the extraction effort [212,213].

## 4. Bulk Encapsulation of Bioactive Compounds

The stability of bioactive compounds is an important criterion to be considered while developing any functional food product. Some health-promoting polyphenols because of their unsaturated bonds in their molecular structure are very sensitive to heat, light, oxygen, and pH [214]. One of the best strategies to protect the sensitive bioactive compounds from environmental impact is by enclosing them in a solid matrix, otherwise known as encapsulation [215]. Encapsulation can also aid in an additional benefit of bioavailability enhancement, masking astringent flavors, and controlled release in the gastrointestinal tract [216]. As there is a variety of possible encapsulation methods, an appropriate technique must be selected based on the target compound and its susceptibility to its operational parameters. Table 3 summarizes the various wall materials used for different bioactive compounds and their suitable encapsulation technique. Moreover, Table 4 describes the in-vivo pharmacological effect and release stability of encapsulated bioactive compounds.

**Table 3.** Wall materials used for different bioactive compounds and their suitable encapsulation techniques.

| Bioactive Compounds | Wall Materials | Advantages of Wall Material | Limitations of Wall Material | Suitable Encapsulation Techniques | References |
|---|---|---|---|---|---|
| Lycopene, Citrus reticulata polyphenol extract | Gum Arabic | Good emulsifying capacity, high solubility | Limited protection to oxidation | Spray drying, freeze-drying | [217,218] |
| Anthocyanin from blackberry by-products, Betanain | Maltodextrin | Low cost, low oxygen permeability, rapid film-forming ability | Poor emulsifying property increase the viscosity | Spray drying | [219,220] |
| Limonene, Lycopene, betalains | Whey protein isolate | Excellent emulsifying abilities provide good emulsion stability | Limited heat and freeze stability | Freeze drying, Spray drying | [219,221] |
| Curcumin, Banana peel extracts, β-carotene | Soy protein isolate | Good emulsifying ability, fast film formation | Soluble in alkaline pH | Freeze drying | [222–224] |
| Blackberry pulp | Arrowroot starch and gum arabic | Gelling agent, good emulsifying ability | High viscosity | Spray drying | [225] |
| Chokeberry anthocyannanis extract | Pectin | Gelling agent and colloidal stabilizer | Forms clumps during dispersion, encapsulation depends greatly on methylation degree | Spray drying | [226] |
| Lutein | Inulin | Requires low drying temperature for film formation | Sensitive to environmental conditions | Spray drying | [227,228] |
| Betanins | Xanthan gum | Stabilizes emulsions, protective film against oxidation | High viscosity at low concentration | Spray/freeze drying | [229] |
| β-carotene | Gum acacia | Stabilizes emulsions | High viscosity | Complex coacervation by sonication | [230–232] |
| Curcumin | Skim milk powder | Good film forming and emulsifying ability | pH-dependent gel swelling behavior | Spray drying | [233] |
| Lycopene | Whey protein isolate & Gum acacia | Good retention of bioactive compound | Oxidative degradation and mass loss during drying | Complex coacervation, freeze-drying | [234] |

**Table 4.** In-vivo studies showing pharmacological effect and release stability of encapsulated bioactive compounds.

| Type of Study | Encapsulated Bioactive Compound | Dose | Duration | Results | References |
|---|---|---|---|---|---|
| Randomized | Resveratrol | 6 mg | 35 days | Inhibition of cell growth in tumor | [235] |
| Randomized cross-over | Curcumin | 1 g | 3 days | Biotransformation of curcumin are delayed | [236] |
| Controlled | E. hirta powder | 500 mg/kg bw | 15 days | Potential antidiabetic activity | [237] |
| Randomized | Betanin | 60 mg/kg bw | 28 days | Positive effect on regulating hyperglycemia, hyperlipidemia, and oxidative Stress | [238] |
| Randomized | astaxanthin | 100 mg/kg | 72 h | Rate of release and extent of digestion was improved | [239] |

### *4.1. Ultrasound for Bulk Encapsulation*

Ultrasound offers a great advantage in the emulsification process for food applications. The prime driving force involves acoustic cavitation where bubbles form, grow and collapse at the emulsion interface resulting in very fine emulsions through disruption and mixing. Two mechanisms are majorly responsible for emulsification; (1) Dispersion of liquid/dispersed phase into second/continuous phase resultant from the interfacial waves produced by sound waves; (2) The acoustic cavitation causes high shear forces that break to the formation of sub-micron sized droplets of liquid phase [185]. The fine-tuning of process conditions such as power density, processing time, and temperature affects the formation and stability of emulsions. It is evident that high intensity and low frequency generate very strong shear forces favorable for sudden bubble collapse dispersing very small droplets of a dispersed phase in the continuous phase, thereby, exceptionally stabilizing the emulsions [240]. Contrarily, Silva et al. [241] observed small lumps in the emulsion (consisting of annatto seed oil and modified starch) due to the gelatinization of starch (wall material) that was promoted by hot spots generated in the emulsion. Hence, for intense process conditions, the cooling of the emulsion during the process is necessary. It is also observed that high shear forces and localized temperature produced during acoustic cavitation have the ability to unfold and denature proteins, while in certain cases it can aggregate proteins through crosslinking (hydrogen bonds, covalent bonds, hydrophobic interactions) [242]. These proteins further aid in the stabilization of the emulsion interface, eliminating the need for surfactants [243]. The formation of emulsions by ultrasonication with dairy proteins as emulsifying agents is of growing interest. The use of ultrasound for the extraction of bioactive compounds is quite popular, however, encapsulation of phenolic compounds is limited [188,189].

### *4.2. Spray Drying for Bulk Encapsulation*

Spray drying is most commonly used for encapsulation due to its simplicity, low cost, and ease of scale-up. Briefly, the liquid feed containing a core and coating material is first homogenized into an emulsion. This feed solution is then injected into the drying chamber through an atomizer or nozzle to obtain small microcapsules in the collector chamber after solvent (water) evaporation [244]. Organic solvents are rarely used due to The attributes of spray-dried powders are associated with the operating conditions including feed flow rate, concentration of core and coating agent, speed of atomizer, drying air flow rate, and drying temperature [245]. Generally, polysaccharides (e.g., gum Arabic, maltodextrin, cyclodextrin with varying dextrose equivalent (DE)), and proteins (e.g., whey protein, milk protein, soy protein, and caseinate salts) are used for spray drying [246]. Nogueira et al. [225] demonstrated good retention of antioxidant properties of spray-dried microcapsules of blackberry pulp (coating material arrowroot starch/gum Arabic: 1:1.78). Correia et al. [247] studied the effect of different protein sources (chickpea flour, coconut flour, arrowhead, wheat flour, soy protein isolate) on the encapsulation of blueberry pomace extracts by spray drying. It was evident that micro-particles from soy protein isolate had better storage stability compared to wheat flour, chickpea flour, and coconut flour with the highest antioxidant capacity and showed maximum polyphenols retention (90%) during the storage period. Sormoli and Langrish [248] obtained 95% retention of phenolic contents after encapsulating the orange peel extract in whey protein isolate (WPI) by limiting the outlet air temperature to 80 °C for preventing denaturation of WPI. Contrarily, Agudelo et al. [249] demonstrated a significant reduction (c.a. 42%) of phenolic compounds in spray-dried grape pulp containing gum Arabic and bamboo fiber at 120 °C inlet air temperature. The high temperature during spray drying results in the degradation of encapsulated heat-sensitive compounds such as carotenoids, lycopene, thereby lowers its antioxidant capacity [250]. Additionally, the wall materials are mainly carbohydrates having low glass transition temperature and change their state from glassy to rubbery during spray drying that forms highly sticky powder [251]. Therefore, there might be a chance of solid loss and less product recovery due to the firm sticking of powder on the cyclone separator [252].

### *4.3. Spray Chilling for Bulk Encapsulation of Temperature-Sensitive Bioactives*

To avoid the high drying temperature, spray chilling is often employed for encapsulating sensitive bioactive compounds. The basic principle is analogous to spray drying. However, the prime distinction in spray chilling is the replacement of the drying chamber by a cooling chamber, where, as the atomized particles fall into the cooling chamber, their energy is removed for cooling or gelling of droplets. Mostly molten carriers such as hydrogenated vegetable oils or lipids (with melting point 45–122 °C) are used as coating materials [14,253]. Depending on the surface area and size of the particles, the cooling capacity and chamber size is designed. The temperature in the cooling chamber must be regulated below the gelling/melting point of the solid to induce proper solidification of the molten carrier. For example, spray-chilled particles containing cinnamon extracts rich in proanthocyanidin enveloped in vegetable fats (melting point 48 °C) were produced which had an encapsulation efficiency (>87%) possessing spherical shape with variable diameters and some aggregates indicating larger particle sizes [254]. Moreover, the involvement of lipid as a carrier matrix eliminates the need for solvents in dissolving wall materials. Tulini et al. [255] obtained spray-chilled microcapsules loaded with proanthocyanidin-rich cinnamon extract in vegetable fat with outstanding antioxidant activity and controlled release of pro-anthocyanidins in the simulated gastrointestinal tract. Similarly, Oriani et al. [256] produced ginger oleoresin microcapsules (retention >96%) with oleic acid or palm fat as coating materials. They also reported that an increase in the concentration of unsaturated lipid decreased the microcapsule crystallinity that facilitated the diffusion of compounds through the lipid matrix. As the process does not include solvent evaporation, the capsules produced by this technique are non-porous and dense, thus they are resistant to oxygen diffusion and show excellent stability [257]. For instance, Mazzocato et al. [258] investigated the encapsulation of a heat-sensitive micronutrient (cyanocobalamin) and reported encapsulation efficiency of up to 100%. The solid lipid microparticles had a smooth and spherical surface influencing good powder flowability while promoting superior protection (>91.1%) even after 120 days of storage period at 25 °C in the absence of light compared to free one (75.2%).

### 4.4. Fluidised Bed for Additional Coating

The application of the fluidized-bed coating is a promising technique that allows uniform coating of the core material or additional coating of the powder particles to improve the protection of particle surface from environmental stresses such as pH, temperature, oxygen, or light and enhance functionality/bioavailability of the particles [259]. The particles are suspended by an air stream at a predefined temperature and then sprayed by a coating material through an atomizer. The airstream suspends the particles by overturning the gravitational force of these particles that is mainly due to the particle weight, this state is known as the fluidized state. Carrier materials must possess film forming capabilities, adequate viscosity, and thermal stability. A wide range of materials involving starch derivatives, proteins, gums, cellulose, and molten lipid could be employed for this process [14]. The coating materials can either be sprayed at the top or bottom of the device followed by solvent (water) evaporation. The solvent evaporation by heat and mass transfer can be regulated by the water content, airflow rate, spraying rate, humidity of the inlet air, and temperature of the air [14,260]. Generally, the airflow rate is 80% at the center flow in the inner column and 20% at the peripheral that causes the circulation of powder particles [261]. The powder particles to be coated must be dense and spherical with good flowability and narrow size distribution. Spherical shaped particles require fewer coating materials than non-spherical particles of the same shell thickness due to less surface area. Additionally, dense particles will reduce the accumulation of these particles in the filter bags of the fluidized bed machine [261]. The main driving force for drying is the heat transfer between the coating/particle surface and air. The mass transfer is driven by the partial water vapor difference between the particle surface and air and on mass transfer coefficient [262]. Hence, the water content, temperature, and relative humidity of the air play a major role in controlling the drying rate of the coated particles. This technique has a wide application in encapsulating probiotics and vitamins for enhancing its bioavailability by hindering interactions with other compounds (e.g., tannins, phytates) [263]. The development of agglomerated particles is the major limitation of this technique that occurs when the temperature of the particle surface is above the glass transition temperature of the coating material. This results in the coalescence of the wet coating materials that form liquid bridges with the particles through adhesion. These liquid bridges solidify after drying, forming an agglomerated larger particle [264]. However, the phenomenon of uncontrolled agglomeration is influenced by the process parameters viz. initial fluidization velocity, minimum fluidization velocity, feed flowrate (encapsulating materials). For instance, Benelli and Oliveira [265] in their study reported an increase in percentage agglomeration on decreasing the feed flow rate because of the collision between wet particles that strengthened the cohesive forces formed by the liquid bridges. Thus, future research on the use of this method for coating bioactive compounds with minimal agglomeration needs to be addressed.

### *4.5. Freeze Drying Bulk Encapsulation*

Lyophilization, also called freeze-drying or cryodesiccation, is applied for heat-sensitive bioactive compounds because of its low-temperature dehydration process. It is a multi-stage operation that includes pre-freezing of feed emulsion at sub-zero conditions to concentrate the formulation; freezing stage involves cooling the material below its triple point to ensure proper sublimation of ice crystals; primary drying refers to the drying phase where the vacuum pressure is maintained along with the application of enough heat to induce sublimation; secondary drying aims at removal of unfrozen water molecules by increasing the temperature above the primary drying (<0 °C), typically the product temperature is maintained between 20–40 °C, to break hydrogen bond between the bound water and materials [266]. The freeze-dried powders have low moisture content with high powder porosity due to the slow freezing rate and formation of large ice crystals that induce the expansion of matrix structure during the freeze-drying process [267]. In a study conducted by Rezende et al. [268] on encapsulation of bioactive compounds from acerola pulp and residue, the microencapsulation efficiency of freeze-dried microcapsules was found higher than spray-dried powders (gum Arabic + maltodextrin—1:1). The freeze-dried powders had a porous and irregular surface which accelerated the premature release of core materials during the drying process. Despite the porous surface, the freeze-dried powders showed good antioxidant activity comparable to spray-dried powder. Due to the application of vacuum, it is a relatively energy-consuming process that might be reduced by optimizing the freeze-drying cycle to fit more cycles in the life span as well as the batch drying process is time extensive (around 24–48 h). Overall, the initial investment is the limiting factor, while the operational and capital cost of the industrial freeze dryer was recorded to be 702 €/cycle [269].

