Review

Sustainable Recovery of Preservative and Bioactive Compounds from Food Industry Bioresidues

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Abstract: With the increasing demand for convenient and ready-to-eat foods, the use of antioxidants and preservative additives in foodstuff formulation is essential. In addition to their technological functions in food, bio-based additives confer beneficial properties for human health for having antioxidant capacity and acting as antimicrobial, antitumor, and anti-inflammatory agents, among others. The replacement of preservatives and other additives from synthetic origin, usually related to adverse effects on human health, faces some challenges such as availability and cost. An opportunity to obtain these compounds lies in the food industry itself, as a great variety of food waste has been identified as an excellent source of high value-added compounds. Large amounts of seeds, fibrous strands, peel, bagasse, among other parts of fruits and vegetables are lost or wasted during industrial processing, despite being rich sources of bioactive compounds. From a circular economy perspective, this work reviewed the main advances on the recovery of value-added compounds from food industry bioresidues for food application. Bioactive compounds, mainly phenolic compounds, have been largely obtained, mostly from seeds and peels, and have been successfully incorporated into foods. Additionally, alternative and eco-friendly extraction techniques, as ultrasound and microwave, have showed advantages in extracting antioxidant and preservatives compounds.

Keywords: bioresidues; value-added compounds; antioxidant molecules; green extraction methods; food applications

1. Introduction

According to a survey carried out between 2010 and 2011, it is estimated that about one-third of the food produced for human consumption in the world is lost or wasted, which represents ~1.3 billion tons per year [1]. The interest in estimating these values is not new; in 2007, Mahro & Timm [2] carried out a study about the possibilities of using food processing residues as a biomass resource and concluded that, despite the well-established state of food industry, reliable data on the amounts of the generated waste along the distinct processing stages were difficult to obtain.

More recently, this topic has been gaining interest and, in 2018, Corrado & Sala [3] published a review of existing studies on the generation of food waste on a global and European scale. Through this study, variations in food waste were estimated from 194 to 389 kg per person per year worldwide and from 158 to 298 kg per person per year in the EU. Among the reported works, the project FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies) stands out, with the estimation of food waste generated at an European level [4]. This project was carried out between 2012 and 2016 through the 7th Framework Program of the European Community, and represented...
a milestone in the accounting of food waste, with the generation of a manual on food waste quantification [5].

The interest in estimating these values is in line with the concern for the reduction of food waste generated worldwide. In the EU, as summarized on the EUbusiness portal [6], the Waste Framework Directive (Directive 2006/12/EC) has been revised through the Directive 2008/98/EC, to encourage the reuse and the recycling of waste materials and to simplify existing legislation, establishing measures to protect the environment and human health. Another action was through the United Nations Sustainable Development Goal 12.3 [7], where member states have pledged to halve per capita global food waste, in retail and consumer levels, by reducing food waste along production and supply chains by 2030.

Achieving reduced food waste and losses has been the focus of several recent studies, which involves identifying the dynamics of bioresidues generation and developing mechanisms to avoid this generation, as also managing unavoidable losses through strategies such as reuse. In fact, a great variety of bioresidues has proven to be a valuable source for the recovery of high value-added compounds, mainly with antioxidant capacity [8–15].

In this context, this review aims to explore the potential of using these bioresidues and by-products, through the concept of a circular economy, for the extraction of bioactive compounds. It also addresses the application of green and environmentally-friendly extraction methods and the incorporation of the recovered compounds into foodstuff.

Characterization

In addition to governmental interests in decreasing the volume of generated waste, views of characterization and ways of using these residues have also been gaining traction in the scientific circles [8,10,13,16]. The food waste data, discussed by Stenmark et al. [4], were divided into the following sectors: primary production, processing, wholesale and logistics combined with retail and market, food services, and household; according to food waste quantification manual [5]. Through the results obtained, it is possible to verify that the biggest impact on the generation of waste comes from household and processing in the food manufacturing, in more detail 53% and 19%, respectively, considering food and inedible parts of food. The beginning of the food supply chain (primary production and processing) resulted in an estimated loss of approximately 26 million tons of food wasted in 2012 by the EU-28 [4]. Some cases of food waste are reported by the author Tristram Stuart in his famous book entitled “Waste: discovering the global waste scandal” [16], with the outstanding example of bread processing, which generates the waste of 4 slices from each loaf, the crust, and the first slice at either end, amounting to 13,000 slices of fresh bread wasted every day. However, the most impactful pictures are related to the waste generated at the harvest level, where thousands of fruits and vegetables are discarded for not meeting the sales standard, in terms of size and overall appearance.

FAO data [1] reports that in low-income countries, the generation of food waste is bigger during the initial and intermediate stages of the food supply chain. In industrialized countries, on the other hand, more than 40% of food losses occur at retail and consumer levels, despite also occurring at the beginning of the food supply chain in significant quantities. Analyzing data, it is also verified that, in Europe, more than 50% of the production of roots and tubers and ~46% of the production of fruits and vegetables are lost or wasted, considering the edible parts of food products produced for human consumption. The sub-Saharan Africa region has the lowest production volume of fruit and vegetable group, along with North America and Oceania, compared to other five groups of regions in the world (Europe, Industrialized Asia, North Africa, West and Central Asia, South and Southeast Asia, and Latin America), and ~20% of the amount is lost during industrial processing.

In another study [17], it was found that, due to cumulative losses, the proportion of global agricultural dry biomass consumed as food is only 6% and 24.8% of the harvested biomass, i.e., only a small fraction of agricultural production is consumed as food. While losses during processing are also considerable (15–59% of processed crops), they widely vary between dry matter, energy, protein, and wet mass.
This brief information reveals a huge lack in the use of food. The potential of waste in commercial exploitation and circular use will be discussed below, focusing on by-products generated at industrial levels. Table 1 summarizes recent works in terms of the characterization of the main components of nutritional and/or commercial value that can be recovered from food industry biowaste and explored for different purposes.

Table 1. Biocompounds found in bioresidues from food industry.

| Industrialization Process         | By-Product(s)/Bioresidue(s) | Biocompounds                                                                 | References |
|----------------------------------|----------------------------|------------------------------------------------------------------------------|------------|
| Processed potatoes               | Peel                       | Polyphenols, antioxidants, proteins, polysaccharides, vitamins, and minerals | [8,9]      |
| Depulping of jucara fruit        | Pomace and seeds—about 74% | Antioxidants compounds and unconventional starch                             | [10]       |
| Pumpkin processing               | Peel, seeds, and the flesh between seeds | Phenolic compounds and carotenes                                           | [11]       |
| Kiwi fruit processing            | Skin and bagasse           | Dietary fiber and bioactive compounds with antioxidant activity             | [12]       |
| Blackthorn fruit processing      | Epicarp                    | Anthocyanins                                                               | [13]       |
| Açaí fruit processing            | Seeds, slurry, and pulp residue—about 80 to 95% | Antioxidant compounds, polyphenols and flavonoids, cellulose, hemicellulose, and lignin | [14]       |
| Passion fruit processing         | Rinds and bagasse—about 40 to 60% | Tocopherols and tocotrienols, fatty acids, carotenoid, and phenolic compounds (mostly piceatannol) | [18]       |
| Wine production                  | Bagasse (grape skins and seeds), stalks, and sludge—about 30% | Organic matter, phytochemicals, and compounds with nutraceutical properties | [15]       |
| Cashew nut processing            | Shell liquid, testa, cashew apple, and cashew apple bagasse | Bioactive compounds, polymers, and potent lignocellulosic material           | [19]       |
| Tamarind processing              | Peel, fiber, and seeds—about 50 to 70% | Phytochemicals, mainly polyphenols, fatty acids, and polysaccharides         | [20]       |
| Sugar cane industry              | Sugarcane bagasse          | Cellulose, hemicellulose, and lignin                                        | [21]       |
| Cereal grinding                  | Cereal bran                | Minerals, phenolic acids, amino acids, and vitamins                         | [22]       |
| Beer production                  | Spent grain                | Oligosaccharides, for example arabino-xylooligosaccharides (prebiotic nutraceutical) | [23,24]   |
| Tomato processing                | Peels or mixture of peels, seeds, and a small amount of pulp | Carotenoids, mainly lycopene                                               | [25]       |
| Vanilla extract processing       | Bagasse of the pod         | Water- and ethanol-insoluble aromatic compounds                             | [26]       |
| Tropical fruit processing        | Seeds, peels, and leaves—up to 60% | Phenolic compounds, carotenoids, proteins, vitamins, or dietary fibers       | [27]       |
| Sardine processing               | Waste from canning facility—about 20 to 75% | Proteins, peptides, amino acids, lipids (omega-3 polyunsaturated fatty acids, PUFAs), enzymes (pepsin, trypsin), vitamins (A, D, E) and biopolymer | [28]       |
| Jabuticaba processing            | Epicarp                    | Antioxidant compounds, tocopherols, anthocyanins, and ellagitannins         | [29]       |
| Melon cruzi processing           | Epicarp                    | Anthocyanins and tocopherols                                               | [30]       |

PUFA: polyunsaturated fatty acids.
It is possible to highlight the fruit and vegetable group as the food raw materials that generate bioresidues with greater potential and interest for scientific study and commercial exploitation. This is because residues from fruit and vegetable processing are rich in organic matter, phytochemicals, and compounds with nutraceutical properties [31]. However, in general, diverse food residues are important sources of value-added compounds, with considerable levels of phenolic compounds, dietary fibers, polysaccharides, vitamins, carotenoids, pigments, oils, and others [32], justifying their recovery [33,34].

The works performed by Buratto et al. [14] and Cádiz-Gurrea et al. [27] are recent examples of that, as summarized in Table 1. In the first study, it was found that about 5–15% of the weight of açai fruit is edible, being almost 80% of the weight of the total fruit composed of seeds and lost during processing. In the extract of these seeds, significant amounts of polyphenols and total flavonoids were identified, among other compounds, with high ORAC (oxygen radical absorbance capacity) value. In the second study, a value of ~60% for the generation of by-products from the processing of tropical fruits was accounted, where the bioresidues, composed mostly by peels and seeds, revealed to be rich in photochemical compounds.

2. Value-Added Compounds

The bioactive compounds (e.g., antioxidants, polyphenols, tocopherols, carotenoids, and vitamins) naturally present in food are important for human nutrition [35,36]. Found in cereals, fruits, vegetables, grains, and several other foods and its subproducts, these compounds are secondary plant metabolites [37,38] that can cause a significant impact in human and animal body functionality, with pharmacological or toxicological effects [39]. The primary metabolites are responsible for the growth and development of the plant, e.g., proteins, lipids, and carbohydrates [36,40]. On the other hand, and despite being considered as by-products of metabolic and biosynthetic pathways of those molecules, bioactive compounds exert significant functionality in plants. They exert, for example, protective support, acting as free radical scavengers; they are able to act as signalers, appealing to pollinating insects or seed dispersers; and can also provide defense, repelling insects, parasites or competing plants, among other diverse functions, through the many varieties of compounds [33,38].

When these bioactive compounds are incorporated into the diet, by food or medicinal bases, they can provide benefits to human health, developing positive effects on body functionality. Studies have linked the consumption of foods rich in bioactive compounds with a reduction in the risk of developing chronic diseases such as cancer, diabetes, obesity, and cardiovascular diseases [33,35]. The beneficial health effects exhibited by these compounds are due to their ability to modulate metabolic processes, such as antioxidant activity, enzyme inhibition or induction, inhibition of receptor activities, and induction and inhibition of gene expression [36]. In fact, the antioxidant activity is often highlighted among their functions [41–43], once they protect the body’s cells against oxidative damage, reducing the oxidative stress and preventing cancer, arteriosclerosis, and aging processes. These properties have been reported as highly suitable for preservative, fortifier, and stabilizer additives development [36].

Many different illnesses, such as cancer, cardiovascular and pulmonary diseases, neurological disorders, diabetes, arthritis, ageing process, and other neurological and endocrinological disorders, result from oxidative stress (OS). In turn, the OS is the result of an imbalance between the free radicals and the antioxidants on the metabolism, originated from environmental causes, inflammation processes, exposure to radiation, drugs, and others unfavorable conditions [39]. In this case, when the antioxidant defense enzymes are overwhelmed, the nutrients with antioxidant capacity, found in natural food, are important to help the body combating these free radicals. Thus, when significant amounts of bioactive compounds are part of the diet regularly, they are capable of exerting antioxidant activities [39,44].
There are several therapeutic properties and mechanisms of modulation of metabolic processes reported in the literature. In a recent review [45], the antiviral capacity of bioactive compounds focused on the COVID-19 management was highlighted. A two-way strategy to combat SARS Cov-2 infection using bioactive compounds as blockers has been reported: blocking S protein of the virus and blocking ACE2 receptor of the cell. In addition to nutraceutical properties, as previously measured, bioactive compounds are also known for their functional properties (antioxidant activity, solubility, absorption, coloring, stabilization, flavor, preserving, etc.). Natural pigments such as anthocyanins, carotenoids, and betalains are proposed as natural colorant additives in foods, being also linked to other benefits, such as antioxidant effects [46]. Carotenoids, e.g., lycopene, are also used in cosmetic products, due to its photo-protection capacity, protecting the skin from the sun [47]. In another study, Rodriguez-Garcia et al. [48] proposed the essential oil obtained from oregano as antimicrobial and antioxidant food additive. In the food industry, there is a growing interest in isolating these compounds from natural sources for further application in processed food, as alternatives to the use of synthetic additives (preservatives, nutritional additives, flavoring agents, coloring agents, texturizing agents, or miscellaneous additives).

In general, numerous studies have been reporting that a great variety of food wastes are rich sources of bioactive compounds, with great potential for recovery and application in food, cosmetic, and pharmaceutical industries [38]. Vitamin D$_2$, e.g., was recovered from the biological surplus remaining from the mushroom cultivation industry [49]; phenolic acids and flavonoids were obtained from tomato crop remains (pruning and end-of-cycle plant materials) [50], and organic acids, phenolic compounds, and high concentrations of anthocyanins were extracted from *Sicana odorifera* fruit epicarp [30]. The recovery of value-added compounds from bioresidues and their applicability in food will be further discussed in topic 4.

There are approximately more than 200,000 chemicals isolated and identified, considering primary and secondary metabolites, from higher plants worldwide [51]—such as proteins and amino acids, phenolic compounds, and other molecules with antioxidant activity, vitamins, dietary fiber and functional polysaccharides, minerals, fatty acids, enzymes, aromatic compounds, etc.—that can have added value by recovery from undervalued sources in agriculture and industry [52,53]. Note that the recovery of these compounds from natural sources is normally affected by some factors as the matrix properties of the plant materials and the extraction method conditions (e.g., solvent, temperature, pressure, and time) [54,55].

Bioactive compounds can be classified considering their solubility, polarity, and distribution in nature [39]. They are also commonly classified based on the biosynthetic route, the structural features, the basis of clinical function related to their pharmacological effect, and the botanical approach considering their families [38]. This classification results in a vast and heterogeneous number of classes of these compounds, e.g., phenolic compounds, carotenoids, tocopherols, alkaloids, and vitamins [37]. More details are presented through the diagram in Figure 1.

Phenolic compounds are one of the most widely found groups of secondary metabolites in plants [56]. They have a great structural diversity that, based on the number of constitutive carbon atoms conjugated with the structure of the basic phenolic skeleton, result in different subclasses: flavonoids, phenolic acids, stilbenes, lignans, tannins, and oxidized polyphenols [39,57]. These compounds are final products of the shikimate and acetate pathways, and their structure comprises aromatic hydroxylated compounds, having one or more aromatic rings with one or more hydroxyl groups. They can range from relatively simple phenolic molecules to highly polymerized compounds, most commonly being conjugated to mono- and polysaccharides, associated with one or more phenolic groups, and can also be linked to methyl esters and esters [51,57].
Among the more than 8000 known phenolic compounds, approximately 6000 constitute the group of flavonoids [51,56]. Flavonoid compounds are often stored in the plant linked to one or more sugars, being this form more stable than the free flavonoid [51]. These compounds generally have a yellow to red color and, when added to food products, they contribute to the color and flavor of food, in addition to being able to prevent oxidation of fats and protect vitamins and enzymes [43,51]. Anthocyanins, on the other hand, present red, blue, and purple colors, with a structure consisting of two aromatic rings linked by a three carbon heterocyclic ring that contains oxygen [46], while tannins, or tannic acids, exert antimicrobial action and are responsible for the astringency of many fruits, containing in its structure a large number of hydroxyl or other functional groups [51].

In turn, alkaloids and glycosides are the categories, pointed by Vuong [38], which are currently attracting increasing attention for research regarding their recovery from industrial food bioresidues, once these natural nitrogen-containing organic compounds present great biological activities. For example, steroidal alkaloids were extracted from potato peel waste [58]; alkaloids were obtained from cocoa bean shell [59]; glycosides were extracted from pineapple waste [60], and quercetin glycosides from onion solid waste [61]. These groups of compounds, and others molecules, e.g., terpenoids and coumarins, were studied for their potential to protect against liver fibrosis [62]. The terpenoids are generally insoluble in water and based on five carbon units [37]. Carotenoids are an example of terpenoid compounds (tetraterpenes) widely explored from plant material.

3. Green Extraction Methods

The extraction of bioactive compounds from natural sources is an extensive topic of discussion. On the one hand, the seek to increase yield, optimize the parameters of extraction processes, and minimize the influences that affect the extraction and degradation of target compounds, in addition to reducing costs and process times. On the other hand, the challenge remains of obtaining the best results through methods that do not impact the environment nor the consumers’ health, reducing energy costs and using safe solvents.

The term green method is used to classify extraction methods that have certain advantages over conventional ones. While conventional methods generally require long extraction times to obtain greater performance and involve large amounts of solvent, which...
are sometimes toxic, alternative methods are more sustainable, using green solvents and more ecological techniques with high extraction yield and compounds preservation.

3.1. Extraction Solvents

Green solvents, in general, have non-toxic characteristics, are biodegradable, and obtained from renewable sources. In the databook of green solvents [63], it is possible to find more than 300 green solvents, with detailed information about usage considerations, physical properties, health and safety issues, potential substitutes, and for which products the solvent is recommended.

Among the green solvents, water is a great option with greenness characteristic as non-toxicity to health and the environment, safety, bioavailability, and price. In addition, it is possible to tune the properties of water by changing the temperature: at high temperatures, coupled to high pressure to keep the water in a liquid state (subcritical condition), the dielectric constant is decreased and the penetration of water into the sample matrix is favored, along with the decrease of the surface tension and viscosity, and the improvement of the analyte diffusion and mass-transfer kinetics [64]. Another well-known solvent is ethanol, a cheap and renewable solvent, produced by the fermentation of biological material, recognized as non-toxic, although flammable, but a final purification step is required in some processes. The equilibrium constant of this alcohol is strongly influenced by temperature, as the extractability of the material increases with temperature [65]. It has been presenting great selectivity to extract oil [65] and has been employed in many researches on the extraction of phenolic compounds, in hydroalcoholic solutions (see Table 2).

Recently, the large application of organic solvents such as benzene, toluene, xylene, methanol, and ethanol in many laboratories and industrial chemical processes has generated an environmental concern due to its high volatility, which contributes to global climatic changes, air pollution, and human health-related issues [66]. With this, new alternatives, such as supercritical fluids (SCFs), eutectic solvents (ESs), fluorous solvents, and ionic liquids (ILs), have been widely proposed [66–68].

The challenge of choosing the solvent involves considerations such as: being suitable for the method and efficient for the target compound and its matrix, economically viable, safe for health, and environmentally friendly. Some methods can help predict solvent performance through its physicochemical and thermodynamic properties. Mokashi et al. [69] used a mathematical model equation to estimate the extraction efficiency of various solvents for the recovery of pyruvic acid. The model relates Hansen Solubility Parameters (HSPs) with distribution coefficient, where HSPs is an equation of solubility parameters with different types of energy including polar, diffusivity, and hydrogen bonding interactions. In another work [67], a review of computational methods for screening green solvents is presented. The quantum chemistry (QC) methods based on continuum solvation models (CSM), used for solvent selection and design, and methods based on the Conductor-like Screening Model (COSMO) are discussed, which guides solvent selection from thermodynamic performance indicators.