## 5. Development of Functional and Nutraceutical Food Products

F&V by-products are rich in bioactive components and can be effectively incorporated into food products. In this way, the F&V waste reintroduces into the food chain and mimic the ecological burden. The developed functional food products with bioactives can have antioxidant, antimicrobial, neurotransmitter, anti-diabetic, antifungal, anticancer properties, etc. [18]. These by-products in some forms are added in various food products like in animal products such as beef, chicken, meat, sausages, etc., dairy products, i.e., cheese, yogurt, curd, butter, ice-cream, beverages i.e., orange, apple, carrot juices and in bakery products like cookies, cakes, muffins, etc., and in candies and fruit purees [21,270]. Table 5 summarizes some recent food products developed from extracted bioactives from various F&V by-products. Lipid oxidation is a serious problem in the processing of food products, thus affecting the organoleptic properties and shortening the shelf life of food products. The addition of bioactives in cheese, butter, curd, meat products, and fish products mimic lipid oxidation. Basanta et al. [271] added β-carotene, lutein, tocopherols, and polyphenols extracted from plum pomace in chicken patties to prevent lipid oxidation. Abid et al. [272] extracted lycopene and phenolics from tomato waste and added them to butter. The authors reported that butter enriched with 400 mg of tomato by processing extract/kg of butter has the lowest peroxide values after 60 days of storage at 4 °C and concluded that lycopene and phenolics extended the shelf life of butter while reducing the lipid oxidation. Beverages are a direct way to consume bioactives. Several studies have reported that TPC and AA were significantly improved after the addition of F&V by-products in beverages [273–276]. Furthermore, to enrich the nutritional value of bakery products, F&V by-products can be added in form of powders or extracts. For instance, Hidalgo, A., Brandolini, A., Čanadanović-Brunet, J., Ćetković, G., and Šaponjac, V. T. J. F. c. [277] incorporated beetroot pomace extracts (PE) and microencapsulated pomace extracts (PME) in the biscuits. PME-enriched biscuits were rich in TPC, AA, and betanin content compared to PE. In another study, wheat flour was partially replaced by grape pomace powder (0–20%) in the preparation of cookies. TPC, TFC, and anthocyanin content in the cookies were increased 2.3, 2, and 12.5-fold respectively, compared to cookies without pomace powder [278]. It can be seen from Table 3 that maximal extraction was achieved using solvent extraction technology for product development. Very few studies have reported the use of non-thermal extraction techniques. Pasqualone et al. [279] extracted phenolic compounds from artichoke extracts using ultrasonication-assisted extraction technology. The extracts were incorporated in fresh pasta and it was found that antioxidant activity and phenolic compounds increased relative to a control pasta. Amofa-Diatuo, Anang, Barba, and Tiwari [280] extracted isothiocyanates (ITC) from cauliflower stems and leaves using sonication. These extracts were incorporated in apple juice and 10% extract addition was found to be acceptable with good sensory properties. PEF and MAE technologies have been used for the extraction of bioactives however, the development of functional food using PEF and MAE continuous extraction technology is still under research [281,282]. Functional food product development using SCFE and PLE methods is also limited to date [283]. A lot of research has been done for the extraction of bioactives, but their application in the food industry is limited. Recently, Souza et al. [284] extracted total flavonols, gallic acid, and caffeine from the black tea using the PLE technique and developed bread. They found that no loses of extracted flavonols during baking of bread at 180 °C for 20 min. The demand for functional and nutraceutical food products enriched with bioactives is increasing continuously [285,286]. Thus, further research on the development of food products using green extraction technologies like UAE, PLE, MAE, PEF is needed. Moreover, these techniques are the best alternative to conventional methods and require less extraction time, chemical requirements, and low-cost process. The selection of extraction methods may influence the extraction efficiencies in different food products. We need to look for the best extraction technique for the development of specific food products.

**Table 5.** Development of value-added food products from different waste parts of fruits and vegetables.

| Raw Material | Waste Part | Extracted/Target Compound | Raw material Processing Method | Value-Added Product | Reported Functional Improvements | References |
|---|---|---|---|---|---|---|
| Apple | Pomace | TPC, TFC, DPPH; TDF | Tray drying | Gluten-free cracker; Ice cream | Rich in antioxidants, dietary fiber, and minerals, specific for coeliac disease patients; dietary fiber-rich products | [287,288] |
| Tamarind | Seed | β-carotene, TPC, TFC, TAA, TCT | Sun drying | Cookies and mango juice | Natural antioxidants enhance nutraceutical properties | [274] |
| Banana | Peel | DPPH, ABTS | Solvent Extraction | Orange juice | Increased antioxidant activity | [275,276] |
| Grapes | Pomace | TPC, DPPH | Freeze-dried; | Yogurt Cheese | Antioxidant properties, anti-inflammatory, anticancer, antimicrobial, and cardiovascular protective properties; | [289,290] |
| | | TPC, DPPH, FRAP | Solid-phase extraction | Bread | Help in prevention of diseases like atherosclerosis, cancer, cardiovascular disease, and type 2 diabetes; | [291] |
| | | TPC, DPPH, ORAC, ICA | Solvent Extraction | Chicken Meat | Antioxidant properties; | [292] |
| | | TPC, TFC, ABTS, FRAP | Solvent Extraction | Cheese | Improved nutritional properties, sensory attributes like friability and adhesiveness | [293] |
| | | TPC, ARP | Solvent Extraction | Fermented milk | Natural antioxidants | [294] |

**Table 5.** *Cont.*

| Raw Material | Waste Part | Extracted/Target Compound | Raw material Processing Method | Value-Added Product | Reported Functional Improvements | References |
|---|---|---|---|---|---|---|
| Beetroot | Pomace | TPC, AA, Betalain<br>TPC, FRAP, ABTS, Betacyanins | Solvent Extraction<br>Solvent Extraction with ultrasound | Candy<br>Biscuit | Rich in betalain, antioxidant, and phenolics<br>Increased pathogen resistance, anti-inflammatory effect, and antioxidant activities | [277,295] |
| Pineapple<br>Apple<br>Melon | Central Axis<br>Endocarp<br>Peels | TDF | Freeze drying | Cookies | Improved nutritional properties | [296] |
| Raspberry | Pomace | TPC, TAC, RSC, Free EA, ETs | Solvent Extraction and freeze-dried | Fruit Purees | Antioxidant, antimutagenic, anticarcinogenic, antibacterial, and antiviral properties | [297] |
| Orange | Peel and pulp | TPC, DPPH | Sonication | Carrot juice | Improved functional quality and shelf life | [273] |
| Artichoke | outer bracts, leaves and stems<br>outer bracts, leaves and stems<br>outer bracts, leaves and stems,<br>Outer bracts, leaves, and stems | TPC, AA | Ultrasound-assisted extraction (UAE) | Pasta | Nutraceutical properties, reduction of cholesterol, antioxidant properties | [279] |
| Ripe Mango | Peel | TPC, DPPH | Tray drying | Whole Wheat Bread | Rich in antioxidants, help in the prevention of cardiovascular and neurodegenerative diseases, cancers, etc. | [298] |
| Mango | Seed Kernel | TPC, DPPH | Solvent Extraction | Mango Powder | Natural antibiotic and antifungal properties | [299] |
| Blueberry and Cranberry | Pomace | TPC, RSA | Solvent Extraction | Mustard | Anticancer, antioxidant, and antimicrobial properties | [300] |
| Pomegranate | Peel | TPC, DPPH, ABTS<br>TPC, FRAP, DPPH | Solvent Extraction<br>Solvent Extraction and freeze-drying | Curd<br>Cookies | Increase the anti-oxidative attributes and shelf life of the product<br>Antioxidant, antimicrobial & nutraceutical properties | [301,302] |
| Pineapple | Peel and stems | Bromelain (BR) | Polyelectrolyte precipitation | Flour | Enhance the growth of good bacteria in the human microbiota, high antioxidant activity in human gut | [303] |
| Passion fruit and Orange | Albedo | TDF | Oven drying | Cake | Reduce cholesterol, and reduce diabetes risks and obesity | [304] |
| Tomato | Peels and seeds | TPC, RSA, lycopene | Solvent Extraction | Butter | Extended shelf life of butter with antioxidant properties | [272] |
| Cauliflower | Leaves and stem | Isothiocyanates (ITC), TPC, TAA | Ultrasound-assisted extraction (UAE) | Apple juice beverage | Anticarcinogenic properties | [280] |

TPC—total phenolic content; DPPH—2,2-diphenyl-1-picrylhydrazyl; TDF—Total Dietary Fibre; TFC—Total flavonoid content; TAA—Total antioxidant activity; TCT—total condensed tannins; RSA—radical scavenging activity; FRAP—Ferric reducing antioxidant power; ABTS—2 2′-azino-bis(3 ethylbenzothiazoline-6- sulfonic acid); ORAC—oxygen radical absorbance capacity; ARP—Antiradical power; AA—Antioxidant activity; TAC—Total anthocyanin content; EA—ellagic acid; ETs—ellagitannins contents.

In nut and shell, developed food products with F&V by-products are rich in bioactives and fibers. The amount of F&V added in the food products depends upon the dosage of bioactives required, the matrix in which they are added, sensory analysis, and consumer acceptability.

## 6. Summary and Future Trends

Food production and processing results in an enormous quantity of waste. These food wastes contain many beneficial bioactive compounds. The utilization of such food wastes by extracting functional compounds will help reduce environmental waste load and add value to the developed functional food product. Different extraction methods have been illustrated, providing an overview of recent trends to maximize yields. The demand for extracting bioactives by green technology with no solvent or minimal use of GRAS classified solvent is increasing. Targeted selection and optimization of an extraction technique for a specific bioactive may enhance the extraction efficiencies. However, owing to the potential toxicity of some organic solvents, solvents such as $CO_2$, water, and deep eutectic solvents can be used as alternatives. Advanced extraction methods that do not require any solvents is a future aim. More focus on non-thermal emergent technologies like PEF, or combinations of two or more techniques, could be given to ascertain the potential to obtain higher extraction yields, lower energy consumption, and environmental impact. Development of value-added food products by incorporating these F&V by-products directly and extracted bioactives can improve the nutritional value of food products. The quality of the bioactive components in the developed food products depends upon the processing methods and parameters. Moreover, there are limited studies on the amount of bioactive reaching the targeted site in the human body. So, further research on in vitro studies and animal studies needs to be done to evaluate the health benefits to the consumers.

## 7. Methodology of the Study

This review was focused on several key aspects that combine both theoretical knowledge and potential practical aspects of valorization of plant wastes. A semi-systematic approach was followed to conduct a literature review. The main criterion we chose was the inclusion of the majority of papers published in the last decade on the topics of this review that had a high citation. We used google scholar and web of science databases.

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## References

1. Choudhary, M.; Tripathi, S.; Kesharwani, R.K. Nutraceuticals Role in Stress, Aging, and Neuro-degenerative Disorders. In *Nutraceutical and Functional Foods in Disease Prevention*; IGI Global: Philadelphia, PSA, USA, 2019; pp. 288–306.
2. Esparza, I.; Jiménez-Moreno, N.; Bimbela, F.; Ancín-Azpilicueta, C.; Gandía, L.M. Fruit and vegetable waste management: Conventional and emerging approaches. *J. Environ. Manag.* **2020**, *265*, 110510. [CrossRef] [PubMed]
3. Jiménez-Moreno, N.; Esparza, I.; Bimbela, F.; Gandía, L.M.; Ancín-Azpilicueta, C. Valorization of selected fruit and vegetable wastes as bioactive compounds: Opportunities and challenges. *Crit. Rev. Environ. Sci. Technol.* **2020**, *50*, 2061–2108. [CrossRef]
4. Sawicka, B. Post-harvest Losses of Agricultural Produce. *Hist. Sci.* **2019**, 1–16. [CrossRef]
5. Joglekar, S.N.; Pathak, P.D.; Mandavgane, S.A.; Kulkarni, B.D. Process of fruit peel waste biorefinery: A case study of citrus waste biorefinery, its environmental impacts and recommendations. *Environ. Sci. Pollut. Res.* **2019**, *26*, 34713–34722. [CrossRef] [PubMed]
6. Da Silva, A.C.; Jorge, N. Bioactive compounds of the lipid fractions of agro-industrial waste. *Food Res. Int.* **2014**, *66*, 493–500. [CrossRef]
7. Dorta, E.; Sogi, D.S. Value added processing and utilization of pineapple by-products. In *Hand-Book of Pineapple Technology, Production, Postharvest Science, Processing and Nutrition*; John Wiley and Sons: Oxford, UK, 2017; pp. 196–220.
8. Banerjee, J.; Singh, R.; Vijayaraghavan, R.; MacFarlane, D.; Patti, A.F.; Arora, A. Bioactives from fruit processing wastes: Green approaches to valuable chemicals. *Food Chem.* **2017**, *225*, 10–22. [CrossRef]
9. Kumar, K.; Yadav, A.N.; Kumar, V.; Vyas, P.; Dhaliwal, H.S. Food waste: A potential bioresource for extraction of nutraceuticals and bioactive compounds. *Bioresour. Bioprocess.* **2017**, *4*, 18. [CrossRef]
10. Machado, A.P.D.F.; Pereira, A.L.D.; Barbero, G.F.; Martínez, J. Recovery of anthocyanins from residues of *Rubus fruticosus*, *Vaccinium myrtillus* and *Eugenia brasiliensis* by ultrasound assisted extraction, pressurized liquid extraction and their combination. *Food Chem.* **2017**, *231*, 1–10. [CrossRef]
11. Sagar, N.A.; Pareek, S.; Sharma, S.; Yahia, E.M.; Lobo, M.G. Fruit and vegetable waste: Bioactive compounds, their extraction, and possible utilization. *Compr. Rev. Food Sci. Food Saf.* **2018**, *17*, 512–531. [CrossRef]

12. Zainal-Abidin, M.H.; Hayyan, M.; Hayyan, A.; Jayakumar, N.S. New horizons in the extraction of bioactive compounds using deep eutectic solvents: A review. *Anal. Chim. Acta* **2017**, *979*, 1–23. [CrossRef]
13. Norfezah, M.N.; Hardacre, A.; Brennan, C.S. Comparison of waste pumpkin material and its potential use in extruded snack foods. *Food Sci. Technol. Int.* **2011**, *17*, 367–373. [CrossRef] [PubMed]
14. Đorđević, V.; Balanč, B.; Belščak-Cvitanović, A.; Lević, S.; Trifković, K.; Kalušević, A.; Nedović, V. Trends in encapsulation technologies for delivery of food bioactive compounds. *Food Eng. Rev.* **2015**, *7*, 452–490. [CrossRef]
15. Drosou, C.G.; Krokida, M.K.; Biliaderis, C.G. Encapsulation of bioactive compounds through electrospinning/electrospraying and spray drying: A comparative assessment of food-related applications. *Dry. Technol.* **2017**, *35*, 139–162. [CrossRef]
16. Rehman, A.; Ahmad, T.; Aadil, R.M.; Spotti, M.J.; Bakry, A.M.; Khan, I.M.; Tong, Q. Pec-tin polymers as wall materials for the nano-encapsulation of bioactive compounds. *Trends Food Sci. Technol.* **2019**, *90*, 35–46. [CrossRef]
17. Shishir, M.R.I.; Xie, L.; Sun, C.; Zheng, X.; Chen, W. Advances in micro and nano-encapsulation of bioactive compounds using biopolymer and lipid-based transporters. *Trends Food Sci. Technol.* **2018**, *78*, 34–60. [CrossRef]
18. Ahmad, F.; Zaidi, S.; Ahmad, S. *Role of By-Products of Fruits and Vegetables in Functional Foods Functional Food Products and Sustainable Healt*; Springer: Berlin/Heidelberg, Germany, 2020; pp. 199–218.
19. Kruczek, M.; Gumul, D.; Kačániová, M.; Ivanišhová, E.; Mareček, J.; Gambuś, H. Industrial Apple Pomace By-Products as A Potential Source of Pro-Health Compounds In Functional Food. *J. Microbiol. Biotechnol. Food Sci.* **2019**, *2019*, 22–26. [CrossRef]
20. Kumar, A.; Mishra, S. Formulation and Processing of papaya by products. *Int. J. Food Sci. Nutr.* **2019**, *4*, 143–148.
21. Trigo, J.P.; Alexandre, E.M.; Saraiva, J.A.; Pintado, M.E. High value-added compounds from fruit and vegetable by-products–Characterization, bioactivities, and application in the development of novel food products. *Crit. Rev. Food Sci. Nutr.* **2020**, *60*, 1388–1416. [CrossRef]
22. Espinosa-Alonso, L.G.; Valdez-Morales, M.; Aparicio-Fernandez, X.; Medina-Godoy, S.; Guevara-Lara, F. Vegetable By-products. In *Food Wastes By-Products Nutraceutical Health Potential*; Wiley-Blackwell: Hoboken, NJ, USA, 2020; pp. 223–266. [CrossRef]
23. Bar-Ya'akov, I.; Tian, L.; Amir, R.; Holland, D. Primary metabolites, anthocyanins, and hydrolyzable tannins in the pomegranate fruit. *Front. Plant Sci.* **2019**, *10*, 620. [CrossRef]
24. Jan, N.U.; Ahmad, B.; Ali, S.; Adhikari, A.; Ali, A.; Jahan, A.; Ali, H. Steroidal alkaloids as an emerging therapeutic alternative for investigation of their immunosuppressive and hepatoprotective potential. *Front. Pharmacol.* **2017**, *8*, 114. [CrossRef]
25. Sharma, G.N.; Gupta, G.; Sharma, P. A comprehensive review of free radicals, antioxidants, and their relationship with human ailments. *Crit. Rev.™ Eukaryot. Gene Expr.* **2018**, *28*, 139–154. [CrossRef] [PubMed]
26. Ben-Othman, S.; Jõudu, I.; Bhat, R. Bioactives from agri-food wastes: Present insights and future challenges. *Molecules* **2020**, *25*, 510. [CrossRef] [PubMed]
27. Padam, B.S.; Tin, H.S.; Chye, F.Y.; Abdullah, M.I. Banana by-products: An under-utilized renewable food biomass with great potential. *J. Food Sci. Technol.* **2014**, *51*, 3527–3545. [CrossRef] [PubMed]
28. Szymańska-Chargot, M.; Chylińska, M.; Gdula, K.; Kozioł, A.; Zdunek, A. Isolation and charac-terization of cellulose from different fruit and vegetable pomaces. *Polymers* **2017**, *9*, 495. [CrossRef]
29. Merhan, O. Biochemistry and antioxidant properties of carotenoids. *Carotenoids* **2017**, *5*, 51.
30. Nguyen, V.T.; Scarlett, C.J. Mass proportion, bioactive compounds and antioxidant capacity of carrot peel as affected by various solvents. *Technologies* **2016**, *4*, 36. [CrossRef]
31. Mezzomo, N.; Ferreira, S.R. Carotenoids functionality, sources, and processing by supercritical technology: A review. *J. Chem.* **2016**, *2016*, 3164312. [CrossRef]
32. Islamian, J.P.; Mehrali, H. Lycopene as a carotenoid provides radioprotectant and antioxidant effects by quenching radiation-induced free radical singlet oxygen: An overview. *Cell J. (Yakhteh)* **2015**, *16*, 386.
33. Wang, Y.; Chung, S.J.; McCullough, M.L.; Song, W.O.; Fernandez, M.L.; Koo, S.I.; Chun, O.K. Dietary carotenoids are associated with cardiovascular disease risk biomarkers mediated by serum carotenoid concentrations. *J. Nutr.* **2014**, *144*, 1067–1074. [CrossRef]
34. Cerna, J.; Athari, N.; Robbs, C.; Walk, A.; Edwards, C.; Adamson, B.; Khan, N. Macular Carotenoids, Retinal Morphometry, and Cognitive Function in Multiple Sclerosis (OR05–07–19). *Curr. Dev. Nutr.* **2019**, *3* (Suppl. S1), nzz029-OR05. [CrossRef]
35. Hwang, S.; Lim, J.W.; Kim, H. Inhibitory effect of lycopene on amyloid-β-induced apoptosis in neuronal cells. *Nutrients* **2017**, *9*, 883. [CrossRef] [PubMed]
36. Wu, J.; Cho, E.; Willett, W.C.; Sastry, S.M.; Schaumberg, D.A. Intakes of Lutein, Zeaxanthin, and Other Carotenoids and Age-Related Macular Degeneration during 2 Decades of Prospective Follow-up. *JAMA Ophthalmol.* **2015**, *133*, 1415–1424. [CrossRef] [PubMed]
37. Graff, R.E.; Pettersson, A.; Lis, R.T.; Ahearn, T.U.; Markt, S.C.; Wilson, K.M.; Mucci, L.A. Dietary lycopene intake and risk of prostate cancer defined by ERG protein expression. *Am. J. Clin. Nutr.* **2016**, *103*, 851–860. [CrossRef] [PubMed]
38. Gul, K.; Tak, A.; Singh, A.K.; Singh, P.; Yousuf, B.; Wani, A.A. Chemistry, encapsulation, and health benefits of β-carotene-A review. *Cogent Food Agric.* **2015**, *1*, 1018696. [CrossRef]
39. Khoo, H.E.; Prasad, K.N.; Kong, K.W.; Jiang, Y.; Ismail, A. Carotenoids and their isomers: Color pigments in fruits and vegetables. *Molecules* **2011**, *16*, 1710–1738. [CrossRef]
40. Pénicaud, C.; Achir, N.; Dhuique-Mayer, C.; Dornier, M.; Bohuon, P. Degradation of β-carotene during fruit and vegetable processing or storage: Reaction mechanisms and kinetic aspects: A review. *Fruits* **2011**, *66*, 417–440. [CrossRef]

41. Averilla, J.N.; Oh, J.; Kim, H.J.; Kim, J.S.; Kim, J.S. Potential health benefits of phenolic compounds in grape processing by-products. *Food Sci. Biotechnol.* **2019**, *28*, 1607–1615. [CrossRef]
42. Taofiq, O.; González-Paramás, A.M.; Barreiro, M.F.; Ferreira, I.C. Hydroxycinnamic acids and their derivatives: Cosmeceutical significance, challenges and future perspectives, a review. *Molecules* **2017**, *22*, 281. [CrossRef]
43. Deng, Y.; Li, Y.; Yang, F.; Zeng, A.; Yang, S.; Luo, Y.; Zhang, Y.; Xie, Y.; Ye, T.; Xia, Y.; et al. The extract from Punica granatum (pomegranate) peel induces apoptosis and impairs metastasis in prostate cancer cells. *Biomed. Pharmacother.* **2017**, *93*, 976–984. [CrossRef]
44. Durgadevi, P.K.S.; Saravanan, A.; Uma, S. Antioxidant Potential and Antitumour Activities of Nendran Banana Peels in Breast Cancer Cell Line. *Indian J. Pharm. Sci.* **2019**, *81*, 464–473.
45. Chacar, S.; Hajal, J.; Saliba, Y.; Bois, P.; Louka, N.; Maroun, R.G.; Faivre, J.F.; Fares, N. Long-term intake of phenolic compounds attenuates age-related cardiac remodeling. *Aging Cell* **2019**, *18*, e12894. [CrossRef] [PubMed]
46. Song, J.; Li, J.; Hou, F.; Wang, X.; Liu, B. Mangiferin inhibits endoplasmic reticulum stress-associated thioredoxin-interacting protein/NLRP3 inflammasome activation with regulation of AMPK in endothelial cells. *Metabolism* **2015**, *64*, 428–437. [CrossRef] [PubMed]
47. Testai, L.; Calderone, V. Nutraceutical value of citrus flavanones and their implications in cardiovascular disease. *Nutrients* **2017**, *9*, 502. [CrossRef] [PubMed]
48. Ho, G.T.T.; Kase, E.T.; Wangensteen, H.; Barsett, H. Phenolic elderberry extracts, anthocyanins, procyanidins, and metabolites influence glucose and fatty acid uptake in human skeletal muscle cells. *J. Agric. Food Chem.* **2017**, *65*, 2677–2685. [CrossRef] [PubMed]
49. Braidy, N.; Behzad, S.; Habtemariam, S.; Ahmed, T.; Daglia, M.; Mohammad Nabavi, S.; Fazel Naba, S. Neuroprotective effects of citrus fruit-derived flavonoids, nobiletin and tangeretin in alzheimer's and parkinson's disease. *CNS Neurol. Disord. Drug Targets Former. Curr. Drug Targets-CNS Neurol. Disord.* **2017**, *16*, 387–397. [CrossRef]
50. Havsteen, B.H. The biochemistry and medical significance of the flavonoids. *Pharmacol. Ther.* **2002**, *96*, 67–202. [CrossRef]
51. Moeller, S.M.; Voland, R.; Tinker, L.; Blodi, B.A.; Klein, M.L.; Gehrs, K.M.; Parekh, N. Associations between age-related nuclear cataract and lutein and zeaxanthin in the diet and serum in the Carotenoids in the Age-Related Eye Disease Study (CAREDS), an ancillary study of the women's health initiative. *Arch. Ophthalmol.* **2008**, *126*, 354–364. [CrossRef]
52. Bensalem, J.; Dudonné, S.; Gaudout, D.; Servant, L.; Calon, F.; Desjardins, Y.; Pallet, V. Poly-phenol-rich extract from grape and blueberry attenuates cognitive decline and improves neuronal function in aged mice. *J. Nutr. Sci.* **2018**, *7*, e19. [CrossRef]
53. Haskell-Ramsay, C.F.; Stuart, R.C.; Okello, E.J.; Watson, A.W. Cognitive and mood improvements following acute supplementation with purple grape juice in healthy young adults. *Eur. J. Nutr.* **2017**, *56*, 2621–2631. [CrossRef]
54. Ciriminna, R.; Fidalgo, A.; Delisi, R.; Carnaroglio, D.; Grillo, G.; Cravotto, G.; Pagliaro, M. High-quality essential oils extracted by an eco-friendly process from different citrus fruits and fruit regions. *ACS Sustain. Chem. Eng.* **2017**, *5*, 5578–5587. [CrossRef]
55. Jadhav, S.S. Value added products from Sapota: A review. *Int. J. Food Sci. Nutr.* **2018**, *3*, 114–120.
56. Baskar, M.; Hemalatha, G.; Muneeshwari, P. Traditional and *Med.* Importance of Sapota–Review. *Int. J. Curr. Microbiol. Appl. Sci.* **2020**, *9*, 1711–1717. [CrossRef]
57. Jain, P.K.; Soni, P.; Upmanyu, N.; Shivhare, Y. Evaluation of analgesic activity of *Manilkara zapota* (Leaves). *Eur. J. Exp. Biol.* **2011**, *1*, 14–17.
58. Rakholiya, K.; Kaneria, M.; Chanda, S. Inhibition of microbial pathogens using fruit and vegeta-ble peel extracts. *Int. J. Food Sci. Nutr.* **2014**, *65*, 733–739. [CrossRef]
59. Srivastava, M.; Hegde, M.; Chiruvella, K.K.; Koroth, J.; Bhattacharya, S.; Choudhary, B.; Raghavan, S.C. *Sapodilla plum* (*Achras sapota*) induces apoptosis in cancer cell lines and inhibits tumor progression in mice. *Sci. Rep.* **2014**, *4*, 6147. [CrossRef]
60. García, A.; Rodríguez-Juan, E.; Rodríguez-Gutiérrez, G.; Rios, J.J.; Fernández-Bolaños, J. Ex-traction of phenolic compounds from virgin olive oil by deep eutectic solvents (DESs). *Food Chem.* **2016**, *197*, 554–561. [CrossRef]
61. Lafarga, T.; Viñas, I.; Bobo, G.; Simó, J.; Aguiló-Aguayo, I. Effect of steaming and sous vide processing on the total phenolic content, vitamin C and antioxidant potential of the genus Brassica. *Innov. Food Sci. Emerg. Technol.* **2018**, *47*, 412–420. [CrossRef]
62. Rostagno, M.A.; Manchon, N.; Guillamon, E.; García-Lafuente, A.; Garicochea, A.V.; Martinez, J.A. Methods and techniques for the analysis of isoflavones in foods. In *Chromatography Types, Techniques and Methods*; Hurst, W.J., Ed.; Nova Science Publishers Inc.: Hauppauge, NY, USA, 2010; pp. 157–198.
63. Tambunan, A.P.; Bahtiar, A.; Tjandrawinata, R.R. Influence of extraction parameters on the yield, phytochemical, TLC-densitometric quantification of quercetin, and LC-MS profile, and how to standardize different batches for long term from *Ageratum conyoides* L. leaves. *Pharmacogn. J.* **2017**, *9*, 767–774. [CrossRef]
64. Su, D.; Wang, Z.; Dong, L.; Huang, F.; Zhang, R.; Jia, X.; Zhang, M. Impact of thermal processing and storage temperature on the phenolic profile and antioxidant activity of different varieties of lychee juice. *LWT* **2019**, *116*, 108578. [CrossRef]
65. Srinivasan, M.; Devipriya, N.; Kalpana, K.B.; Menon, V.P. Lycopene: An antioxidant and radio-protector against $\gamma$-radiation-induced cellular damages in cultured human lymphocytes. *Toxicology* **2009**, *262*, 43–49. [CrossRef]
66. Wang, Y.; Jacobs, E.J.; Newton, C.C.; McCullough, M.L. Lycopene, tomato products and prostate cancer-specific mortality among men diagnosed with nonmetastatic prostate cancer in the Cancer Prevention Study II Nutrition Cohort. *Int. J. Cancer* **2016**, *138*, 2846–2855. [CrossRef] [PubMed]