3.2. Extraction Methods

3.2.1. Principles

The solid–liquid extraction process has been used for many decades, from home use to prepare tonics to a popular way of obtaining essential oils and bioactive compounds. The process consists of extracting the target compound by mixing the solid raw material with a solvent for a certain time. Thereafter, the solid–liquid phases are separated and the extract is purified. This technique is the principle of traditional extractions and many new enhanced extraction methods [70,71]. Figure 2 shows a simplified scheme of the main extraction methods employed in natural matrices.
3.2.1. Principles

The solid–liquid extraction process has been used for many decades, from home use to industrial applications, for extracting target compounds from natural matrices. The process consists of extracting the target compound by mixing the solid raw material with a solvent for a certain time. Thereafter, the solid–liquid phases are separated and the solvent is recovered for reuse. The dynamic of extraction is influenced by parameters such as the choice of the solvent, pH of the medium, solid–liquid ratio, process temperature, and contact area between the solid and the solvent. In turn, these variables affect the energy consumption, the quantity of solvent used and its recovery capacity, the extraction yield, and other factors, which are increasingly studied through the optimization of parameters and comparison between techniques for different target compounds and their matrix [13,70].

3.2.2. Main Methods Explored in the Literature

Maceration (ME) consists of mixing the plant material with an appropriate solvent in a vessel and staying in contact for a certain (and usually long) time [72]. This process can be assisted by heating and/or stirring, e.g., thermostatic water bath, electro-magnetic stirring, and bain-marie with agitation. Generally, the solid matrix is ground to increase the surface area. It involves isolation and purification steps, usually by filtration and solvent evaporation [38].

Advantages and limitations: it is a simple and low-cost method, but requires long times of extraction and high quantities of solvent [73].

Soxhlet (SE) was originally developed for the extraction of lipids from a solid material, but it has also been adapted for bioactive compounds from various natural sources. In the Soxhlet equipment, the plant material is placed in a thimble of the apparatus and accoupled in a distillation flask containing the solvent, where the sample is washed by the solvent through intermittent reflux. When the solvent heats and condenses to an overflow level, a siphon system arrangement drains out the solution (solvent plus extracted solute) into the flask. There, the solution is heated until the solvent vaporizes and the process runs repeatedly for exhaustive extraction [74,75].

Advantages and limitations: it is a simple technique that demands less quantity of solvent, when compared to maceration, due to solvent recirculation. However, the extraction time is long and heat-labile compounds can be affected [73].

Ultrasound-assisted extraction (UAE) is based on the dispersion of sound waves in the liquid medium (solvent) that contains the sample to be extracted. Upon the waves reaching sufficient intensity of successive compression and distension in the medium, cavitation bubbles are formed. These bubbles, when collapsing, cause the rupture of cellular structures, facilitating the penetration of the solvent and increasing the mass transfer [76].

Advantages and limitations: it is an inexpensive and simple method, capable of improving extraction yield and faster kinetics [71], in addition to less consumption of energy, solvent, and extraction time. Nevertheless, the heat generated can affect heat-labile compounds and the reproducibility can be reduced by the aging of the instrument [76].
Microwave-assisted extraction (MAE) is a method that uses microwave radiation, i.e., non-ionizing electromagnetic waves (300 MHz to 300 GHz). Through this technique, an electric field is generated by the simultaneous effects of ionic conduction and dipolar rotation. The larger the dielectric constant of the solvent, the higher the heating and dipolar rotation. Through this mechanism, pressure is generated inside the plant cell and its consequent rupture, exposing the cell and then facilitating solvent penetration [77].

Advantages and limitations: it is a low-cost equipment, which requires reduced extraction time and quantity of solvent, with improved extraction yield. It also allows processing without using solvent. On the other hand, the heat generated can affect heat-labile compounds and it loses efficiency in scaling up [71,76].

Supercritical fluid extraction (SFE) has as principle the use of the solvent fluid in its supercritical state. For this, the temperature and pressure parameters of the process are controlled to achieve the conditions in which the fluid is between the gas and liquid states, presenting similar liquid density and gas viscosity [38]. Carbon dioxide (CO₂) is an attractive solvent largely used in this method [78]. The supercritical solvent flows through the raw material, placed in an extractor vessel, transports the dissolved solute to the separator, and then can be regenerated and returned to the process [38].

Advantages and limitations: high selectivity for non-polar compounds, non-degradation of heat sensitive compounds, and non-residues of toxic solvents. However, it demands high costs and complex operation and training [76,78].

Pressurized liquid extraction (PLE) uses pressurized solvents at high temperatures and pressures, but without reaching the critical point values. Through this mechanism, it is possible to ensure rapid extraction rate, by decreasing the dielectric constant of the solvent [74].

Advantages and limitations: the use of pressure allows a faster extraction, with less solvents and higher yields, but, the high temperatures can damage thermolabile compounds [74].

Enzyme-assisted extraction (EAE) utilizes enzymes, as cellulase, xylanase, and pectinase, for example, capable to degrade the cell wall structure, facilitating the extraction of many bioactive compounds, to which the access is often hindered because they are linked to the constituents of the cell wall [79].

Advantages and limitations: it presents high selectivity and improves yield, however, the enzymes are expensive and demand rigorous control of medium pH and temperature for optimal enzyme action [76].

3.3. Extraction Parameters

Despite the summarized contextualization of the principles of the most common extraction methods, there is a great deal of processes and combinations of these in the literature. Table 2 presents some recent extraction studies and the used parameters, as well as the conditions optimized and/or highlighted by the authors.

There are several factors that can influence the success and yield of the extraction. Parameters as solvent type, liquid–solid ratio (LSR), particle size, temperature, time of exposure, power, and pressure, are commonly studied. To outline the best conditions of the extraction procedure for different plant materials and target compounds, optimization studies are very important. For this, the most relevant independent parameters are evaluated, in a predetermined range of values, combined (or not) with the comparison of different extraction methods.

For instance, anthocyanin-rich extracts were obtained in optimization and comparison studies of heat- and ultrasound-assisted extraction techniques, using different fruits as sources: *Arbutus unedo* L. fruits [80], *Prunus spinosa* L. fruit epicarp [13], and *Ficus carica* L. fruit peel [81]. These works followed the same evaluation structure, however, the alternative UAE method proved to be more efficient for *F. carica* and *P. spinosa*, while for *A. unedo* the conventional method (heat-assisted extraction) was the most effective in the evaluated responses. These results demonstrate the influence of the matrix on the method’s performance. In another study [74], the conventional method (Soxhlet) also stood out when compared to the emerging technology pressurized liquid extraction (PLE), for
the extraction of phenolic compounds and mannitol from olive leaves. However, although the Soxhlet extraction revealed a better performance in most of the analyzed variables, the authors highlighted shorter extraction times (5 min versus 4 h), and lower solvents consumption and energy costs as advantages achieved by PLE method, which is important to be considered in industrial scale application.

Reduction of extraction time and energy consumption was also reported by Jesus et al. [82], by using the microwave-assisted extraction method in comparison to the heat-assisted one. In addition to these advantages, through the alternative method, the authors achieved higher yields and concentrations of ellagic acid. The conventional maceration technique was compared to the heat and ultrasound assisted extraction processes to obtain polyphenols from *Thymus serpyllum* L. herb [83]. In this work, the UAE was the most efficient, followed by the HAE (heat-assisted extraction) and, last, the ME. The authors discussed the influence of the process time and, in the preliminary screening, the high time of exposure caused a slight decline in the polyphenol content. On the other hand, in the results obtained in the optimization study (running in low temperatures), time did not significantly affect the extraction, with the relevant factors being the particle size, solid-to-solvent ratio, solvent type, and extraction procedure.

Other studies reported enzymes being used as pretreatment for supercritical carbon dioxide extraction of lycopene from tomato [84]. The use of plant cell wall glycosidases led to a significant increase in the concentrations of lycopene and total lipids in the matrices, when compared to the control. On the other hand, Jiang et al. [68] defended the use of deep eutectic solvents (DESs) as an alternative to organic solvents for more efficient and green extraction. DESs are a mixture of two or more hydrogen bond acceptor and donor, bound together by strong intermolecular interactions, which are being proved as new high-efficiency extraction solvents. In this study, the authors optimized an efficient DESs extraction method to different types of bioactive alkaloids. Moreover, Babova et al. [85] combined the supercritical (SC) and subcritical (SubC) CO$_2$ extraction methods in a multi-stage process to improve the extraction of antioxidant compounds (anthocyanins, other flavonoids, other phenolics, and proanthocyanidins) from bilberry (*Vaccinium myrtillus* L.). This methodology proved to be efficient showing great performance of selectivity through the stepwise extraction procedure. Other high-pressure methods (SFE and PLE) were compared to low-pressure methods (SE and UAE) to obtain an ethanolic extract with high antioxidant potential from black pepper [86]. The authors pointed out that each extraction procedure presented particular characteristics, but, in general, SE and UAE extracts presented higher yields when compared to SFE method; PLE has shown good results to the extraction of bioactive compounds; and SFE showed effectiveness for the recovery of extracts rich in piperine, providing a high value-added and solvent-free extract.
Table 2. Optimized green methods for the extraction of natural compounds.

| Method                                      | Source                        | Compound                                | Solvent       | Extraction Conditions                                      | Reference |
|---------------------------------------------|-------------------------------|-----------------------------------------|---------------|------------------------------------------------------------|-----------|
| Maceration extraction (ME)                  | Exsylphus globulus L. leaves  | Phenolic compounds (mostly flavonoids)  | Ethanol       | LSR 20 L/Kg, 2 Hz, 50 °C, 225 min, 50% ethanol             | [87]      |
| Arbutus unedo L. fruits                     | Anthocyanins                  | Ethanol (pH 4, 0.05% of hydrochloric acid) | LSR 5–40 L/Kg, 8.33 Hz, 5 min, 90 °C, 80% ethanol | [80]      |
| Lamiaceae (Origanum glandulosum Desf.)      | Phenolic compounds (mostly gallicatechin) | Ethanol | LSR 15 L/Kg, 850 W/2455 MHz, 42 °C, 2 min, 0% ethanol | [77]      |
| Lamiaceae (Thymus fontanesii Boiss. et Reut.) | Phenolic compounds (mostly rosmarinic acid) | Ethanol | LSR 15 L/Kg, 850 W/2.455 × 10⁹ Hz, 150 °C, 9.5 min, 50% ethanol | [77]      |
| Coriulux versicolor (L. ex Fr) Quel. mushroom | Phenolic compounds            | Ethanol                                 | LSR 10 L/Kg, 125 W, 3.8 min, 40% ethanol | [88]      |
| Vine pruning residue                        | Phenolic compounds (mostly ellagic acid and apigenin) | Ethanol | LSR 40 L/Kg, 120 °C, 5 min, 60% ethanol | [82]      |
| Morus nigra L. fruits                       | Phenolic compounds (mostly anthocyanins) | Ethanol | LSR 50 L/Kg, 500 W, 35 °C, 10 min, 35% ethanol | [89]      |
| Arbutus unedo L. fruits                     | Flavonoids                    | Ethanol                                 | LSR 20 L/Kg, 400 W, 120 °C, 1.5 min, 0% ethanol | [72]      |
| Goji berry fruit                            | Carbohydrates and phenolic compounds | Water | LSR 28 L/Kg, 283 W, 64.29 °C, 39.7 min | [90]      |
| Thymus serpyllum L. herb                    | Phenolic compounds            | Ethanol                                 | LSR 30 Kg/L, 25 °C, 15 min, 50% ethanol (750 W output with a 2 × 10⁴ Hz converter) | [83]      |
| Prunus spinosa L. fruit epicarp              | Anthocyanins                  | Ethanol (pH 3, citric acid)            | LSR 20 L/Kg, 400 W, 5 min, 47.98% ethanol | [13]      |
| Ficus carica L. peel                        | Anthocyanins                  | Ethanol                                 | LSR 6.66 L/Kg, 310 W, 21 min, 100% ethanol | [81]      |
| Tarchonanthis camphoratus L. leaves         | Parthenolide                  | Ethanol                                 | LSR 20.4 L/Kg, 38.8 °C, 50 min, 100% ethanol | [91]      |
| Agro-industrial acerola (Malpighia emarginata DC) residue | Anthocyanins, other flavonoids, other phenolic compounds, carotenoids, and ascorbic acid | Ethanol (pH 2, hydrochloric acid 2 mol/L) | LSR 8.66 L/Kg, 50 kHz and 250 VA, 30 °C, 49.30 min, 46.49% ethanol | [92]      |
| Black mulberry, wall germander, wild geranium, and comfrey | Phenolic compounds (mostly gallic acid) | Water | LSR 40 L/Kg, 160 °C, 1 × 10⁶ Pa, 3 Hz, 30 min | [93]      |
| Chestnut shells                             | Phenolic antioxidants (mostly caffeoylquinic acid isomers) | Water | LSR 10 L/Kg, 220 °C, 4 × 10⁶ Pa, 30 min | [94]      |
| Canola seeds                                | Tocopherol-rich oil           | Carbon dioxide (CO₂)                   | 70 °C, 8 × 10⁶ Pa, 30 min, 1.67 × 10⁻⁵ L/s | [78]      |
| Raspberry seeds                             | Oil                           | Carbon dioxide (CO₂)                   | 40 °C, 3.5 × 10⁷ Pa, 240 min, 1.11 × 10⁻⁴ Kg/s | [95]      |
| Apple seeds                                 | Fatty acids rich oil          | Carbon dioxide (CO₂)                   | 40 °C, 4 × 10⁶ Pa, 140 min, 2.78 × 10⁻⁴ L/s | [96]      |
Table 2. Cont.

| Method                        | Source                      | Compound                                   | Solvent       | Extraction Conditions                                                                 | Reference |
|-------------------------------|-----------------------------|--------------------------------------------|---------------|----------------------------------------------------------------------------------------|-----------|
| Pressurized liquid extraction (PLE) | Olive leaves               | Phenolic compounds and mannitol           | Ethanol       | LSR $3 \times 10^{-3}$ Kg dw sample into $2.2 \times 10^{-2}$ L stainless steel cells, $190^\circ$ C, 5 min, 60% ethanol | [74]      |
|                               | Pomegranate peels           | Condensed tannins, anthocyanins, other flavonoids, other phenolic compounds | Ethanol       | LSR $60$ L/Kg, $4.92 \times 10^8$ Pa, $20$–$38^\circ$ C, 30 min, 37% ethanol             | [97]      |
|                               | Truffles Tuber melanosporum Vittad. | Sterols and $\beta$-glucans              | Ethanol and water | $5 \times 10^{-4}$ Kg, $1.67 \times 10^7$ Pa, $180^\circ$ C, 30 min, 100% ethanol or water | [98]      |

LSR: liquid–solid ratio.

4. Value-Added Compounds in the Development of Innovative Food Products

The recovery and valorization of compounds through green methodologies and from bioresidues, adding value to what would be wasted, corroborates the principles of a circular economy [99]. The circular economy is the concept related to the reduction, reuse, and recycling of food losses and wastes along the food supply chain [100]. The use of bioresidues to obtain value-added compounds is a management strategy for waste and food loss, which can contribute to reducing its environmental impacts, minimizing the use of virgin materials, in addition to promoting opportunities for savings, as innovation of products and methods, competitiveness and productivity [100].

Innovation in the food industry through the use of biocompounds not only adds to the circular economy sustainability concept but is also an opportunity to attend consumers’ expectations. In fact, consumers’ concern for safer and healthier foods is increasing, and food industry is under pressure to offer healthy, convenient, and ready-to-eat foods, able to meet daily nutritional needs, provide pleasure and satiety, and attend to consumers’ expectations and safety issues [101,102]. In this scenario, the replacement of synthetic compounds, generally associated with toxicity and allergenic problems, with healthy natural alternatives is increasingly evident [101]. Alongside, the enrichment of products by using compounds with nutritional value is also a growing tendency. The use of agro-industrial residues, rich in bioactive compounds, has been the focus of studies that propose the use of these by-products in the formulation of functional foods [102]. As synthetized in Table 3, value-added compounds were recovered from industrial processes wastewater, from commercially unexplored fruits, and industrial processing by-products, and their applicability was verified. Below, some relevant works available in the literature on the valorization of these compounds and practical applications in foodstuff are discussed.

For example, potato peel wastes were valorized as a source of protein and dietary fiber through their addition to cake [109]. The protein and soluble and insoluble fiber contents of the potato peel powders were about 15%, 19%, and 10%, respectively. The cakes enriched with 10% of potato peel flour achieved a percentage of protein improvement of ~17%. Regarding dietary fiber, the soluble fiber content increased from 3.3% in control cake to almost 5% in enriched cakes, and the insoluble fiber content significantly increased from 15.9% (control) to ~22% for cakes with potato peel flour. In addition to improving the nutritional value, the authors reported technological effects: the incorporation of potato peel powder at 5% increased the dough strength and elasticity-to-extensibility ratio.

Grape seeds and apple peels were also valorized as sources of natural antioxidants, especially phenolic compounds, through the fortification of yogurts with these bioresidues powders [110]. In this line, the authors also optimized the extraction conditions, using green solvents, to obtain extracts with high phenolic compounds content from these by-products. In another study, Chen et al. [111] discussed the applications of grape seed extract in food industry as preservative. They proposed the use of the extract as raw material to develop healthy foods as it improves the nutritional value and promotes benefits such as enhancing the body immunity, prevent hyperlipidemia, hypertension, and diabetes;
as natural antioxidant and preservative in food, due to its antioxidant and antimicrobial activity; as food film/coating in food packaging, to improve certain functional properties; and as substitute of nitrite and nitrate in meat products, and sulfur dioxide (SO₂) and animal protein in wine making.

**Table 3.** Value-added compounds recovery from food waste and its applicability.

| Compound(s) of Interest | Source(s) | Benefit for Health | Applicability | Reference |
|------------------------|-----------|--------------------|---------------|-----------|
| Vitamin D₂             | Surplus mushrooms | Antitumoral | Food industry | [49]      |
| Anthocyanins           | Fig peel and blackthorn fruit epicarp | Antioxidant and antimicrobial activities | Natural purple colorant in pastry products | [41] |
| Dietary fiber          | Pumpkin seeds and rinds | Nutritional value | High fiber bakery product | [103] |
| Phenolic compounds     | Peel of camu-camu fruit | Antimicrobial potential | Yogurt fortification | [104] |
| Anthocyanins           | Strawberry tree fruit | Antioxidant and antifungal activities | Natural colorant in wafers | [42] |
| Phenols                | Olive mill wastewater | UVA and UVB filter potential | UV booster in cosmetics | [105] |
| Sugar                  | Coffee silverskin and spent coffee grounds | N.A. ¹ | Ethanol production by fermentation | [106] |
| Phenolic acids, hydrolysable tannins, flavonoids, and anthocyanins | Pomegranate epicarp | Antioxidant and antibacterial activities | Natural colorant and antioxidant in pastry products | [43] |
| Phenolic and carotenoid compounds | Pumpkin peel | Antioxidant activity | Retard canola oil oxidation | [107] |
| Anthocyanins           | Jabuticaba epicarp | Antioxidant, antimicrobial, antitumor and anti-inflammatory activities | Natural colorant in macarons | [108] |

¹ Not Applicable.

Moreover, the ethanolic extracts of apple peels were fractionated and their use for inhibition of fish oil oxidation was studied using the thiobarbituric acid reactive substances (TBARS) assay [112]. The crude and fractionated extracts presented inhibitory effect on fish oil oxidation, where the greatest antioxidant capacity was verified with the fractions containing quercetin glycosides and epicatechin in combination with other polyphenols, such as phloridzin and cyanidin-3-galactoside. The apple peel was also successfully used as prebiotic in yoghurt [113]. Through this study, a probiotic yoghurt fortified with apple peel polyphenol extract was obtained, which can act as natural high-quality antioxidant and bioactive compound.

In another study [114], a green extraction method was used to obtain phenolic compound-rich extracts from olive leaves. The extracts were obtained by solvent-free MAE and presented high antioxidant activity, so they were proposed as having a great potential as functional ingredients for food packaging. In fact, the developed biodegradable films based on carrageenan containing olive leaf extract showed good barrier and mechanical properties, and the total phenolic compounds and antioxidant activity of the films significantly increased with increased concentrations of the olive leaf extract.

Promising antioxidant extracts were also obtained from the peel of eggplant. Horincar et al. [115] used the green method of UAE to obtain a methanolic extract of this by-product. Six anthocyanins were identified in the extract: delphinidin-3-rutinoside, delphinidin-3-glucoside, cyanidin-3-rutinoside, delphinidin-3-rutinoside-5-glucoside, malvidin-3-rutinoside-5-glucoside, and petunidin-3-rutinoside. In a subsequent study [116], the extract was microencapsulated with whey protein and acacia gum, resulting in a purple colored powder. The addition of the eggplant peel powder in a pastry cream allowed a significant
increase of total phenolic content and antioxidant activity, which were rather stable over 72 h of storage under refrigeration conditions. The ethanolic extract of eggplant peel was, then, proposed as supplement in beer [117], with the supplemented beer presenting high functional potential and good sensory characteristics, being stable without the incorporation of artificial preservatives.