67. Cheng, H.M.; Koutsidis, G.; Lodge, J.K.; Ashor, A.; Siervo, M.; Lara, J. Tomato and lycopene supplementation and cardiovascular risk factors: A systematic review and meta-analysis. *Atherosclerosis* **2017**, *257*, 100–108. [CrossRef] [PubMed]
68. Pandya, D.; Akbari, S.; Bhatt, H.; Joshi, D.C. Standardization of solvent extraction process for *Lycopene extraction* from tomato pomace. *J. Appl. Biotechnol. BioEng.* **2017**, *2*, 00019. [CrossRef]
69. Huang, W.; Li, Z.; Niu, H.; Li, D.; Zhang, J. Optimization of operating parameters for supercritical carbon dioxide extraction of lycopene by response surface methodology. *J. Food Eng.* **2008**, *89*, 298–302. [CrossRef]
70. Friedman, M.; Huang, V.; Quiambao, Q.; Noritake, S.; Liu, J.; Kwon, O.; Cheng, L.W. Potato peels and their bioactive glycoalkaloids and phenolic compounds inhibit the growth of pathogenic trichomonads. *J. Agric. Food Chem.* **2018**, *66*, 7942–7947. [CrossRef]
71. Kenny, O.M.; Brunton, N.P.; Rai, D.K.; Collins, S.G.; Jones, P.W.; Maguire, A.R.; O'Brien, N.M. Cytotoxic and apoptotic potential of potato glycoalkaloids in a number of cancer cell lines. *J. Agric. Sci. Appl.* **2013**, *2*, 184–192. [CrossRef]
72. Lee, K.R.; Kozukue, N.; Han, J.S.; Park, J.H.; Chang, E.Y.; Baek, E.J.; Friedman, M. Glycoalkaloids and metabolites inhibit the growth of human colon (HT29) and liver (HepG2) cancer cells. *J. Agric. Food Chem.* **2004**, *52*, 2832–2839. [CrossRef]
73. Ji, X.; Rivers, L.; Zielinski, Z.; Xu, M.; MacDougall, E.; Stephen, J.; Robertson, G.S. Quantitative analysis of phenolic components and glycoalkaloids from 20 potato clones and in vitro evaluation of antioxidant, cholesterol uptake, and neuroprotective activities. *Food Chem.* **2012**, *133*, 1177–1187. [CrossRef]
74. Friedman, M.; Roitman, J.N.; Kozukue, N. Glycoalkaloid and calystegine contents of eight potato cultivars. *J. Agric. Food Chem.* **2003**, *51*, 2964–2973. [CrossRef]
75. Martinez-Fernandez, J.S.; Seker, A.; Davaritouchaee, M.; Gu, X.; Chen, S. Recovering Valuable Bioactive Compounds from Potato Peels with Sequential Hydrothermal Extraction. *Waste Biomass Valorization* **2020**, 1–17. [CrossRef]
76. Kamiloglu, S.; Grootaert, C.; Capanoglu, E.; Ozkan, C.; Smagghe, G.; Raes, K.; Van Camp, J. Anti-inflammatory potential of black carrot (*Daucus carota* L.) polyphenols in a co-culture model of intestinal Caco-2 and endothelial EA. hy926 cells. *Mol. Nutr. Food Res.* **2017**, *61*, 1600455. [CrossRef] [PubMed]
77. Sevimli-Gur, C.; Cetin, B.; Akay, S.; Gulce-Iz, S.; Yesil-Celiktas, O. Extracts from black carrot tissue culture as potent anticancer agents. *Plant Foods Hum. Nutr.* **2013**, *68*, 293–298. [CrossRef] [PubMed]
78. Ghazala, I.; Sila, A.; Frikha, F.; Driss, D.; Ellouz-Chaabouni, S.; Haddar, A. Antioxidant and antimicrobial properties of water soluble polysaccharide extracted from carrot peels by-products. *J. Food Sci. Technol.* **2015**, *52*, 6953–6965. [CrossRef]
79. Chantaro, P.; Devahastin, S.; Chiewchan, N. Production of antioxidant high dietary fiber powder from carrot peels. *LWT Food Sci. Technol.* **2008**, *41*, 1987–1994. [CrossRef]
80. Sotiroudis, G.; Melliou, E.; Sotiroudis, T.G.; Chinou, I. Chemical analysis, antioxidant and antimicrobial activity of three *Greek cucumber* (*Cucumis sativus*) cultivars. *J. Food Bio-Chem.* **2010**, *34*, 61–78. [CrossRef]
81. Dixit, Y.; Kar, A. Protective role of three vegetable peels in alloxan induced diabetes mellitus in male mice. *Plant Foods Human Nutr.* **2010**, *65*, 284–289. [CrossRef]
82. Zeyada, N.N.; Zeitoum, M.A.M.; Barbary, O.M. Utilization of some vegetables and fruit waste as natural antioxidants. *Alex. J. Food Sci. Technol.* **2008**, *5*, 1–11.
83. Tadee, P.; Chukiatsiri, K.; Amornlerdpisan, D.; Paserakung, A.; Kittiwan, N. Antimicrobial effect of *Japanese pumpkin* (*Cucurbita maxima*) extract on local mastitis pathogen. *Vet. Integr. Sci.* **2020**, *18*, 141–152.
84. Chen, X.; Qian, L.; Wang, B.; Zhang, Z.; Liu, H.; Zhang, Y.; Liu, J. Synergistic hypoglycemic effects of pumpkin polysaccharides and puerarin on type II diabetes mellitus mice. *Molecules* **2019**, *24*, 955. [CrossRef]
85. Saavedra, M.J.; Aires, A.; Dias, C.; Almeida, J.A.; De Vasconcelos, M.C.B.M.; Santos, P.; Rosa, E.A. Evaluation of the potential of squash pumpkin by-products (seeds and shell) as sources of antioxidant and bioactive compounds. *J. Food Sci. Technol.* **2015**, *52*, 1008–1015. [CrossRef]
86. Wu, H.; Luo, T.; Li, Y.M.; Gao, Z.P.; Zhang, K.Q.; Song, J.Y.; Cao, Y.P. Granny Smith apple procyanidin extract upregulates tight junction protein expression and modulates oxidative stress and inflammation in lipopolysaccharide-induced Caco-2 cells. *Food Funct.* **2018**, *9*, 3321–3329. [CrossRef] [PubMed]
87. Zielinska, D.; Laparra-Llopis, J.M.; Zielinski, H.; Szawara-Nowak, D.; Giménez-Bastida, J.A. Role of apple phytochemicals, phloretin and phloridzin, in modulating processes related to intestinal inflammation. *Nutrients* **2019**, *11*, 1173. [CrossRef] [PubMed]
88. Ferretti, G.; Turco, I.; Bacchetti, T. Apple as a Source of Dietary Phytonutrients: Bioavailability and Evidence of Protective Effects against Human Cardiovascular Disease. *Sci. Res.* **2014**, *5*, 1234–1246. [CrossRef]
89. Lam, C.K.; Zhang, Z.; Yu, H.; Tsang, S.Y.; Huang, Y.; Chen, Z.Y. Apple polyphenols inhibit plasma CETP activity and reduce the ratio of non-HDL to HDL cholesterol. *Mol. Nutr. Food Res.* **2008**, *52*, 950–958. [CrossRef] [PubMed]
90. McCann, M.J.; Gill, C.I.R.; O'brien, G.; Rao, J.R.; McRoberts, W.C.; Hughes, P.; Rowland, I.R. Anti-cancer properties of phenolics from apple waste on colon carcinogenesis in vitro. *Food Chem. Toxicol.* **2007**, *45*, 1224–1230. [CrossRef] [PubMed]
91. Vodnar, D.C.; Călinoiu, L.F.; Dulf, F.V.; Ştefănescu, B.E.; Crişan, G.; Socaciu, C. Identification of the bioactive compounds and antioxidant, antimutagenic and antimicrobial activities of thermally processed agro-industrial waste. *Food Chem.* **2017**, *231*, 131–140. [CrossRef]
92. Fernández, K.; Labra, J. Simulated digestion of proanthocyanidins in grape skin and seed ex-tracts and the effects of digestion on the angiotensin I-converting enzyme (ACE) inhibitory activity. *Food Chem.* **2013**, *139*, 196–202. [CrossRef]

93. Lanzi, C.R.; Perdicaro, D.J.; Antoniolli, A.; Fontana, A.R.; Miatello, R.M.; Bottini, R.; Prieto, M.A.V. Grape pomace and grape pomace extract improve insulin signaling in high-fat-fructose fed rat-induced metabolic syndrome. *Food Funct.* **2016**, *7*, 1544–1553. [CrossRef]
94. Hogan, S.; Zhang, L.; Li, J.; Sun, S.; Canning, C.; Zhou, K. Antioxidant rich grape pomace extract suppresses postprandial hyperglycemia in diabetic mice by specifically inhibiting alpha-glucosidase. *Nutr. Metab.* **2010**, *7*, 1–9. [CrossRef]
95. Jara-Palacios, M.J.; Hernanz, D.; Cifuentes-Gomez, T.; Escudero-Gilete, M.L.; Heredia, F.J.; Spencer, J.P. Assessment of white grape pomace from winemaking as source of bioactive compounds, and its antiproliferative activity. *Food Chem.* **2015**, *183*, 78–82. [CrossRef]
96. Chacar, S.; Itani, T.; Hajal, J.; Saliba, Y.; Louka, N.; Faivre, J.F.; Maroun, R.; Fares, N. The impact of long-term in-take of phenolic compoundsrich grape pomace on rat gut microbiota. *J. Food Sci.* **2018**, *83*, 246–251. [CrossRef] [PubMed]
97. Gouvinhas, I.; Santos, R.A.; Queiroz, M.; Leal, C.; José, M.; Domínguez-perles, R.; Barros, A.I.R.N.A. Industrial Crops & Products Monitoring the antioxidant and antimicrobial power of grape (*Vitis vinifera* L.) stems phenolics over long-term storage. *Ind. Crops Prod.* **2018**, *126*, 83–91.
98. Iora, S.R.; Maciel, G.M.; Zielinski, A.A.; da Silva, M.V.; Pontes, P.V.D.A.; Haminiuk, C.W.; Gran-ato, D. Evaluation of the bioactive compounds and the antioxidant capacity of grape pomace. *Int. J. Food Sci. Technol.* **2015**, *50*, 62–69. [CrossRef]
99. Neyrinck, A.M.; Van Hée, V.F.; Bindels, L.B.; De Backer, F.; Cani, P.D.; Delzenne, N.M. Polyphenol-rich extract of pomegranate peel alleviates tissue inflammation and hypercholesterolaemia in high-fat diet-induced obese mice: Potential implication of the gut microbiota. *Br. J. Nutr.* **2013**, *109*, 802–809. [CrossRef] [PubMed]
100. Kanlayavattanakul, M.; Chongnativisit, W.; Chaikul, P.; Lourith, N. Phenolic-rich Pomegranate Peel Extract: In Vitro, Cellular, and In Vivo Activities for Skin Hyperpigmentation Treatment. *Planta Medica* **2020**, *86*, 749–759. [CrossRef] [PubMed]
101. Li, Y.; Guo, C.; Yang, J.; Wei, J.; Xu, J.; Cheng, S. Evaluation of antioxidant properties of pomegranate peel extract in comparison with pomegranate pulp extract. *Food Chem.* **2006**, *96*, 254–260. [CrossRef]
102. Bigoniya, P.; Singh, K. Ulcer protective potential of standardized hesperidin, a citrus flavonoid isolated from *Citrus sinensis*. *Rev. Bras. Farmacogn.* **2014**, *24*, 330–340. [CrossRef]
103. Rawson, N.E.; Ho, C.T.; Li, S. Efficacious anti-cancer property of flavonoids from citrus peels. *Food Sci. Hum. Wellness* **2014**, *3*, 104–109. [CrossRef]
104. Chen, Z.T.; Chu, H.L.; Chyau, C.C.; Chu, C.C.; Duh, P.D. Protective effects of sweet orange (Citrus sinensis) peel and their bioactive compounds on oxidative stress. *Food Chem.* **2012**, *135*, 2119–2127. [CrossRef]
105. Omar, J.; Alonso, I.; Garaikoetxea, A.; Etxebarria, N. Optimization of focused ultrasound extraction (FUSE) and supercritical fluid extraction (SFE) of citrus peel volatile oils and antioxidants. *Food Anal. Methods* **2013**, *6*, 1244–1252. [CrossRef]
106. Jagannath, A.; Biradar, R. Comparative Evaluation of Soxhlet and Ultrasonics on the Structural Morphology and Extraction of Bioactive Compounds of Lemon (*Citrus limon* L.) Peel. *J. Food Chem. NanoTechnol.* **2019**, *5*, 56–64. [CrossRef]
107. Singanusong, R.; Nipornram, S.; Tochampa, W.; Rattanatraiwong, P. Low power ultrasound-assisted extraction of phenolic compounds from mandarin (*Citrus reticulata* Blanco cv. *Sainam-pueng*) and lime (*Citrus aurantifolia*) peels and the antioxidant. *Food Anal. Methods* **2015**, *8*, 1112–1123. [CrossRef]
108. Mahato, N.; Sinha, M.; Sharma, K.; Koteswararao, R.; Cho, M.H. Modern Extraction and Purification Techniques for Obtaining High Purity Food-Grade Bioactive Compounds and Value-Added Co-Products from Citrus Wastes. *Foods* **2019**, *8*, 523. [CrossRef] [PubMed]
109. Saleh, S.; El-Maraghy, N.; Reda, E.; Barakat, W. Modulation of diabetes and dyslipidemia in diabetic insulin-resistant rats by mangiferin: Role of adiponectin and TNF-α. *Anais Acad. Bra-Sileira Ciênc.* **2014**, *86*, 1935–1948. [CrossRef] [PubMed]
110. Hou, J.; Zheng, D.; Zhong, G.; Hu, Y. Mangiferin mitigates diabetic cardiomyopathy in strepto-zotocin-diabetic rats. *Can. J. Physiol. Pharmacol.* **2013**, *91*, 759–763. [CrossRef]
111. Kim, H.; Moon, J.Y.; Kim, H.; Lee, D.S.; Cho, M.; Choi, H.K.; Cho, S.K. Antioxidant and antiproliferative activities of mango (*Mangifera indica* L.) flesh and peel. *Food Chem.* **2010**, *121*, 429–436. [CrossRef]
112. Torres-León, C.; Rojas, R.; Contreras-Esquivel, J.C.; Serna-Cock, L.; Belmares-Cerda, R.E.; Aguilar, C.N. Mango seed: Functional and nutritional properties. *Trends Food Sci. Technol.* **2016**, *55*, 109–117. [CrossRef]
113. Jeong, J.J.; Jang, S.E.; Hyam, S.R.; Han, M.J.; Kim, D.H. Mangiferin ameliorates colitis by inhibiting IRAK1 phosphorylation in NF-κB and MAPK pathways. *Eur. J. Pharmacol.* **2014**, *740*, 652–661. [CrossRef]
114. Ajila, C.M.; Bhat, S.G.; Rao, U.P. Valuable components of raw and ripe peels from two Indian mango varieties. *Food Chem.* **2007**, *102*, 1006–1011. [CrossRef]
115. Guo, H.; Luo, H.; Yuan, H.; Xia, Y.; Shu, P.; Huang, X.; Deng, J. Litchi seed extracts diminish prostate cancer progression via induction of apoptosis and attenuation of EMT through Akt/GSK-3β signaling. *Sci. Rep.* **2017**, *7*, 1–13. [CrossRef]
116. Wang, X.; Yuan, S.; Wang, J.; Lin, P.; Liu, G.; Lu, Y.; Wei, Y. Anticancer activity of litchi fruit pericarp extract against human breast cancer in vitro and in vivo. *Toxicol. Appl. Pharmacol.* **2006**, *215*, 168–178. [CrossRef] [PubMed]
117. Rangkadilok, N.; Sitthimonchai, S.; Worasuttayangkurn, L.; Mahidol, C.; Ruchirawat, M.; Satayavivad, J. Evaluation of free radical scavenging and antityrosinase activities of standardized longan fruit extract. *Food Chem. Toxicol.* **2007**, *45*, 328–336. [CrossRef] [PubMed]
118. Zhu, X.R.; Wang, H.; Sun, J.; Yang, B.; Duan, X.W.; Jiang, Y.M. Pericarp and seed of litchi and longan fruits: Constituent, extraction, bioactive activity, and potential utilization. *J. Zhejiang Univ.-Sci. B* **2019**, *20*, 503–512. [CrossRef] [PubMed]

119. Kunworarath, N.; Rangkadilok, N.; Suriyo, T.; Thiantanawat, A.; Satayavivad, J. Longan *(Dimo-carpus longan* Lour.) inhibits lipopolysaccharide-stimulated nitric oxide production in macrophages by suppressing NF-κB and AP-1 signaling pathways. *J. Ethnopharmacol.* **2016**, *179*, 156–161. [CrossRef] [PubMed]
120. Li, C.Q.; Liao, X.B.; Li, X.H.; Guo, J.W.; Qu, X.L.; Li, L.M. Effect and mechanism of *Litchi semen* effective constituents on insulin resistance in rats with type 2 diabetes mellitus. *Zhong yao cai= Zhongyaocai= J. Chin. Med. Mater.* **2015**, *38*, 1466.
121. Panyathep, A.; Chewonarin, T.; Taneyhill, K.; Vinitketkumnuen, U. Antioxidant and anti-matrix metalloproteinases activities of dried longan (*Euphoria longana*) seed extract. *Scienceasia* **2013**, *39*, 12–18. [CrossRef]
122. Sudjaroen, Y.; Hull, W.E.; Erben, G.; Würtele, G.; Changbumrung, S.; Ulrich, C.M.; Owen, R.W. Isolation and characterization of ellagitannins as the major polyphenolic components of Lon-gan (*Dimocarpus longan* Lour) seeds. *Phytochemistry* **2012**, *77*, 226–237. [CrossRef]
123. Bai, X.; Pan, R.; Li, M.; Li, X.; Zhang, H. HPLC profile of Longan (cv. Shixia) pericarp-sourced phenolics and their antioxidant and cytotoxic effects. *Molecules* **2019**, *24*, 619. [CrossRef]
124. Kamal, A.M.; Taha, M.S.; Mousa, A.M. The Radioprotective and Anticancer Effects of Banana Peels Extract on Male Mice. *J. Food Nutr. Res.* **2019**, *7*, 827–835. [CrossRef]
125. Rattanavichai, W.; Cheng, W. Effects of hot-water extract of banana (*Musa acuminata*) fruit's peel on the antibacterial activity, and anti-hypothermal stress, immune responses and disease resistance of the giant freshwater prawn, *Macrobrachium rosenbegii*. *Fish Shellfish. Immunol.* **2014**, *39*, 326–335. [CrossRef]
126. Yin, X.; Quan, J.; Kanazawa, T. Banana prevents plasma oxidative stress in healthy individuals. *Plant Foods Hum. Nutr.* **2008**, *63*, 71–76. [CrossRef] [PubMed]
127. Kumar, K.S.; Bhowmik, D.; Duraivel, S.; Umadevi, M. Traditional and medicinal uses of banana. *J. Pharmacogn. Phytochem.* **2012**, *1*, 51–63.
128. Rebello, L.P.G.; Ramos, A.M.; Pertuzatti, P.B.; Barcia, M.T.; Castillo-Muñoz, N.; Hermosín-Gutiérrez, I. Flour of banana (Musa AAA) peel as a source of antioxidant phenolic com-pounds. *Food Res. Int.* **2014**, *55*, 397–403. [CrossRef]
129. Emmanuel, E.U.; Onagbonfeoana, E.S.; Adanma, O.C.; Precious, O.C.; Faith, A.I.; Ndukaku, O.Y. In vivo and in vitro antioxidant and hypolipidemic activity of methanol extract of pineapple peels in Wistar rats. *Int. J. Biosci.* **2016**, *8*, 64–72.
130. Leipner, J.; Iten, F.; Saller, R. Therapy with proteolytic enzymes in rheumatic disorders. *Bio-Drugs* **2001**, *15*, 779–789. [CrossRef]
131. Kaur, H.; Corscadden, K.; Lott, C.; Elbatarny, H.S.; Othman, M. Bromelain has paradoxical effects on blood coagulability: A study using thromboelastography. *Blood Coagul. Fibrinolysis* **2016**, *27*, 745–752. [CrossRef]
132. Pillai, K.; Akhter, J.; Chua, T.C.; Morris, D.L. Anticancer property of bromelain with therapeutic potential in malignant peritoneal mesothelioma. *Cancer Investig.* **2013**, *31*, 241–250. [CrossRef]
133. Morais, D.R.; Rotta, E.M.; Sargi, S.C.; Schmidt, E.M.; Bonafe, E.G.; Eberlin, M.N.; Visentainer, J.V. Antioxidant activity, phenolics and UPLC–ESI (–)–MS of extracts from different tropical fruits parts and processed peels. *Food Res. Int.* **2015**, *77*, 392–399. [CrossRef]
134. Bhat, G.P.; Surolia, N. In vitro antimalarial activity of extracts of three plants used in the traditional medicine of India. *Am. J. Trop. Med. Hyg.* **2001**, *65*, 304–308. [CrossRef]
135. Chávez-Quintal, P.; González-Flores, T.; Rodríguez-Buenfil, I.; Gallegos-Tintoré, S. Antifungal activity in ethanolic extracts of Carica papaya L. cv. Maradol leaves and seeds. *Indian J. Microbiol.* **2011**, *51*, 54–60. [CrossRef]
136. Abdulazeez, A.; Ibrahim, S.; Ayo, J. Effect of fermented and unfermented seed extracts of *Carica papaya* on pre-implantation embryo development in female *Wistar rats* (*Rattus norvegicus*). *Sci. Res. Essays* **2009**, *4*, 1080–1084.
137. Nayak, B.S.; Pereira, L.P.; Maharaj, D. Wound healing activity of *Carica papaya* L. in experimentally induced diabetic rats. *Indian J. Exp. Biol.* **2007**, *45*, 739–743.
138. Aravind, G.; Bhowmik, D.; Duraivel, S.; Harish, G. Traditional and medicinal uses of Carica papaya. *J. Med. Plants Stud.* **2013**, *1*, 7–15.
139. Rodrigues, L.G.G.; Mazzutti, S.; Vitali, L.; Micke, G.A.; Ferreira, S.R.S. Recovery of bioactive phenolic compounds from papaya seeds agroindustrial residue using subcritical water extraction. *Biocatal. Agric. Biotechnol.* **2019**, *22*, 101367. [CrossRef]
140. Vuong, Q.V.; Hirun, S.; Roach, P.D.; Bowyer, M.C.; Phillips, P.A.; Scarlett, C.J. Effect of ex-traction conditions on total phenolic compounds and antioxidant activities of Carica papaya leaf aqueous extracts. *J. Herbal Med.* **2013**, *3*, 104–111. [CrossRef]
141. Çam, M.; İçyer, N.C.; Erdoğan, F. Pomegranate peel phenolics: Microencapsulation, storage stability and potential ingredient for functional food development. *LWT-Food Sci. Technol.* **2014**, *55*, 117–123. [CrossRef]
142. Goula, A.M.; Ververi, M.; Adamopoulou, A.; Kaderides, K. Green ultrasound-assisted extraction of carotenoids from pomegranate wastes using vegetable oils. *Ultrason. Sonochem.* **2017**, *34*, 821–830. [CrossRef] [PubMed]
143. Moo-Huchin, V.; Estrada-Mota, I.; Estrada-León, R.; Cuevas-Glory, L.F.; Sauri-Duch, E. Chemical composition of crude oil from the seeds of pumpkin (*Cucurbita* spp.) and mamey sapota (Pout-eria sapota Jacq.) grown in Yucatan, Mexico. *CYTA-J. Food* **2013**, *11*, 324–327.
144. Banožić, M.; Banjari, I.; Jakovljević, M.; Šubarić, D.; Tomas, S.; Babić, J.; Jokić, S. Optimization of ultrasound-assisted extraction of some bioactive compounds from tobacco waste. *Molecules* **2019**, *24*, 1611. [CrossRef]
145. Medina-Torres, N.; Espinosa-Andrews, H.; Trombotto, S.; Ayora-Talavera, T.; Patrón-Vázquez, J.; Gonzá-lez-Flores, T.; Pacheco, N. Ultrasound-assisted extraction optimization of phenolic compounds from *Citrus latifolia* waste for chitosan bioactive nanoparticles development. *Molecules* **2019**, *24*, 3541. [CrossRef]