Anthocyanin-rich extracts from blackthorn epicarp [13] and fig peel [81], obtained by a green optimized extraction method (previously discussed in Section 3.3), were proposed as alternative natural colorants. The extracts were incorporated in confectionery products, more specifically “beijinhos” (a typical Brazilian pastry) and doughnut icing. The obtained purple colorant extracts conferred attractive color to the products, improved the texture properties, and significantly increased the antioxidant and antimicrobial activities. In fact, anthocyanins are widely found in many fruits. As reviewed by Albuquerque et al. [118], fruits and their bioresidues are an excellent source of natural compounds, including a wide range of coloring, in addition to bioactive properties and with great potential to be implemented in the food industry as alternative to the use of synthetic additives. Moreover, the bioresidues from food industry of Morus nigra L. and Rubus fruticosus L., for not presenting adequate size or properties to be marketed, were also studied as sources of anthocyanins [119]. The juices from these fruits were used in the preparation of solid colorants using the spray-drying technique, which resulted in colorants with a great and stable coloring capacity over time and safe for application in the food industry. In another study [120], an anthocyanin-rich extract was obtained from purple and red potatoes and evaluated as natural colorant in a soft drink formulation in comparison with the commercial colorant E163. The extracts showed suitable profiles in the sensory and shelf-life assessments, with high color stability during a 30-day shelf-life. Despite their multiple health benefits, some of these fruits are not used for consumption for not presenting the suitable size or properties to be included in the market, constituting a food industry residue.

Furthermore, as alternative for the use of synthetic additives in food industry, sage (Salvia officinalis L.) and basil (Ocimum basilicum L.) were exploited for their preservative purposes [121]. For that, extracts were obtained and incorporated into yogurt. The results were very satisfactory, with the extracts presenting antioxidant and antimicrobial activity, without changing the physicochemical and nutritional characteristics of the yogurts and the growth of lactic acid bacteria.

However, there is a wide range of sources to be explored and valued. In the literature, several biowastes were characterized and identified as having great potential for the recovery of value-added compounds, which could be applied in the food industry. Grape (Vitis vinifera L. var. Albariño) and mulberry (Morus nigra L.) seed pomace was characterized and the first presented high contents of organic acids and phenolic compounds, mainly catechins, while the mulberry seeds revealed to be rich in tocopherols and ellagic acid derivatives. The extracts containing these compounds showed antioxidant and antimicrobial activity and no cytotoxicity on PLP2 cells (a primary culture of porcine liver non-tumor cells), being their use proposed as natural preservative in the food industry. The epicarp of the eggplant fruit (Solanum melongena L.) was highlighted by the authors [122] as a potential natural source of coloring compounds for food application, once it is rich in anthocyanins. Cereal by-products from the flour milling industry, more specifically wheat germ, maize bran–germ mixture, rye bran, and wheat bran, were reported [123] as underexploited alternative sources of nutrients and bioactive compound, such as protein and vitamin E.

5. Conclusions

Bioresidues from food industry have a great potential for the recovery of many value-added compounds. In the inedible parts as seeds, peel, and bagasse, as well as edible but rejected raw materials, many nutritional and bioactive compounds with high antioxidant capacity have been identified. The valorization of by-products and bioresidues, and the recovery of these compounds through green and environmentally friendly methods goes
towards a circular economy. In the literature, several reports of the successful application of compounds obtained from food waste can be increasingly found. However, the transition to a circular food system with an efficient use of resources and food distribution is still a long challenge. There is a huge quantity of residues and unexploited plants to be characterized and valorized, and extraction processes to be optimized, leading to energy, solvent, and time reduction, among other relevant parameters. Studies on the stability of the recovered compounds, their stabilization through innovative techniques, and application in different matrices, as well as the scale-up process from laboratory to industrial level are also of great importance and increasingly needed. In general, this review aimed to contribute with new perspectives on underexploited and wasted biomaterials, aiming at the sustainability in industrial processes with the consequent increase in the use of natural compounds compared to artificial ones, meeting the emerging expectations of consumers, and promoting a circular food economy.

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**References**

1. Faò, G. Global Food Losses and Food Waste-Extent, Causes and Prevention; United Nations: Rome, Italy, 2011; pp. 1–37. [CrossRef]
2. Mahro, B.; Timm, M. Potential of Biowaste from the Food Industry as a Biomass Resource. *Eng. Life Sci.* 2007, 7, 457–468. [CrossRef]
3. Corrado, S.; Sala, S. Food waste accounting along global and European food supply chains: State of the art and outlook. *Waste Manag.* 2018, 79, 120–131. [CrossRef] [PubMed]
4. Stenmarck, Å.; Jensen, C.; Quested, T.; Moates, G.; Buksti, M.; Cseh, B.; Juul, S.; Parry, A.; Politano, A.; Redlingshofer, B.; et al. Estimates of European Food Waste Levels; IVL Swedish Environmental Research Institute: Stockholm, Sweden, 2016.
5. Tostivint, C.; Östergren, K.; Quested, T.E.; Soethoudt, J.M.; Stenmarck, Å.; Svanes, E.; O’Connor, C.L. Food Waste Quantification Manual to Monitor Food Waste Amounts and Progression; Wageningen University: Wageningen, The Netherlands, 2016.
6. EUbusiness Waste Framework Directive. Available online: www.eubusiness.com/topics/environ/waste-framework/ (accessed on 26 January 2021).
7. UN General Assembly. *Transforming Our World: The 2030 Agenda for Sustainable Development*, Resolution Adopted by the General Assembly on 25 September 2015; United Nations: New York, NY, USA, 2015.
8. Gaudino, E.C.; Colletti, A.; Grillo, G.; Tabasso, S.; Cravotto, G. Emerging Processing Technologies for the Recovery of Valuable Bioactive Compounds from Potato Peels. *Foods* 2020, 9, 1598. [CrossRef]
9. Martinez-Fernandez, J.S.; Seker, A.; Davaritouchae, M.; Gu, X.; Chen, S. Recovering Valuable Bioactive Compounds from Potato Peels with Sequential Hydrothermal Extraction. *Waste Biomass Valor.* 2020, 12, 1465–1481. [CrossRef]
10. Carpinié, D.; Dągostin, J.L.A.; Mazon, E.; Barbi, R.C.T.; Alves, F.E.D.S.B.; Chaimsohn, F.P.; Ribani, R.H. Valorization of Euterpe edulis Mart. agroindustrial residues (pomace and seeds) as sources of unconventional starch and bioactive compounds. *J. Food Sci.* 2019, 85, 96–104. [CrossRef] [PubMed]
11. Klava, D.; Kampuse, S.; Tomson, L.; Kinca, T.; Ozola, L. Effect of drying technologies on bioactive compounds maintenance in pumpkin by-products. *Agron. Res.* 2018, 16, 1728–1741. [CrossRef]
12. Squezetta, M.B.; Stefanello, F.S.; Huerta, K.D.M.; Monteiro, S.S.; da Rosa, C.S.; Terra, N.N. Characterization of physiochemical and microbiological properties, and bioactive compounds, of flour made from the skin and bagasse of kiwi fruit (Actinidia deliciosa). *Food Chem.* 2016, 199, 471–478. [CrossRef]
13. Lichtweins, M.G.; Pereira, C.; Prieto, M.; Barreiro, M.F.; Barros, L.; Ferreira, J.C. Ultrasound as a Rapid and Low-Cost Extraction Procedure to Obtain Anthocyanin-Based Colorants from *Prunus spinosa* L. Fruit Epicarp: Comparative Study with Conventional Heat-Based Extraction. *Molecules* 2019, 24, 573. [CrossRef] [PubMed]
14. Buratto, R.T.; Cocero, M.J.; Martin, A. Characterization of industrial açaí pulp residues and valorization by microwave-assisted extraction. *Chem. Eng. Process. Process. Intensif.* 2020, 160, 108269. [CrossRef]
15. Brazil, N.M.; Massia, A.G.; Meireles, G.C.; Oliveira, R.; Jacques, A.C. Caracterização físico-química de bagaço de uva Chardonnay proveniente do processo de vinificação. Rev. Congr. Sul Bras. Eng. Aliment. 2016, 2, 1–5.

16. Cádiz-Gurrea, M.D.I.L.; Villegas-Aguilar, M.D.C.; Leyva-Jiménez, F.J.; Pimentel-Moral, S.; Fernández-Ochoa, Á.; Alaínó, M.E.; Segura-Carretero, A. Revalorization of bioactive compounds from tropical fruit by-products and industrial applications by means of sustainable approaches. Food Res. Int. 2020, 138, 109786. [CrossRef]

17. Stuart, T. Waste: Uncovering the Global Waste Scandal, 1st ed.; Penguin Books: Longon, UK, 2009.

18. Alexander, P.; Brown, C.; Arneth, A.; Finnigan, J.; Moran, D.; Rounsevell, M. Losses, inefficiencies and waste in the global food system. Agric. Syst. 2017, 153, 190–200. [CrossRef]

19. Viganó, J.; Assis, B.F.D.P.; Náthia-Neves, G.; dos Santos, P.; Meireles, M.A.A.; Veggi, P.C.; Martínez, J. Extraction of bioactive compounds from defatted passion fruit bagasse (Passiflora edulis sp.) applying pressurized liquids assisted by ultrasound. Ultrason. Sonochemistry 2020, 64, 104999. [CrossRef]

20. Sharma, P.; Gaur, V.K.; Sirohi, R.; Larroche, C.; Kim, S.H.; Pandey, A. Valorization of cashew nut processing residues for industrial applications. Ind. Crop. Prod. 2020, 152, 112550. [CrossRef]

21. Martins, C.M.; Ferro, D.M.; de Brito, E.S.; Ferreira, S.R.S. Industrial relevance of Tamarindus indica L. by-products as source of valuable active metabolites. Innov. Food Sci. Emerg. Technol. 2020, 66, 102518. [CrossRef]

22. Pandey, A.; Soccol, C.R.; Nigam, P.; Soccol, V.T. Biotechnological potential of agro-industrial residues. I: Sugarcane bagasse. Bioresour. Technol. 2000, 74, 69–80. [CrossRef]

23. Bartkieni, E.; Mozurien, E.; Lele, V.; Zokaityte, E.; Gruzauskas, R.; Jakobson, I.; Juodeikiene, G.; Ruibys, R.; Bartkevics, V. Changes of bioactive compounds in barley industry by-products during submerged and solid state fermentation with antimicrobial Penicillium ocacei acidilactici strain LUN529. Food Sci. Nutr. 2019, 8, 340–350. [CrossRef]

24. Amorim, C.; Silverio, S.C.; Rodrigues, L.R. One-step process for producing prebiotic arabinino-xylooligosaccharides from brewer’s spent grain employing Trichoderma species. Food Chem. 2018, 270, 86–94. [CrossRef]

25. Steinmacher, N.C.; Honna, F.A.; Gasparetto, A.V.; Anibal, D.; Grossmann, M.V. Bioconversion of brewer’s spent grains by reactive extrusion and their application in bread-making. LWT 2012, 46, 542–547. [CrossRef]

26. Pataro, G.; Carullo, D.; Falcone, M.; Ferrari, G. Recovery of lycopene from industrially derived tomato processing by-products by pulsed electric fields-assisted extraction. Innov. Food Sci. Emerg. Technol. 2020, 63, 102369. [CrossRef]

27. Baqueiro-Peña, I.; Guerrero-Beltrán, J. Vanilla (Vanilla planifolia Andr.), its residues and other industrial by-products for recovering high value flavor molecules: A review. J. Appl. Res. Med. Aromat. Plants 2017, 6, 1–9. [CrossRef]

28. Melgosa, R.; Trigueros, E.; Sanz, M.T.; Cardeira, M.; Rodrigues, L.; Fernández-Nieto, N.; Matias, A.A.; Bronze, M.R.; Marques, M.; Paiva, A.; et al. Supercritical CO2 and sub-critical water technologies for the production of bioactive extracts from sardine (Sardina pilchardus) waste. J. Supercrit. Fluids 2020, 164, 104943. [CrossRef]

29. Albuquerque, B.R.; Pereira, C.; Calhelha, R.C.; Alves, M.J.; Abreu, R.M.; Barros, L.; Oliveira, B.; Ferreira, I.C. Jabuticaba residues (Myrciaria jaboticaba (Vell.) Berg) are rich sources of valuable compounds with bioactive properties. Innovative Food Sci. Emerg. Technol. 2019, 70, 102925. [CrossRef]

30. Albuquerque, B.R.; Pereira, C.; Calhelha, R.C.; Alves, M.J.; Abreu, R.M.; Barros, L.; Oliveira, B.; Ferreira, I.C. Jabuticaba residues (Myrciaria jaboticaba (Vell.) Berg) are rich sources of valuable compounds with bioactive properties. Innovative Food Sci. Emerg. Technol. 2019, 70, 102925. [CrossRef]

31. Sharma, P.; Gaur, V.K.; Sirohi, R.; Larroche, C.; Kim, S.H.; Pandey, A. Valorization of cashew nut processing residues for industrial applications. Ind. Crop. Prod. 2020, 152, 112550. [CrossRef]

32. Bartkieni, E.; Mozurien, E.; Lele, V.; Zokaityte, E.; Gruzauskas, R.; Jakobson, I.; Juodeikiene, G.; Ruibys, R.; Bartkevics, V. Changes of bioactive compounds in barley industry by-products during submerged and solid state fermentation with antimicrobial Penicillium ocacei acidilactici strain LUN529. Food Sci. Nutr. 2019, 8, 340–350. [CrossRef]

33. Khan, M.K.; Chemat, F.; Sattar, S.; Imran, M.; Imran, A.; Arshad, M.U.; Laihtisham-Ul-Haq; Suleria, H.A.R. Bioactive Compounds from Plant Origin: Extraction, Applications, and Potential Health Benefits, 1st ed.; Suleria, H.A.R., Barrow, C., Eds.; Apple Academic Press Inc.: Boca Raton, FL, USA, 2019.

34. Vuong, Q.V.; Golding, J.B.; Nguyen, M.; Roach, P.D. Extraction and isolation of catechins from tea. J. Sep. Sci. 2010, 33, 3415–3428. [CrossRef]

35. Hooper, L.; Cassidy, A. A review of the health care potential of bioactive compounds. J. Sci. Food Agric. 2006, 86, 1805–1813. [CrossRef]

36. Galanakis, C.M. Nutraceutical and functional food components: Effects of innovative processing techniques. In Nutraceutical and Functional Food Components: Effects of Innovative Processing Techniques; Galanakis, C.M., Ed.; Nikki Levy: London, UK, 2017, pp. 1–10.

37. Verma, N.; Shukla, S. Impact of various factors responsible for fluctuation in plant secondary metabolites. J. Appl. Res. Med. Aromat. Plants 2015, 2, 105–113. [CrossRef]

38. Vuong, Q.V. Utilisation of Bioactive Compounds from Agricultural and Food Waste, 1st ed.; Vuong, Q.V., Ed.; CRC Press: Boca Raton, FL, USA, 2017.

39. Goyal, M.; Ayeleso, A. Bioactive Compounds of Medicinal Plants: Properties and Potential for Human HEALTH, 1st ed.; Goyal, M.R., Ayeleso, A.O., Eds.; Apple Academic Press: Toronto, ON, Canada, 2018.
40. Santos, D.Y.A.C. dos Botânica aplicada: Metabólicos secundários na interação planta-ambiente. Ph.D. Thesis, Universidade de São Paulo, São Paulo, Brazil, 2015.

41. Backes, E.; Leichtweis, M.G.; Pereira, C.; Carocho, M.; Barreira, J.C.; Kamal Genena, A.; José Baraldi, I.; Filomena Barreiro, M.; Barros, L.; Ferreira, I.C. Ficus carica L. and Prunus spinosa L. extracts as new anthocyanin-based food colorants: A thorough study in confectionery products. Food Chem. 2020, 333, 127457. [CrossRef]

42. Jiménez-López, C.; Caleja, C.; Prieto, M.A.; Sokovic, M.; Calhelha, R.C.; Barros, L.; Ferreira, I.C. Stability of a cyanidin-3-O-glucoside extract obtained from Arbutus unedo L. and incorporation into wafers for colouring purposes. Food Chem. 2018, 275, 426–436. [CrossRef]

43. Veloso, F.D.S.; Caleja, C.; Calhelha, R.C.; Pires, T.C.S.; Alves, M.J.; Barros, L.; Genena, A.K.; Barreira, J.C.M.; Ferreira, I.C.F.R. Characterization and Application of Pomegranate Epicarp Extracts as Functional Ingredients in a Typical Brazilian Pastry Product. Molecules 2020, 25, 1481. [CrossRef]

44. Carocho, M., Ferreira, I.C. A review on antioxidants, prooxidants and related controversy: Natural and synthetic compounds, screening and analysis methodologies and future perspectives. Food Chem. Toxicol. 2013, 51, 15–25. [CrossRef] [PubMed]

45. Bhushan, I.; Sharma, M.; Mehta, M.; Badyal, S.; Sharma, V.; Sharma, I.; Singh, H.; Sistla, S. Bioactive compounds and probiotics—a ray of hope in COVID-19 management. Food Sci. Hum. Wellness 2021, 10, 131–140. [CrossRef]

46. Rodríguez-Amaya, D.B. Update on natural food pigments—A mini-review on carotenoids, anthocyanins, and betalains. Food Res. Int. 2019, 124, 200–205. [CrossRef] [PubMed]

47. Bin-Jumah, M.; Alwakeel, S.S.; Moga, M.; Buvnariu, L.; Rocha, F.; Barretto, A.M.; Carvalho, A.M.; Barros, L.; Ferreira, I.C.F.R. Application of Carotenoids in Cosmetics. In Carotenoids: Structure and Function in the Human BODY; Zia-Ul-Haq, M., Dewanjee, S., Riaz, M., Eds.; Springer: Cham, Switzerland, 2021; pp. 747–756.

48. Rodríguez-Garcia, I.; Silva-Espinoza, B.; Ortega-Ramírez, L.; Leyva, J.; Siddiqui, M.W.; Valenzuela, M.R.C.; González-Aguilar, G.; Zavala, J.F.A. Oregano Essential Oil as an Antimicrobial and Antioxidant Additive in Food Products. Crit. Rev. Food Sci. Nutr. 2015, 56, 1717–1727. [CrossRef]

49. Cardoso, R.; Ferreira, I.C.F.R.; Barros, L. A Case Study on Surplus Mushrooms Production: Extraction and Recovery of Vitamin D2. Agriculture 2021, 11, 579. [CrossRef]

50. Añibarro-Ortega, M.; Pióro, J.; Ciurea, A.; Martins, V.; Rocha, F.; Soković, M.D.; Barata, A.M.; Carvalho, A.M.; Barros, L.; Ferreira, I.C. Valorisation of tomato crop by-products: Phenolic profiles and in vitro antioxidant and antimicrobial activities. Food Bioprod. Process. 2020, 124, 307–319. [CrossRef]

51. Campos, M.R.S. Bioactive Compounds: Health Benefits and Potential Applications, 1st ed.; Campos, M.R.S., Ed.; Elsevier: London, UK, 2019.