146. Moorthy, I.G.; Maran, J.P.; Ilakya, S.; Anitha, S.L.; Sabarima, S.P.; Priya, B. Ultrasound as-sisted extraction of pectin from waste Artocarpus heterophyllus fruit peel. *Ultrason. Sonochem.* **2017**, *34*, 525–530. [CrossRef] [PubMed]
147. De Andrade Lima, M.; Kestekoglou, I.; Charalampopoulos, D.; Chatzifragkou, A. Supercritical fluid extraction of carotenoids from vegetable waste matrices. *Molecules* **2019**, *24*, 466. [CrossRef] [PubMed]
148. Ferrentino, G.; Morozova, K.; Mosibo, O.K.; Ramezani, M.; Scampicchio, M. Biorecovery of antioxidants from apple pomace by Supercritical fluid extraction. *J. Clean. Prod.* **2018**, *186*, 253–261. [CrossRef]
149. Ndayishimiye, J.; Chun, B.S. Optimization of carotenoids and antioxidant activity of oils obtained from a co-extraction of citrus (*Yuzu ichandrin*) by-products using supercritical carbon diox-ide. *Biomass Bioenergy* **2017**, *106*, 1–7. [CrossRef]
150. Erşan, S.; Üstündağ, Ö.G.; Carle, R.; Schweiggert, R.M. Subcritical water extraction of phenol-ic and antioxidant constituents from pistachio (*Pistacia vera* L.) hulls. *Food Chem.* **2018**, *253*, 46–54. [CrossRef]
151. Ko, M.J.; Kwon, H.L.; Chung, M.S. Pilot-scale subcritical water extraction of flavonoids from satsuma mandarin (*Citrus unshiu* Markovich) peel. *Innov. Food Sci. Emerg. Technol.* **2016**, *38*, 175–181. [CrossRef]
152. Jesus, M.S.; Genisheva, Z.; Romaní, A.; Pereira, R.N.; Teixeira, J.A.; Domingues, L. Bioactive compounds recovery optimization from vine pruning residues using conventional heating and microwave-assisted extraction methods. *Ind. Crops Prod.* **2019**, *132*, 99–110. [CrossRef]
153. Filip, S.; Pavlić, B.; Vidović, S.; Vladić, J.; Zeković, Z. Optimization of microwave-assisted ex-traction of polyphenolic compounds from *Ocimum basilicum* by response surface methodology. *Food Anal. Methods* **2017**, *10*, 2270–2280. [CrossRef]
154. Kulkarni, V.; Rathod, V. Green process for extraction of mangiferin from Mangifera indica leaves. *J. Biol. Act. Prod. Nat.* **2016**, *6*, 406–411. [CrossRef]
155. Drosou, C.; Kyriakopoulou, K.; Bimpilas, A.; Tsimogiannis, D.; Krokida, M. A comparative study on different extraction techniques to recover red grape pomace polyphenols from vinification byproducts. *Ind. Crops Prod.* **2015**, *75*, 141–149. [CrossRef]
156. Pongmalai, P.; Devahastin, S.; Chiewchan, N.; Soponronnarit, S. Enhancement of microwave-assisted extraction of bioactive compounds from cabbage outer leaves via the application of ultra-sonic pretreatment. *Sep. Purif. Technol.* **2015**, *144*, 37–45. [CrossRef]
157. Hossain, M.B.; Aguiló-Aguayo, I.; Lyng, J.G.; Brunton, N.P.; Rai, D.K. Effect of pulsed electric field and pulsed light pre-treatment on the extraction of steroidal alkaloids from potato peels. *Innov. Food Sci. Emerg. Technol.* **2015**, *29*, 9–14. [CrossRef]
158. Bobinaitė, R.; Pataro, G.; Lamanauskas, N.; Šatkauskas, S.; Viškelis, P.; Ferrari, G. Application of pulsed electric field in the production of juice and extraction of bioactive compounds from blue-berry fruits and their by-products. *J. Food Sci. Technol.* **2015**, *52*, 5898–5905. [CrossRef] [PubMed]
159. Teh, S.S.; Niven, B.E.; Bekhit, A.E.D.A.; Carne, A.; Birch, E.J. Microwave and pulsed electric field assisted extractions of polyphenols from defatted canola seed cake. *Int. J. Food Sci. Technol.* **2015**, *50*, 1109–1115. [CrossRef]
160. Bubalo, M.C.; Vidović, S.; Redovniković, I.R.; Jokić, S. New perspective in extraction of plant biologically active compounds by green solvents. *Food Bioprod. Process.* **2018**, *109*, 52–73. [CrossRef]
161. Wang, L.; Weller, C.L. Recent advances in extraction of nutraceuticals from plants. *Trends Food Sci. Technol.* **2006**, *17*, 300–312. [CrossRef]
162. Da Silva, R.P.; Rocha-Santos, T.A.; Duarte, A.C. Supercritical fluid extraction of bioactive compounds. *TrAC Trends Anal. Chem.* **2016**, *76*, 40–51. [CrossRef]
163. Soquetta, M.B.; Terra, L.D.M.; Bastos, C.P. Green technologies for the extraction of bioactive compounds in fruits and vegetables. *CyTA-J. Food* **2018**, *16*, 400–412. [CrossRef]
164. Da Porto, C.; Decorti, D.; Natolino, A. Water and ethanol as co-solvent in supercritical fluid ex-traction of proanthocyanidins from grape marc: A comparison and a proposal. *J. Supercrit. Fluids* **2014**, *87*, 1–8. [CrossRef]
165. Floris, T.; Filippino, G.; Scrugli, S.; Pinna, M.B.; Argiolas, F.; Argiolas, A.; Reverchon, E. Antioxidant compounds recovery from grape residues by a Supercritical antisolvent assisted pro-cess. *J. Supercrit. Fluids* **2010**, *54*, 165–170. [CrossRef]
166. Sosa, M.V.; Rodríguez-Rojo, S.; Mattea, F.; Cismondi, M.; Cocero, M.J. Green tea encapsulation by means of high pressure antisolvent coprecipitation. *J. Supercrit. Fluids* **2011**, *56*, 304–311. [CrossRef]
167. Mezzomo, N.; Comim, S.R.R.; Campos, C.E.; Ferreira, S.R. Nanosizing of sodium ibuprofen by SAS method. *Powder Technol.* **2015**, *270*, 378–386. [CrossRef]
168. Zhong, Q.; Jin, M.; Xiao, D.; Tian, H.; Zhang, W. Application of supercritical anti-solvent technologies for the synthesis of delivery systems of bioactive food components. *Food Biophys.* **2008**, *3*, 186–190. [CrossRef]
169. Zabot, G.L.; Meireles, M.A.A. On-line process for pressurized ethanol extraction of onion peels extract and particle formation using supercritical antisolvent. *J. Supercrit. Fluids* **2016**, *110*, 230–239. [CrossRef]
170. Czaikoski, K.; Mesomo, M.C.; de Paula Scheer, A.; Dalla Santa, O.R.; Queiroga, C.L.; Corazza, M.L. Kinetics, composition and biological activity of *Eupatorium intermedium* flower extracts obtained from scCO2 and compressed propane. *J. Supercrit. Fluids* **2015**, *97*, 145–153. [CrossRef]
171. Espinosa-Pardo, F.A.; Martinez, J.; Martinez-Correa, H.A. Extraction of bioactive compounds from peach palm pulp (*Bactris gasipaes*) using supercritical CO2. *J. Supercrit. Fluids* **2014**, *93*, 2–6. [CrossRef]
172. Santos-Zea, L.; Gutiérrez-Uribe, J.A.; Benedito, J. Effect of ultrasound intensification on the supercritical fluid extraction of phytochemicals from Agave salmiana bagasse. *J. Supercrit. Fluids* **2019**, *144*, 98–107. [CrossRef]

173. Zhang, J.; Wen, C.; Zhang, H.; Duan, Y.; Ma, H. Recent advances in the extraction of bioactive compounds with subcritical water: A review. *Trends Food Sci. Technol.* **2020**, *95*, 183–195. [CrossRef]
174. Gbashi, S.; Adebo, O.A.; Piater, L.; Madala, N.E.; Njobeh, P.B. Subcritical water extraction of biological materials. *Sep. Purif. Rev.* **2017**, *46*, 21–34. [CrossRef]
175. Munir, M.T.; Kheirkhah, H.; Baroutian, S.; Quek, S.Y.; Young, B.R. Subcritical water extraction of bioactive compounds from waste onion skin. *J. Clean. Prod.* **2018**, *183*, 487–494. [CrossRef]
176. Yan, Z.; Luo, X.; Cong, J.; Zhang, H.; Ma, H.; Duan, Y. Subcritical water extraction, identification and antiproliferation ability on HepG2 of polyphenols from lotus seed epicarp. *Ind. Crops Prod.* **2019**, *129*, 472–479. [CrossRef]
177. Xian, Z.H.U.; Chao, Z.H.U.; Liang, Z.H.A.O.; CHENG, H. Amino acids production from fish proteins hydrolysis in subcritical water. *Chin. J. Chem. Eng.* **2008**, *16*, 456–460.
178. Getachew, A.T.; Chun, B.S. Influence of pretreatment and modifiers on subcritical water liquefaction of spent coffee grounds: A green waste valorization approach. *J. Clean. Prod.* **2017**, *142*, 3719–3727. [CrossRef]
179. Teo, C.C.; Tan, S.N.; Yong, J.W.H.; Hew, C.S.; Ong, E.S. Pressurized hot water extraction (PHWE). *J. Chromatogr. A* **2010**, *1217*, 2484–2494. [CrossRef] [PubMed]
180. Todd, R.; Baroutian, S. A techno-economic comparison of subcritical water, supercritical CO2 and organic solvent extraction of bioactives from grape marc. *J. Clean. Prod.* **2017**, *158*, 349–358. [CrossRef]
181. Cravotto, G.; Boffa, L.; Mantegna, S.; Perego, P.; Avogadro, M.; Cintas, P. Improved extraction of vegetable oils under high-intensity ultrasound and/or microwaves. *Ultrason. Sonochem.* **2008**, *15*, 898–902. [CrossRef] [PubMed]
182. Vardanega, R.; Santos, D.T.; Meireles, M.A.A. Intensification of bioactive compounds extraction from medicinal plants using ultrasonic irradiation. *Pharm. Rev.* **2014**, *8*, 88.
183. Wen, C.; Zhang, J.; Zhang, H.; Dzah, C.S.; Zandile, M.; Duan, Y.; Luo, X. Advances in ultra-sound assisted extraction of bioactive compounds from cash crops–A review. *Ultrason. Sonochem.* **2018**, *48*, 538–549. [CrossRef]
184. Alzorqi, I.; Manickam, S. Ultrasonic process intensification for the efficient extraction of nutritionally active ingredients of polysaccharides from bioresources. In *Handbook of Ultrasonics and Sonochemistry*; Springer: Singapore, 2015.
185. Leong, T.S.; Martin, G.J.; Ashokkumar, M. Ultrasonic encapsulation—A review. *Ultrason. Sonochem.* **2017**, *35*, 605–614. [CrossRef]
186. Kaderides, K.; Goula, A.M.; Adamopoulos, K.G. A process for turning pomegranate peels into a valuable food ingredient using ultrasound-assisted extraction and encapsulation. *Innov. Food Sci. Emerg. Technol.* **2015**, *31*, 204–215. [CrossRef]
187. González-Centeno, M.R.; Knoerzer, K.; Sabarez, H.; Simal, S.; Rosselló, C.; Femenia, A. Effect of acoustic frequency and power density on the aqueous ultrasonic-assisted extraction of grape pomace (*Vitis vinifera* L.)—A response surface approach. *Ultrason. Sonochem.* **2014**, *21*, 2176–2184. [CrossRef] [PubMed]
188. Ahmed, M.; Ramachandraiah, K.; Jiang, G.H.; Eun, J.B. Effects of Ultra-Sonication and Agitation on Bioactive Compounds and Structure of Amaranth Extract. *Foods* **2020**, *9*, 1116. [CrossRef] [PubMed]
189. Das, P.R.; Eun, J.B. A comparative study of ultra-sonication and agitation extraction techniques on bioactive metabolites of green tea extract. *Food Chem.* **2018**, *253*, 22–29. [CrossRef]
190. Albu, S.; Joyce, E.; Paniwnyk, L.; Lorimer, J.P.; Mason, T.J. Potential for the use of ultrasound in the extraction of antioxidants from Rosmarinus officinalis for the food and pharmaceutical industry. *Ultrason. Sonochem.* **2004**, *11*, 261–265. [CrossRef] [PubMed]
191. Chemat, F.; Rombaut, N.; Sicaire, A.G.; Meullemiestre, A.; Fabiano-Tixier, A.S.; Abert-Vian, M. Ultrasound assisted extraction of food and natural products. Mechanisms, techniques, combinations, protocols and applications. A review. *Ultrason. Sonochem.* **2017**, *34*, 540–560. [CrossRef]
192. Jadhav, A.J.; Holkar, C.R.; Goswami, A.D.; Pandit, A.B.; Pinjari, D.V. Acoustic cavitation as a novel approach for extraction of oil from waste date seeds. *ACS Sustain. Chem. Eng.* **2016**, *4*, 4256–4263. [CrossRef]
193. Safdar, M.N.; Kausar, T.; Jabbar, S.; Mumtaz, A.; Ahad, K.; Saddozai, A.A. Extraction and quantification of polyphenols from kinnow (*Citrus reticulate* L.) peel using ultrasound and macera-tion techniques. *J. Food Drug Anal.* **2017**, *25*, 488–500. [CrossRef]
194. Delazar, A.; Nahar, L.; Hamedeyazdan, S.; Sarker, S.D. Microwave-assisted extraction in natural products isolation. *Nat. Prod. Isol.* **2012**, *864*, 89–115.
195. Jaitak, V.; Bandna, B.S.; Kaul, Y.V. An efficient microwave-assisted extraction process of stevioside and rebaudioside-A from *Stevia rebaudiana* (Bertoni). *Phytochem. Anal.* **2009**, *20*, 240–245. [CrossRef]
196. De la Hoz, A.; Díaz-Ortiz, A.; Prieto, P. Microwave-Assisted Green Organic Synthesis. In *Alternative Energy Sources for Green Chemistry*; The Royal Society of Chemistry: London, UK, 2016; pp. 1–33.
197. Liu, Z.; Deng, B.; Li, S.; Zou, Z. Optimization of solvent-free microwave assisted extraction of essential oil from *Cinnamomum camphora* leaves. *Ind. Crops Prod.* **2018**, *124*, 353–362. [CrossRef]
198. Alupului, A.; Calinescu, I.; Lavric, V. Microwave extraction of active principles from medicinal plants. *UPB Sci. Bull. Ser. B* **2012**, *74*, 129–142.
199. Zhang, F.; Chen, B.; Xiao, S.; Yao, S.Z. Optimization and comparison of different extraction techniques for sanguinarine and chelerythrine in fruits of *Macleaya cordata* (Willd) R. Br. *Sep. Purif. Technol.* **2005**, *42*, 283–290. [CrossRef]
200. De la Guardia, M.; Armenta, S. Greening sample treatments. In *Comprehensive Analytical Chemistr*; Elsevier: Amsterdam, The Netherlands, 2011; Volume 57, pp. 87–120.
201. Ciriminna, R.; Carnaroglio, D.; Delisi, R.; Arvati, S.; Tamburino, A.; Pagliaro, M. Industrial feasibility of natural products extraction with microwave technology. *Chem. Sel. Rev.* **2016**, *1*, 549–555. [CrossRef]