52. Rico, X.; Gullón, B.; Alonso, J.L.; Yañez, R. Recovery of high-value-added compounds from pineapple, melon, watermelon and pumpkin processing by-products: An overview. Food Res. Int. 2020, 132, 109086. [CrossRef]

53. Bonilla-Hermosa, V.A.; Duarte, W.F.; Schwän, R. Utilization of coffee by-products obtained from semi-washed process for production of value-added compounds. Bioresour. Technol. 2014, 124, 146–150. [CrossRef]

54. Ben Ayache, S.; Reis, F.S.; Dias, M.I.; Pereira, C.; Glamoˇcli, J.; Soković, M.; Calhelha, R.C. Chemical characterization of carob seeds (Ceratonia siliqua L.) and use of different extraction techniques to promote its bioactivity. Food Chem. 2021, 351, 129263. [CrossRef]

55. Dias, M.; Caleja, C.; Pereira, C.; Calhelha, R.C.; Kostic, M.; Sokovic, M.; Tavares, D.; Baraldi, I.; Barros, L.; Ferreira, I.C. Chemical composition and bioactive properties of byproducts from two different kiwi varieties. Food Res. Int. 2019, 127, 108753. [CrossRef]

56. Tungmunnithum, D.; Thongboonyou, A.; Pholboon, A.; Yangsabai, A. Flavonoids and Other Phenolic Compounds from Medicinal Plants for Pharmaceutical and Medical Aspects: An Overview. Medicines 2018, 5, 93. [CrossRef]

57. Ferreira, L.B.A.R.M.A.I.C.; Barros, L.; Abreu, R. Antioxidants in Wild Mushrooms. Antioxidants 2021, 10, 1827. [CrossRef]

58. Hossain, M.B.; Tiwari, B.K.; Gangopadhyay, N.; O’Donnell, C.; Brunton, N.P.; Rai, D.K. Ultrasonic extraction of steroidal alkaloids from potato peel waste as an antioxidant, urease and xanthine oxidase inhibitors. Food Chem. 2017, 235, 119–126. [CrossRef]

59. Niyisso, R.; Kafai, A.; Kafai, A.; Shikuku, E.; Kayembe, M. Application of pineapple waste for the extraction of bioactive compounds and flavonoids using autohydrolysis. Innov. Food Sci. Emerg. Technol. 2018, 2018, 47, 38–45. [CrossRef]

60. Niyisso, R.; Niyisso, R.; Niyisso, R.; Shikuku, E.; Kayembe, M. Utilization of quercetin and quercetin glycosides from onion (Allium cepa L.) solid waste as an antioxidant, urease and xanthine oxidase inhibitors. Food Chem. 2017, 235, 119–126. [CrossRef]

61. Ma, X.; Jiang, Y.; Wen, J.; Zhao, Y.; Zeng, J.; Guo, Y. A comprehensive review of natural products to fight liver fibrosis: Alkaloids, terpenoids, glycosides, coumarins and other compounds. Eur. J. Pharmacol. 2020, 886, 173578. [CrossRef]

62. Wypych, G. Databook of Green Solvents, 1st ed.; Wypych, G., Ed.; Chemtect Publishing: Toronto, ON, Canada, 2014.

63. Castro-Puyana, M.; Marina, M.L.; Plaza, M. Water as green extraction solvent: Principles and reasons for its use. Curr. Opin. Green Sustain. Chem. 2017, 5, 31–36. [CrossRef]

64. Báumler, E.R.; Carrin, M.E.; Carelli, A.A. Extraction of sunflower oil using ethanol as solvent. J. Food Eng. 2016, 178, 190–197. [CrossRef]
66. Mohammad, A.; Inamuddin, M. 
Green Solvents I: Properties and Applications in Chemistry, 1st ed.; Mohammad, A., Inamuddin, M., Eds.; Springer: New York, NY, USA, 2012.

67. Gonzalez-Miquel, M.; Díaz, I. Green solvent screening using modeling and simulation. 
Curr. Opin. Green Sustain. Chem. 2021, 29, 100469. [CrossRef]

68. Jiang, Z.-M.; Wang, L.-J.; Gao, Z.; Zhuang, B.; Yin, Q.; Liu, E.-H. Green and efficient extraction of different types of bioactive alkaloids using deep eutectic solvents. 
Microchem. J. 2018, 145, 345–353. [CrossRef]

69. Mokashi, A.T.; Patil, K.D.; Kodolikar, S.P.; Topare, N.S. Recovery of pyruvic acid: A theoretical approach for selection of solvents for reactive extraction. 
Mater. Today Proc. 2021. [CrossRef]

70. Chemat, F.; Strube, J. 
Green Extraction of Natural Products: Theory and Practice, 1st ed.; Chemat, F., Strube, J., Eds.; Wiley-VCH: Weinheim, Germany, 2015.

71. Wang, L.; Weller, C.L. Recent advances in extraction of nutraceuticals from plants. 
Trends Food Sci. Technol. 2006, 17, 300–312. [CrossRef]

72. Albuquerque, B.; Prieto, M.A.; Vazquez, J.; Barreiro, M.F.; Barros, L.; Ferreira, I.C. Recovery of bioactive compounds from Arbutus unedo L. fruits: Comparative optimization study of maceration/microwave/ultrasound extraction techniques. 
Food Res. Int. 2018, 109, 455–471. [CrossRef]

73. Rasul, M.G. Conventional extraction methods use in medicinal plants, their advantages and disadvantages. 
Int. J. Basic Sci. Appl. Comput. 2018, 2, 10–14.

74. Lama-Muñoz, A.; Contreras, M.D.M.; Espinola, F.; Moya, M.; Romero, I.; Castro, E. Content of phenolic compounds and mannitol in olive leaves extracts from six Spanish cultivars: Extraction with the Soxhlet method and pressurized liquids. 
Food Chem. 2020, 320, 126626. [CrossRef]

75. Aravind, S.; Barik, D.; Ragupathi, P.; Vignesh, G. Investigation on algae oil extraction from algae Spirogyra by Soxhlet extraction method. 
Mater. Today Proc. 2021, 43, 308–313. [CrossRef]

76. Picot-Allain, C.; Mahomoodally, M.F.; Ak, G.; Zengin, G. Conventional versus green extraction techniques—a comparative perspective. 
Curr. Opin. Food Sci. 2021, 40, 144–156. [CrossRef]

77. Nabet, N.; Gilbert-López, B.; Madani, K.; Herrero, M.; Ibáñez, E.; Mendiola, J.A. Optimization of microwave-assisted extraction recovery of bioactive compounds from Origanum glandulosum and Thymbus fontanesii. 
Ind. Crop. Prod. 2018, 129, 395–404. [CrossRef]

78. Sun, Q.; Shi, J.; Scanlon, M.; Xue, S.J.; Lu, J. Optimization of supercritical-CO2 process for extraction of tocopherol-rich oil from canola seeds. 
LWT 2021, 145, 111435. [CrossRef]

79. Gligor, O.; Mocan, A.; Moldovan, C.; Locatelli, M.; Crișan, G.; Ferreira, I.C. Enzyme-assisted extractions of polyphenols—A comprehensive review. 
Trends Food Sci. Technol. 2019, 88, 302–315. [CrossRef]

80. López, C.J.; Caleja, C.; Prieto, M.A.; Barreiro, M.F.; Barros, L.; Ferreira, I.C.F.R. Optimization and comparison of heat and ultra-sound assisted extraction techniques to obtain anthocyanin compounds from Arbutus unedo L. Fruits. 
Food Chem. 2018, 264, 81–91. [CrossRef] [PubMed]

81. Backes, E.; Pereira, C.; Barros, L.; Prieto, M.A.; Genena, A.K.; Barreiro, M.F.; Ferreira, I.C. Recovery of bioactive anthocyanin pigments from Ficus carica L. peel by heat, microwave, and ultrasound based extraction techniques. 
Food Res. Int. 2018, 113, 197–209. [CrossRef]

82. Jesus, M.S.; Genisheva, Z.; Romani, 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. Crop. Prod. 2019, 132, 99–110. [CrossRef]

83. Jovanović, A.A.; Đorđević, V.B.; Zdunić, G.M.; Pljevljakaušić, D.S.; Šavikin, K.P.; Gođevac, D.M.; Bugarski, B.M. Optimization of the extraction process of polyphenols from Thymus serpyllum L. herb using maceration, heat- and ultrasound-assisted techniques. 
Sep. Purif. Technol. 2017, 179, 369–380. [CrossRef]

84. Lenucci, M.S.; De Caroli, M.; Marrese, P.P.; Iurlaro, A.; Rescio, L.; Böhm, V.; Dalessandro, G.; Piro, G. Enzyme-aided extraction of lycopenes from high-pigment tomato cultivars by supercritical carbon dioxide. 
Food Chem. 2015, 170, 193–202. [CrossRef]

85. Babova, O.; Occhipinti, A.; Capuzzo, A.; Maffei, M.E. Extraction of bilberry (Vaccinium myrtillus) antioxidants using supercritical/subcritical CO2 and ethanol as co-solvent. 
J. Supercrit. Fluids 2016, 107, 358–363. [CrossRef]

86. Andrade, K.S.; Trivellin, G.; Ferreira, S.R.S. Piperine-rich extracts obtained by high pressure methods. 
J. Supercrit. Fluids 2017, 128, 370–377. [CrossRef]

87. Gullón, B.; Gullón, P.; Lú-Chau, T.A.; Moreira, M.T.; Lema, J.; Eibes, G. Optimization of solvent extraction of antioxidants from Eucalyptus globulus leaves by response surface methodology: Characterization and assessment of their bioactive properties. 
Ind. Crop. Prod. 2017, 108, 649–659. [CrossRef]

88. Maeng, J.-H.; Shahbaz, H.; Ameer, K.J.; Jo, Y.; Kwon, J.-H. Optimization of Microwave-Mushroom Assisted Extraction of Bioactive Compounds from Coriolus versicolor Mushroom Using Response Surface Methodology. 
J. Food Process. Eng. 2016, 40, e12421. [CrossRef]

89. Koyu, H.; Kazan, A.; Demir, S.; Haznedaroglu, M.Z.; Yesil-Celiktas, O. Optimization of microwave assisted extraction of Morus nigra L. fruits maximizing tyrosinase inhibitory activity with iso-lation of bioactive constituents. 
Food Chem. 2018, 248, 183–191. [CrossRef]

90. Skenderidis, P.; Petrotos, K.; Giavasis, I.; Hadjidristoudooulu, C.; Tsakalof, A. Optimization of ultrasound assisted extraction of goji berry (Lycium barbarum) fruits and evaluation of extracts’ bioactivity. 
J. Food Process. Eng. 2016, 40, e12522. [CrossRef]
91. Siddiqui, N.A.; Alam, P.; Alrehaily, A.J.; Alqahtani, A.S.; Akhtar, A.; Alhowiriny, T.A.; Almarfadi, O.M.; Mothana, R.A. Optimization of ultrasound-assisted parthenolide extraction from Tarchonanthus camphoratus leaves using response surface methodology: HPTLC and cytotoxicity analysis. *Arab. J. Chem.* 2021, 14, 103914. [CrossRef]

92. Rezende, Y.R.R.S.; Nogueira, J.P.; Narain, N. Comparison and optimization of conventional and ultrasound assisted extraction for bioactive compounds and antioxidant activity from agro-industrial acerola (Malpighia emarginata DC) residue. *LWT* 2017, 85, 158–169. [CrossRef]

93. Nastić, N.; Švarc-Gajić, J.; Delerue-Matos, C.; Barroso, M.F.; Soares, C.; Moreira, M.M.; Morais, S.; Mašković, P.; Srček, V.G.; Slivac, I.; et al. Subcritical water extraction as an environmentally-friendly technique to recover bioactive compounds from traditional Serbian medicinal plants. *Ind. Crop. Prod.* 2018, 111, 579–589. [CrossRef]