202. Azmir, J.; Zaidul, I.S.M.; Rahman, M.M.; Sharif, K.M.; Mohamed, A.; Sahena, F.; Omar, A.K.M. Techniques for extraction of bioactive compounds from plant materials: A review. *J. Food Eng.* **2013**, *117*, 426–436. [CrossRef]
203. Barbosa-Pereira, L.; Guglielmetti, A.; Zeppa, G. Pulsed electric field assisted extraction of bio-active compounds from cocoa bean shell and coffee silverskin. *Food Bioprocess Technol.* **2018**, *11*, 818–835. [CrossRef]
204. Arnal, Á.J.; Royo, P.; Pataro, G.; Ferrari, G.; Ferreira, V.J.; López-Sabirón, A.M.; Ferreira, G.A. Implementation of PEF treatment at real-scale tomatoes processing considering LCA methodology as an innovation strategy in the agri-food sector. *Sustainability* **2018**, *10*, 979. [CrossRef]
205. Siddeeg, A.; Faisal Manzoor, M.; Haseeb Ahmad, M.; Ahmad, N.; Ahmed, Z.; Kashif Iqbal Khan, M.; Ammar, A.F. Pulsed electric field-assisted ethanolic extraction of date palm fruits: Bioactive compounds, antioxidant activity and physicochemical properties. *Processes* **2019**, *7*, 585. [CrossRef]
206. Puértolas, E.; Barba, F.J. Electrotechnologies applied to valorization of by-products from food industry: Main findings, energy and economic cost of their industrialization. *Food Bioprod. Process.* **2016**, *100*, 172–184. [CrossRef]
207. Brito, P.S.; Canacsinh, H.; Mendes, J.P.; Redondo, L.M.; Pereira, M.T. Comparison between monopolar and bipolar microsecond range pulsed electric fields in enhancement of apple juice ex-traction. *IEEE Trans. Plasma Sci.* **2012**, *40*, 2348–2354. [CrossRef]
208. Fincan, M.; DeVito, F.; Dejmek, P. Pulsed electric field treatment for solid–liquid extraction of red beetroot pigment. *J. Food Eng.* **2004**, *64*, 381–388. [CrossRef]
209. Luengo, E.; Álvarez, I.; Raso, J. Improving the pressing extraction of polyphenols of orange peel by pulsed electric fields. *Innov. Food Sci. Emerg. Technol.* **2013**, *17*, 79–84. [CrossRef]
210. Delsart, C.; Ghidossi, R.; Poupot, C.; Cholet, C.; Grimi, N.; Vorobiev, E.; Peuchot, M.M. Enhanced extraction of phenolic compounds from *Merlot grapes* by pulsed electric field treatment. *Am. J. Enol. Vitic.* **2012**, *63*, 205–211. [CrossRef]
211. Barba, F.J.; Brianceau, S.; Turk, M.; Boussetta, N.; Vorobiev, E. Effect of alternative physical treatments (ultrasounds, pulsed electric fields, and high-voltage electrical discharges) on selective recovery of bio-compounds from fermented grape pomace. *Food Bioprocess. Technol.* **2015**, *8*, 1139–1148. [CrossRef]
212. Nowacka, M.; Tappi, S.; Wiktor, A.; Rybak, K.; Miszczykowska, A.; Czyzewski, J.; Tylewicz, U. The impact of pulsed electric field on the extraction of bioactive compounds from beetroot. *Foods* **2019**, *8*, 244. [CrossRef] [PubMed]
213. Quagliariello, V.; Iaffaioli, R.V.; Falcone, M.; Ferrari, G.; Pataro, G.; Donsì, F. Effect of pulsed electric fields–assisted extraction on anti-inflammatory and cytotoxic activity of brown rice bioactive compounds. *Food Res. Int.* **2016**, *87*, 115–124. [CrossRef]
214. Minatel, I.O.; Borges, C.V.; Ferreira, M.I.; Gomez, H.A.G.; Chen, C.Y.O.; Lima, G.P.P. Phenolic compounds: Functional properties, impact of processing and bioavailability. In *Phenolic Compounds Biological Activity*; InTech: Rijeka, Croatia, 2017; pp. 1–24.
215. Echeverria, F.; Jimenez, P.; Castro-Sepulveda, M.; Bustamante, A.; Garcia, P.; Poblete-Aro, C.; Gar-cia-Diaz, D.F. Microencapsulated pomegranate peel extract induces mitochondrial com-plex IV activity and prevents mitochondrial cristae alteration in brown adipose tissue in mice fed on a high-fat diet+. *Br. J. Nutr.* **2020**, 1–37. [CrossRef] [PubMed]
216. Pachuau, L.; Roy, P.K.; Zothantluanga, J.H.; Ray, S.; Das, S. Encapsulation of Bioactive Compound and Its Therapeutic Potential. In *Bioactive Natural Products for Pharmaceutical Applications*; Springer: Cham, Swizerland, 2021; pp. 687–714.
217. Hu, Y.; Li, Y.; Zhang, W.; Kou, G.; Zhou, Z. Physical stability and antioxidant activity of citrus flavonoids in arabic gum-stabilized microcapsules: Modulation of whey protein concentrate. *Food Hydrocoll.* **2018**, *77*, 588–597. [CrossRef]
218. Ramírez, M.J.; Giraldo, G.I.; Orrego, C.E. Modeling and stability of polyphenol in spray-dried and freeze-dried fruit encapsulates. *Powder Technol.* **2015**, *277*, 89–96. [CrossRef]
219. Do Carmo, E.L.; Teodoro, R.A.R.; Félix, P.H.C.; de Barros Fernandes, R.V.; de Oliveira, É.R.; Veiga, T.R.L.A.; Borges, S.V.; Botrel, D.A. Stability of spray-dried beetroot extract using oligosaccharides and whey proteins. *Food Chem.* **2018**, *249*, 51–59. [CrossRef]
220. Saavedra-Leos, Z.; Leyva-Porras, C.; Araujo-Díaz, S.B.; Toxqui-Terán, A.; Borrás-Enríquez, A.J. Technological application of maltodextrins according to the degree of polymerization. *Molecules* **2015**, *20*, 21067–21081. [CrossRef]
221. Souza, A.L.; Hidalgo-Chávez, D.W.; Pontes, S.M.; Gomes, F.S.; Cabral, L.M.; Tonon, R.V. Microencapsulation by spray drying of a lycopene-rich tomato concentrate: Characterization and stability. *LWT* **2018**, *91*, 286–292. [CrossRef]
222. Chen, F.P.; Liu, L.L.; Tang, C.H. Spray-drying Microencapsulation of Curcumin Nanocomplexes with Soy Protein Isolate: Encapsulation, Water Dispersion, Bioaccessibility and Bioactivities of Curcumin. *Food Hydrocoll.* **2020**, *105*, 105821. [CrossRef]
223. Deng, X.X.; Chen, Z.; Huang, Q.; Fu, X.; Tang, C.H. Spray-drying microencapsulation of β-carotene by soy protein isolate and/or OSA-modified starch. *J. App. Polym. Sci.* **2014**, *131*, 40399. [CrossRef]
224. Vu, H.T.; Scarlett, C.J.; Vuong, Q.V. Encapsulation of phenolic-rich extract from banana (*Musa cavendish*) peel. *J. Food Sci. Technol.* **2020**, *57*, 2089–2098. [CrossRef]
225. Nogueira, G.F.; Soares, C.T.; Martin, L.G.P.; Fakhouri, F.M.; de Oliveira, R.A. Influence of spray drying on bioactive compounds of blackberry pulp microencapsulated with arrowroot starch and gum arabic mixture. *J. Microencapsul.* **2020**, *37*, 65–76. [CrossRef]
226. Pieczykolan, E.; Kurek, M.A. Use of guar gum, gum arabic, pectin, beta-glucan and inulin for microencapsulation of anthocyanins from chokeberry. *Int. J. Biol. Macromol.* **2019**, *129*, 665–671. [CrossRef]
227. Ding, Z.; Tao, T.; Wang, X.; Prakash, S.; Zhao, Y.; Han, J.; Wang, Z. Influences of different carbohydrates as wall material on powder characteristics, encapsulation efficiency, stability and degradation kinetics of microencapsulated lutein by spray drying. *Int. J. Food Sci. Technol.* **2020**, *55*, 2872–2882. [CrossRef]
228. Poyrazoglu, E.S.; Ozat, E.T.; Coksari, G.; Ozat, E.; Konar, N. Effect of various process conditions on efficiency and colour properties of Pistacia terebinthus oil encapsulated by spray drying. *Int. J. Food Eng.* **2017**, *3*, 132–135. [CrossRef]

229. ANTIGO, J.L.D.; Bergamasco, R.D.C.; Madrona, G.S. Effect of pH on the stability of red beet extract (*Beta vulgaris* L.) microcapsules produced by spray drying or freeze drying. *Food Sci. Technol.* **2018**, *38*, 72–77. [CrossRef]
230. Aphibanthammakit, C.; Barbar, R.; Nigen, M.; Sanchez, C.; Chalier, P. Emulsifying properties of Acacia senegal gum: Impact of high molar mass protein-rich AGPs. *Food Chem.* **2020**, *6*, 100090. [CrossRef]
231. Jain, A.; Thakur, D.; Ghoshal, G.; Katare, O.P.; Shivhare, U.S. Microencapsulation by complex coacervation using whey protein isolates and gum acacia: An approach to preserve the functionality and controlled release of β-carotene. *Food Bioprocess Technol.* **2015**, *8*, 1635–1644. [CrossRef]
232. Omer, E.A.; AL-Omari, A.A.; Elgamidy, A.H.; Elgamidy, A.A.; Elgamidy, A.M. The emulsifying stability of gum Arabic using the local sesame oil obtained from AL-BAH A area. *Int. J. Eng. Res. Technol.* **2015**, *4*, 1172–1175.
233. Neves, M.I.L.; Desobry-Banon, S.; Perrone, I.T.; Desobry, S.; Petit, J. Encapsulation of curcumin in milk powders by spray-drying: Physicochemistry, rehydration properties, and stability during storage. *Powder Technol.* **2019**, *345*, 601–607. [CrossRef]
234. Gheonea, I.; Aprodu, I.; Cîrciumaru, A.; Râpeanu, G.; Bahrim, G.E.; Stănciuc, N. Microencapsulation of lycopene from tomatoes peels by complex coacervation and freeze-drying: Evidences on phytochemical profile, stability and food applications. *J. Food Eng.* **2021**, *288*, 110166. [CrossRef]
235. Geng, T.; Zhao, X.; Ma, M.; Zhu, G.; Yin, L. Resveratrol-loaded albumin nanoparticles with prolonged blood circulation and improved biocompatibility for highly effective targeted pancreatic tumor therapy. *Nanoscale Res. Lett.* **2017**, *12*, 437. [CrossRef] [PubMed]
236. Vitaglione, P.; Barone Lumaga, R.; Ferracane, R.; Radetsky, I.; Mennella, I.; Schettino, R.; Fogliano, V. Curcumin bioavailability from enriched bread: The effect of microencapsulated ingredients. *J. Agric. Food Chem.* **2012**, *60*, 3357–3366. [CrossRef]
237. Tran, N.; Tran, M.; Truong, H.; Le, L. Spray-drying microencapsulation of high concentration of bioactive compounds fragments from Euphorbia hirta L. extract and their effect on diabetes mellitus. *Foods* **2020**, *9*, 881. [CrossRef]
238. Turan, F.T.; Cengiz, A.; Kahyaoglu, T. Evaluation of ultrasonic nozzle with spray-drying as a novel method for the microencapsulation of blueberry's bioactive compounds. *Innov. Food Sci. Emerg. Technol.* **2015**, *32*, 136–145. [CrossRef]
239. Zhou, Q.; Yang, L.; Xu, J.; Qiao, X.; Li, Z.; Wang, Y.; Xue, C. Evaluation of the physicochemical stability and digestibility of microencapsulated esterified astaxanthins using in vitro and in vivo models. *Food Chem.* **2018**, *260*, 73–81. [CrossRef]
240. Silva, E.K.; Rosa, M.T.M.; Meireles, M.A.A. Ultrasound-assisted formation of emulsions stabilized by biopolymers. *Curr. Opin. Food Sci.* **2015**, *5*, 50–59. [CrossRef]
241. Silva, E.K.; Azevedo, V.M.; Cunha, R.L.; Hubinger, M.D.; Meireles, M.A.A. Ultrasound-assisted encapsulation of annatto seed oil: Whey protein isolate versus modified starch. *Food Hydrocoll.* **2016**, *56*, 71–83. [CrossRef]
242. Shanmugam, A.; Chandrapala, J.; Ashokkumar, M. The effect of ultrasound on the physical and functional properties of skim milk. *Innov. Food Sci. Emerg. Technol.* **2012**, *16*, 251–258. [CrossRef]
243. Shanmugam, A.; Ashokkumar, M. Ultrasonic preparation of stable flax seed oil emulsions in dairy systems–physicochemical characterization. *Food Hydrocoll.* **2014**, *39*, 151–162. [CrossRef]
244. Jeyakumari, A.; Zynudheen, A.A.; Parvathy, U. Microencapsulation of bioactive food ingredients and controlled release-A review. *MOJ Food Process. Technol.* **2016**, *2*, 00059.
245. Tontul, I.; Topuz, A. Spray-drying of fruit and vegetable juices: Effect of drying conditions on the product yield and physical properties. *Trends Food Sci. Technol.* **2017**, *63*, 91–102. [CrossRef]
246. Lee, S.J.; Wong, M. Nano-and microencapsulation of phytochemicals. In *Nano-and Microencapsulation for Foods*; John Wiley & Sons Ltd.: Auckland, New Zealand, 2014; pp. 117–165.
247. Correia, R.; Grace, M.H.; Esposito, D.; Lila, M.A. Wild blueberry polyphenol-protein food ingredients produced by three drying methods: Comparative physico-chemical properties, phyto-chemical content, and stability during storage. *Food Chem.* **2017**, *235*, 76–85. [CrossRef]
248. Sormoli, M.E.; Langrish, T.A. Spray drying bioactive orange-peel extracts produced by *Soxhlet extraction*: Use of WPI, antioxidant activity and moisture sorption isotherms. *LWT-Food Sci. Technol.* **2016**, *72*, 1–8. [CrossRef]
249. Agudelo, C.; Barros, L.; Santos-Buelga, C.; Martínez-Navarrete, N.; Ferreira, I.C. Phytochemical content and antioxidant activity of grapefruit (Star Ruby): A comparison between fresh freeze-dried fruits and different powder formulations. *LWT* **2017**, *80*, 106–112. [CrossRef]
250. Satpute, M.; Annapure, U. Approaches for delivery of heat sensitive nutrients through food systems for selection of appropriate processing techniques: A review. *J. Hyg. Eng. Des.* **2013**, *4*, 71–92.
251. Bazaria, B.; Kumar, P. Effect of dextrose equivalency of maltodextrin together with Arabic gum on properties of encapsulated beetroot juice. *J. Food Meas. Charact.* **2017**, *11*, 156–163. [CrossRef]
252. Ozkan, G.; Franco, P.; De Marco, I.; Xiao, J.; Capanoglu, E. A review of microencapsulation methods for food antioxidants: Principles, advantages, drawbacks and applications. *Food Chem.* **2019**, *272*, 494–506. [CrossRef] [PubMed]
253. Alemzadeh, I.; Hajiabbas, M.; Pakzad, H.; Sajadi Dehkordi, S.; Vossoughi, A. Encapsulation of Food Components and Bioactive Ingredients and Targeted Release. *Int. J. Eng.* **2020**, *33*, 1–11.
254. Tulini, F.L.; Souza, V.B.; Echalar-Barrientos, M.A.; Thomazini, M.; Pallone, E.M.; Favaro-Trindade, C.S. Development of solid lipid microparticles loaded with a proanthocyanidin-rich cinna-mon extract (*Cinnamomum zeylanicum*): Potential for increasing antioxidant content in functional foods for diabetic population. *Food Res. Int.* **2016**, *85*, 10–18. [CrossRef] [PubMed]

255. Tulini, F.L.; Souza, V.B.; Thomazini, M.; Silva, M.P.; Massarioli, A.P.; Alencar, S.M.; Favaro-Trindade, C.S. Evaluation of the release profile, stability and antioxidant activity of a pro-anthocyanidin-rich cinnamon (*Cinnamomum zeylanicum*) extract co-encapsulated with α-tocopherol by spray chilling. *Food Res. Int.* **2017**, *95*, 117–124. [CrossRef] [PubMed]
256. Oriani, V.B.; Alvim, I.D.; Consoli, L.; Molina, G.; Pastore, G.M.; Hubinger, M.D. Solid lipid microparticles produced by spray chilling technique to deliver ginger oleoresin: Structure and com-pound retention. *Food Res. Int.* **2016**, *80*, 41–49. [CrossRef]
257. Pedroso, D.L.; Dogenski, M.; Thomazini, M.; Heinemann, R.J.B.; Favaro-Trindade, C.S. Microencapsulation of *Bifidobacterium animalis* subsp. lactis and *Lactobacillus acidophilus* in cocoa butter using spray chilling technology. *Braz. J. Microbiol.* **2013**, *44*, 777–783. [CrossRef]
258. Mazzocato, M.C.; Thomazini, M.; Favaro-Trindade, C.S. Improving stability of vitamin B12 (Cyanocobalamin) using microencapsulation by spray chilling technique. *Food Res. Int.* **2019**, *126*, 108663. [CrossRef]
259. Meiners, J.A. Fluid bed microencapsulation and other coating methods for food ingredient and nutraceutical bioactive compounds. In *Encapsulation Technologies and Delivery Systems for Food Ingredients and Nutraceuticals*; Woodhead Publishing: Sawston, Cambridge, UK, 2012; pp. 151–176.
260. Nedović, V.; Kalušević, A.; Manojlović, V.; Petrović, T.; Bugarski, B. Encapsulation systems in the food industry. In *Advances in Food Process Engineering Research and Applications*; Springer: Boston, MA, USA, 2013; pp. 229–253.
261. Zuidam, N.J.; Heinrich, J. Encapsulation of aroma. In *Encapsulation Technologies for Food Active Ingredients and Food Processing*; Zuidam, N.J., Nedovic, V.A., Eds.; Springer: London, UK, 2010.
262. Scala, F. *Mass Transfer around Active Particles in Fluidized Beds*; INTECH Open Access Publisher: Rijeka, Croatia, 2011.
263. Champagne, C.P.; Fustier, P. Microencapsulation for the improved delivery of bioactive com-pounds into foods. *Curr. Opin. Biotechnol.* **2007**, *18*, 184–190. [CrossRef]
264. Prata, A.S.; Maudhuit, A.; Boillereaux, L.; Poncelet, D. Development of a control system to anticipate agglomeration in fluidised bed coating. *Powder Technol.* **2012**, *224*, 168–174. [CrossRef]
265. Benelli, L.; Oliveira, W.P. Fluidized bed coating of inert cores with a lipid-based system loaded with a polyphenol-rich Rosmarinus officinalis extract. *Food Bioprod. Process.* **2019**, *114*, 216–226. [CrossRef]
266. Rezvankhah, A.; Emam-Djomeh, Z.; Askari, G. Encapsulation and delivery of bioactive com-pounds using spray and freeze-drying techniques: A review. *Drying Technol.* **2020**, *38*, 235–258. [CrossRef]
267. Silva-Espinoza, M.A.; Ayed, C.; Foster, T.; Camacho, M.D.M.; Martínez-Navarrete, N. The Impact of Freeze-Drying Conditions on the Physico-Chemical Properties and Bioactive Compounds of a Freeze-Dried Orange Puree. *Foods* **2020**, *9*, 32. [CrossRef] [PubMed]
268. Rezende, Y.R.R.S.; Nogueira, J.P.; Narain, N. Microencapsulation of extracts of bioactive compounds obtained from acerola (*Malpighia emarginata* DC) pulp and residue by spray and freeze drying: Chemical, morphological and chemometric characterization. *Food Chem.* **2018**, *254*, 281–291. [CrossRef] [PubMed]
269. Stratta, L.; Capozzi, L.C.; Franzino, S.; Pisano, R. Economic Analysis of a Freeze-Drying Cycle. *Processes* **2020**, *8*, 1399. [CrossRef]
270. Charalampia, D.; Koutelidakis, A.E. From Pomegranate Processing By-Products to Innovative value added Func-tional Ingredients and Bio-Based Products with Several Applications in Food Sector. *BAOJ Biotech.* **2017**, *3*, 210.
271. Basanta, M.F.; Rizzo, S.A.; Szerman, N.; Vaudagna, S.R.; Descalzo, A.M.; Gerschenson, L.N.; Pérez, C.D.; Rojas, A.M. Plum (Prunus salicina) peel and pulp microparticles as natural antioxidant additives in breast chicken patties. *Food Res. Int.* **2018**, *106*, 1086–1094. [CrossRef]
272. Abid, Y.; Azabou, S.; Jridi, M.; Khemakhem, I.; Bouaziz, M.; Attia, H. Storage stability of traditional Tunisian butter enriched with antioxidant extract from tomato processing by-products. *Food Chem.* **2017**, *233*, 476–482. [CrossRef]
273. Adiamo, O.Q.; Ghafoor, K.; Al-Juhaimi, F.; Babiker, E.E.; Ahmed, I.A.M. Thermosonication process for optimal functional properties in carrot juice containing orange peel and pulp extracts. *Food Chem.* **2018**, *245*, 79–88. [CrossRef]
274. Natukunda, S.; Muyonga, J.H.; Mukisa, I.M. Effect of tamarind (*Tamarindus indica* L.) seed on antioxidant activity, phytocompounds, physicochemical characteristics, and sensory acceptability of enriched cookies and mango juice. *Food Sci. Nutr.* **2016**, *4*, 494–507. [CrossRef]
275. Ortiz, L.; Dorta, E.; Lobo, M.G.; González-Mendoza, L.A.; Díaz, C.; González, M. Use of ba-nana (*Musa acuminata* Colla AAA) peel extract as an antioxidant source in orange juices. *Plant Foods Hum. Nutr.* **2017**, *72*, 60–66. [CrossRef]
276. Ortiz, L.; Dorta, E.; Lobo, M.G.; González-Mendoza, L.A.; Díaz, C.; González, M. Use of ba-nana peel extract to stabilise antioxidant capacity and sensory properties of orange juice during pasteurisation and refrigerated storage. *Food Bioprocess Technol.* **2017**, *10*, 1883–1891. [CrossRef]
277. Hidalgo, A.; Brandolini, A.; Čanadanović-Brunet, J.; Ćetković, G.; Šaponjac, V.T. Microencapsulates and extracts from red beetroot pomace modify antioxidant capacity, heat damage and colour of pseudocereals enriched einkorn water biscuits. *Food Chem.* **2018**, *268*, 40–48. [CrossRef] [PubMed]
278. Maner, S.; Sharma, A.K.; Banerjee, K. Wheat flour replacement by wine grape pomace powder positively affects physical, functional and sensory properties of cookies. *Proc. Natl. Acad. Sci. India Sect. B Biol. Sci.* **2017**, *87*, 109–113. [CrossRef]
279. Pasqualone, A.; Punzi, R.; Trani, A.; Summo, C.; Paradiso, V.M.; Caponio, F.; Gambacorta, G. Enrichment of fresh pasta with antioxidant extracts obtained from artichoke canning by-products by ultrasound-assisted Technol. and quality characterisation of the end product. *Int. J. Food Sci. Technol.* **2017**, *52*, 2078–2087. [CrossRef]

280. Amofa-Diatuo, T.; Anang, D.M.; Barba, F.J.; Tiwari, B.K. Development of new apple beverages rich in isothiocyanates by using extracts obtained from ultrasound-treated cauliflower by-products: Evaluation of physical properties and consumer acceptance. *J. Food Compos. Anal.* **2017**, *61*, 73–81. [CrossRef]
281. Xi, J.; Li, Z.; Fan, Y. Recent advances in continuous extraction of bioactive ingredients from food-processing wastes by pulsed electric fields. *Crit. Rev. Food Sci. Nutr.* **2020**, 1–13. [CrossRef]
282. Zin, M.M.; Anucha, C.B.; Bánvölgyi, S.J.F. Recovery of Phytochemicals via Electromagnetic Irradiation (Microwave-Assisted-Extraction): Betalain and Phenolic Compounds in Perspective. *Foods* **2020**, *9*, 918. [CrossRef]
283. Gallego, R.; Bueno, M.; Herrero, M. Sub-and supercritical fluid extraction of bioactive com-pounds from plants, food-by-products, seaweeds and microalgae–An update. *TrAC Trends Anal. Chem.* **2019**, *116*, 198–213. [CrossRef]
284. Souza, M.C.; Santos, M.P.; Sumere, B.R.; Silva, L.C.; Cunha, D.T.; Martinez, J.; Rostagno, M.A. Isolation of gallic acid, caffeine and flavonols from black tea by on-line coupling of pressurized liquid extraction with an adsorbent for the production of functional bakery products. *LWT* **2020**, *117*, 108661. [CrossRef]
285. Majerska, J.; Michalska, A.; Figiel, A. A review of new directions in managing fruit and vegetable processing by-products. *Trends in Food Sci. Technol.* **2019**, *88*, 207–219. [CrossRef]
286. Maoto, M.M.; Beswa, D.; Jideani, A.I. Watermelon as a potential fruit snack. *Int. J. Food Prop.* **2019**, *22*, 355–370. [CrossRef]
287. Ayar, A.; Siçramaz, H.; Öztürk, S.; Öztürk Yilmaz, S. Probiotic properties of ice creams produced with dietary fibres from by-products of the food industry. *Int. J. Dairy Technol.* **2018**, *71*, 174–182. [CrossRef]
288. Mir, S.A.; Bosco, S.J.D.; Shah, M.A.; Santhalakshmy, S.; Mir, M.M. Effect of apple pomace on quality characteristics of brown rice based cracker. *J. Saudi Soc. Agric. Sci.* **2017**, *16*, 25–32. [CrossRef]
289. Demirkol, M.; Tarakci, Z. Effect of grape (*Vitis labrusca* L.) pomace dried by different methods on physicochemical, microbiological and bioactive properties of yoghurt. *LWT* **2018**, *97*, 770–777. [CrossRef]
290. Marchiani, R.; Bertolino, M.; Ghirardello, D.; McSweeney, P.L.; Zeppa, G. Physico-chemical and nutritional qualities of grape pomace powder-fortified semi-hard cheeses. *J. Food Sci. Technol.* **2016**, *53*, 1585–1596. [CrossRef] [PubMed]
291. Šporin, M.; Avbelj, M.; Kovač, B.; Možina, S.S. Quality characteristics of wheat flour dough and bread containing grape pomace flour. *Food Sci. Technol. Int.* **2018**, *24*, 251–263. [CrossRef] [PubMed]
292. Tournour, H.H.; Segundo, M.A.; Magalhães, L.M.; Costa, A.S.; Cunha, L.M. Effect of Touri-ga nacional grape extract on characteristics of mechanically deboned chicken meat kept under frozen storage. *J. Food Process. Eng.* **2017**, *40*, e12434. [CrossRef]
293. Costa, C.; Lucera, A.; Marinelli, V.; Del Nobile, M.A.; Conte, A. Influence of different by-products addition on sensory and physicochemical aspects of *Primosale cheese*. *J. Food Sci. Technol.* **2018**, *55*, 4174–4183. [CrossRef]
294. Aliakbarian, B.; Casale, M.; Paini, M.; Casazza, A.A.; Lanteri, S.; Perego, P. Production of a novel fermented milk fortified with natural antioxidants and its analysis by NIR spectroscopy. *LWT-Food Sci. Technol.* **2015**, *62*, 376–383. [CrossRef]
295. Kumar, V.; Kushwaha, R.; Goyal, A.; Tanwar, B.; Kaur, J. Process optimization for the preparation of antioxidant rich ginger candy using beetroot pomace extract. *Food Chem.* **2018**, *245*, 168–177. [CrossRef]
296. De Toledo, N.M.V.; Nunes, L.P.; da Silva, P.P.M.; Spoto, M.H.F.; Canniatti-Brazaca, S.G. Influence of pineapple, apple and melon by-products on cookies: Physicochemical and sensory aspects. *Int. J. Food Sci. Technol.* **2017**, *52*, 1185–1192. [CrossRef]
297. Bobinaitė, R.; Viskelis, P.; Bobinas, Č.; Mieželienė, A.; Alenčikienė, G.; Venskutonis, P.R. Raspberry marc extracts increase antioxidative potential, ellagic acid, ellagitannin and anthocyanin concentrations in fruit purees. *LWT-Food Sci. Technol.* **2016**, *66*, 460–467. [CrossRef]
298. Pathak, D.; Majumdar, J.; Raychaudhuri, U.; Chakraborty, R. Characterization of physicochemical properties in whole wheat bread after incorporation of ripe mango peel. *J. Food Meas. Charact.* **2016**, *10*, 554–561. [CrossRef]
299. Mutua, J.K.; Imathiu, S.; Owino, W.J.F.S. Evaluation of the proximate composition, antioxidant potential, and antimicrobial activity of mango seed kernel extracts. *Food Sci. Nutr.* **2017**, *5*, 349–357. [CrossRef] [PubMed]
300. Davis, L.; Jung, J.; Colonna, A.; Hasenbeck, A.; Gouw, V.; Zhao, Y. Quality and Consumer Acceptance of Berry Fruit Pomace–Fortified Specialty Mustard. *J. Food Sci.* **2018**, *83*, 1921–1932. [CrossRef]
301. Ismail, T.; Akhtar, S.; Riaz, M.; Hameed, A.; Afzal, K.; Sattar Sheikh, A. Oxidative and microbial stability of pomegranate peel extracts and bagasse supplemented cookies. *J. Food Q.* **2016**, *39*, 658–668. [CrossRef]
302. Sandhya, S.; Khamrui, K.; Prasad, W.; Kumar, M. Preparation of pomegranate peel extract pow-der and evaluation of its effect on functional properties and shelf life of curd. *LWT* **2018**, *92*, 416–421. [CrossRef]
303. Campos, D.A.; Coscueta, E.R.; Vilas-Boas, A.A.; Silva, S.; Teixeira, J.A.; Pastrana, L.M.; Pintado, M.M. Impact of functional flours from pineapple by-products on human intestinal microbiota. *J. Funct. Foods* **2020**, *67*, 103830. [CrossRef]
304. Oliveira, V.R.D.; Preto, L.T.; de Oliveira Schmidt, H.; Komeroski, M.; Silva, V.L.D.; de Oliveira Rios, A. Physicochemical and sensory evaluation of cakes made with passion fruit and orange residues. *J. Culin. Sci. Technol.* **2016**, *14*, 166–175. [CrossRef]