94. Pinto, D.; Vieira, E.F.; Peixoto, A.F.; Freire, C.; Freitas, V.; Costa, P.; Delerue-Matos, C.; Rodrigues, F. Optimizing the extraction of phenolic antioxidants from chestnut shells by subcritical water extraction using response surface methodology. *Food Chem.* 2020, 334, 127521. [CrossRef]

95. Pavlić, B.; Pezo, L.; Marić, B.; Tukuljac, L.P.; Zeković, Z.; Solarov, M.B.; Teslić, N. Supercritical fluid extraction of raspberry seed oil: Experiments and modelling. *J. Supercrit. Fluids* 2019, 157, 104687. [CrossRef]

96. Ferrentino, G.; Giampiccolo, S.; Morozova, K.; Haman, N.; Spillimbergo, S.; Scampicchio, M. Supercritical fluid extraction of oils from apple seeds: Process optimization, chemical characterization and comparison with a conventional solvent extraction. *Innov. Food Sci. Emerg. Technol.* 2020, 64, 102428. [CrossRef]

97. Alexandre, E.; Araújo, P.; Duarte, M.F.; Freitas, V.; Pintado, M.M.; Saraiva, J.A. Experimental Design, Modeling, and Optimization of High-Pressure-Assisted Extraction of Bioactive Compounds from Pomegranate Peel. *Food Bioprocess Technol.* 2017, 10, 886–900. [CrossRef]

98. Usmani, Z.; Sharma, M.; Awasthi, A.K.; Sharma, G.D.; Cysneiros, D.; Nayak, S.; Thakur, V.K.; Naidu, R.; Pandey, A.; Gupta, V.K. Minimizing hazardous impact of food waste in a circular economy—Advances in resource recovery through green strategies. *J. Hazard. Mater.* 2021, 416, 126154. [CrossRef]

99. de Oliveira, M.M.; Lago, A.; Magro, G.P.D. Food loss and waste in the context of the circular economy: A systematic review. *J. Clean. Prod.* 2021, 294, 126284. [CrossRef]

100. Pereira, J.M.G.; Formigoni, M.; Viell, F.L.G.; Pante, G.C.; Bona, E.; Vieira, A.M.S. Aditivos alimentares naturais emergentes: Uma revisão. In *Realidades e Perspectivas em Ciência dos Alimentos*; Nogueira, W.V., Ed.; Pantanal Editora: Nova Xavantina, Brazil, 2020; pp. 46–84.

101. Subiria-Cueto, R.; Coria-Oliveros, A.J.; Wall-Medrano, A.; Rodrigo-Garcia, J.; González-Aguilar, G.A.; Martinez-Ruiz, N.d.R.; Alvarez-Parrilla, E. Antioxidant dietary fiber-based bakery products: A new alternative for using plant-by-products. *Food Sci. Technol.* 2021. [CrossRef]

102. Nyam, K.L.; Lau, M.; Tan, C.P. Fibre from pumpkin (*Cucurbita pepo*) seeds and rinds: Physico-chemical properties, antioxidant capacity and application as bakery product ingredients. *Malays. J. Nutr.* 2019, 13, 99–109. [PubMed]

103. Conceição, N.; Albuquerque, B.R.; Pereira, C.; Corrêa, R.C.G.; Lopes, C.B.; Calhelha, R.C.; Alves, M.J.; Barros, L.; Ferreira, I.C.F.R. By-Products of Camu-Camu [Myrciaria dubia (Kunth) McVaugh] as Promising Sources of Bioactive High Added-Value Food Ingredients: Functionalization of Yoghurts. *Molecules* 2019, 25, 70. [CrossRef]

104. Galanakis, C.M.; Tsatalas, P.; Galanakis, I.M. Implementation of phenols recovered from olive mill wastewater as UV booster in cosmetics. *Ind. Crop. Prod.* 2018, 111, 30–37. [CrossRef]

105. Mussatto, S.I.; Machado, E.M.; Carneiro, L.M.; Teixeira, J. Sugars metabolism and ethanol production by different yeast strains from coffee industry wastes hydrolysates. *Appl. Energy* 2012, 92, 763–768. [CrossRef]

106. Salami, A.; Asefi, N.; Kenari, R.E.; Gherekhani, M. Addition of pumpkin peel extract obtained by supercritical fluid and subcritical water as an effective strategy to retard canola oil oxidation. *J. Food Meas. Charact.* 2020, 14, 2433–2442. [CrossRef]

107. Salami, A.; Asefi, N.; Kenari, R.E.; Sharekhani, M. Addition of pumpkin peel extract obtained by supercritical fluid and subcritical water as an effective strategy to retard canola oil oxidation. *J. Food Meas. Charact.* 2020, 14, 2433–2442. [CrossRef]

108. Albuquerque, B.R.; Pinela, J.; Barros, L.; Oliveira, M.B.P.; Ferreira, I.C. Anthocyanin-rich extract of jabuticaba epicarp as a natural colorant: Optimization of heat- and ultrasound-assisted extractions and application in a bakery product. *Food Chem.* 2020, 316, 126364. [CrossRef]

109. Ben Jeddou, K.; Bouaziz, F.; Zouari-Ellouzi, S.; Chaari, F.; Ellouz-Chaabouni, S.; Ellouz-Ghorbel, R.; Nouri-Ellouz, O. Improvement of texture and sensory properties of cakes by addition of potato peel powder with high level of dietary fiber and protein. *Food Chem.* 2017, 217, 668–677. [CrossRef]

110. Brahmi, F.; Merchiche, F.; Mokhtarí, S.; Smail, L.; Geumghar-Haddadi, H.; Yalaoui-Guellal, D.; Achat, S.; Elsebai, M.F.; Madani, K.; Boulekbache, L. Optimization of some extraction parameters of phenolic content from apple peels and grape seeds and enrichment of yoghurt by their powders: A comparative study. *J. Food Process. Preserv.* 2020, 45, e15126. [CrossRef]

111. Chen, Y.; Wen, J.; Deng, Z.; Pan, X.; Xie, X.; Peng, C. Effective utilization of food wastes: Bioactivity of grape seed extraction and its application in food industry. *J. Funct. Foods* 2020, 73, 104113. [CrossRef]

112. Sekhon-Loodu, S.; Warnakulasuriya, S.N.; Rupasinghe, H.V.; Shahidi, F. Antioxidant ability of fractionated apple peel phenolics to inhibit fish oil oxidation. *Food Chem.* 2013, 140, 189–196. [CrossRef]
113. Ahmad, I.; Khalique, A.; Shahid, M.Q.; Rashid, A.A.; Faiz, F.; Ikram, M.A.; Ahmed, S.; Imran, M.; Khan, M.A.; Nadeem, M.; et al. Studying the Influence of Apple Peel Polyphenol Extract Fortification on the Characteristics of Probiotic Yoghurt. *Plants* 2020, 9, 77. [CrossRef] [PubMed]

114. Da Rosa, G.S.; Vanga, S.K.; Gariepy, Y.; Raghavan, V. Development of biodegradable films with improved antioxidant properties based on the addition of carrageenan containing olive leaf extract for food packaging applications. *J. Polym. Environ.* 2020, 28, 123–130. [CrossRef]

115. Horincar, G.; Enachi, E.; Stânciuc, N.; Răpeanu, G. Extraction and characterization of bioactive compounds from eggplant peel using ultrasound—Assisted extraction. *Ann. Univ. Dunarea Jos Galati Fascicle VI Food Technol.* 2019, 43, 40–53. [CrossRef]

116. Horincar, G.; Enachi, E.; Barbu, V.; Andronoiu, D.G.; Răpeanu, G.; Stânciuc, N.; Aprodu, I. Value-Added Pastry Cream Enriched with Microencapsulated Bioactive Compounds from Eggplant (*Solanum melongena* L.) Peel. *Antioxidants* 2020, 9, 351. [CrossRef]

117. Horincar, G.; Enachi, E.; Bolea, C.; Răpeanu, G.; Aprodu, I. Value-Added Lager Beer Enriched with Eggplant (*Solanum melongena* L.) Peel Extract. *Molecules* 2020, 25, 731. [CrossRef]

118. Albuquerque, B.R.; Oliveira, M.B.P.P.; Barros, L.; Ferreira, I.C.F.R. Could fruits be a reliable source of food colorants? Pros and cons of these natural additives. *Crit. Rev. Food Sci. Nutr.* 2020, 61, 805–835. [CrossRef]

119. Vega, E.; Molina, A.; Pereira, C.; Dias, M.; Heleno, S.; Rodrigues, P.; Fernandes, I.; Barreiro, M.; Stojković, D.; Soković, M.; et al. Anthocyanins from *Rubus fruticosus* L. and *Morus nigra* L. Applied as Food Colorants: A Natural Alternative. *Plants* 2021, 10, 1181. [CrossRef] [PubMed]

120. Sampaio, S.L.; Lonchamp, J.; Dias, M.I.; Liddle, C.; Petropoulos, S.A.; Glamočlija, J.; Alexopoulos, A.; Santos-Buelga, C.; Ferreira, I.C.; Barros, L. Anthocyanin-rich extracts from purple and red potatoes as natural colourants: Bioactive properties, application in a soft drink formulation and sensory analysis. *Food Chem.* 2020, 342, 128526. [CrossRef] [PubMed]

121. Ueda, J.; Pedrosa, M.; Fernandes, F.; Rodrigues, P.; Melgar, B.; Dias, M.; Pinela, J.; Calhelha, R.; Ivanov, M.; Soković, M.; et al. Promising Preserving Agents from Sage and Basil: A Case Study with Yogurts. *Foods* 2021, 10, 676. [CrossRef] [PubMed]

122. Silva, G.F.P.; Pereira, E.; Melgar, B.; Stojković, D.; Soković, M.; Calhelha, R.C.; Pereira, C.; Abreu, R.M.V.; Ferreira, I.C.F.R.; Barros, L. Eggplant Fruit (*Solanum melongena* L.) and Bio-Residues as a Source of Nutrients, Bioactive Compounds, and Food Colorants, Using Innovative Food Technologies. *Appl. Sci.* 2020, 11, 151. [CrossRef]

123. Cardoso, R.; Fernandes, Â.; Pinela, J.; Dias, M.; Pereira, C.; Pires, T.; Carocho, M.; Vasallo, E.; Ferreira, I.; Barros, L. Valorization of Cereal By-Products from the Milling Industry as a Source of Nutrients and Bioactive Compounds to Boost Resource-Use Efficiency. *Agronomy* 2021, 11, 972. [CrossRef]