sustainability

MDPI

Article

A Sustainable Approach for the Development of Innovative Products from Fruit and Vegetable By-Products

Mircea Valentin Muntean [1], Anca Corina Fărcaş [2], Mădălina Medeleanu [2], Liana Claudia Salanţă [2,*] and Andrei Borşa [2,*]

[1] Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, 400372 Cluj-Napoca, Romania

[2] Faculty of Food Science and Technology, University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, 400372 Cluj-Napoca, Romania

* Correspondence: liana.salanta@usamvcluj.ro (L.C.S.); andrei.borsa@usamvcluj.ro (A.B.)

Abstract: The waste generated by small-scale ultra-fresh juice producers, such as bistros and restaurants, has been little studied so far, mainly because it is unevenly distributed and dissipated in the economic ecosystem and would require high costs associated with transportation and subsequent recovery of bio composites. The present article seeks to offer solutions by providing sustainable methods to reduce their waste losses to a minimum and transform them into valuable products, with affordable equipment and techniques. The study focuses on the preliminary phase of quantitative analysis of fruit and vegetable by-products generated on a small scale, the results showing a mean 55% productivity in fresh juices. Due to the high amount of remnant water content in waste, a new process of mechanically pressing the resulting squeezed pulp was introduced, generating an additional yield in juice, ranging from 3.98 to 51.4%. Due to the rising trend in healthier lifestyle, the by-products were frozen or airdried for conservation in each of the processing stages, and the total phenolic compounds and antioxidant activity were analyzed in order to assess the traceability of these bioactive compounds to help maximize their transfer into future final products. The polyphenols transferred into by-products varied between 7 and 23% in pulps and between 6 and 20% in flours. The highest DPPH potential was found in flours, up to three-fold in comparison with the raw material, but the high dry substance content must be accounted for. The results highlight the potential of reusing the processing waste as a reliable source of bioactive compounds.

Keywords: food waste; by-products; valorization; health benefits

Citation: Muntean, M.V.; Fărcaş, A.C.; Medeleanu, M.; Salanţă, L.C.; Borşa, A. A Sustainable Approach for the Development of Innovative Products from Fruit and Vegetable By-Products. *Sustainability* **2022**, *14*, 10862. https://doi.org/10.3390/su141710862

Academic Editors: Ria Millati, Hossain M. Zabed and Teguh Ariyanto

Received: 17 July 2022
Accepted: 16 August 2022
Published: 31 August 2022

1. Introduction

According to research reported by the IMARC Group in August 2021 [1], the worldwide fruit juice market (part of the food industry and categorized as 100% fruit juice, nectars, juice drinks, concentrates, powdered juice and others) peaked at 44.12 billion liters in the previous year and generated waste accordingly. Although they represent the smallest segment within the non-alcoholic drinks market, according to the Consumer Market Outlook from 2022, ultra-fresh juices (with 24 h consumption availability) managed to generate revenue amounts of USD 92.10 billion in 2020, with a significant increase of USD 103.70 billion in 2021, and are expected to witness stable growth over the next five years, generated by the same need for natural juices in the urban areas but with more active ingredients [2]. Non-alcoholic beverage sales are segmented into retail sales for consumption at home and on-premises or foodservice sales for use outside of the home. All retail transactions, including all sales and consumption taxes, realized through super- and hypermarkets, convenience shops or other comparable sales channels, are included in the at-home market, often known as the off-trade market. All sales to hotels, restaurants, caterers, cafés, bars and other similar hospitality service facilities fall under the umbrella of the out-of-home market, also known as the on-trade market, away-from-home market or HORECA, and are the target of our research.

The ultra-fresh juices category includes all bottled juices made entirely of fruit or vegetable juice and exclude juice-based soft drinks and fruit nectars with little or no fruit. Fruit juice with 100% juice content is obtained by mechanically squeezing or macerating a wide range of fresh fruits or vegetables without the use of heat or solvents. Almost half (47.99%) of the customers prefer mixed drinks, followed by fruit content only, while less than 12% prefer vegetables only in their drinks, according to a recent study [2]. By combining them, consumers may enjoy various health benefits from one drink without having to buy other items individually. In addition, mixed juices containing more green vegetables than fruit juices give customers better access to bioactive nutrients. They can be easily incorporated into a vegan or detoxification diet and provide the essential vitamins and minerals to the body to improve the physical and mental well-being or strengthen the consumers' immune systems.

Prior to the emergence of COVID-19, people were steadily moving away from sugary foods, such as soda, cold drinks and other similar liquids, in favor of healthier dietary choices. The pandemic further influenced people to include fruit juices in their diets as healthy food options and evidenced a demographic transition, shaping the age distribution of the population [3–6] associated with many developed and concentrated markets and generating the highest segment growth in juice mixtures and ready-made smoothies [7] and a significant retail market disruption in the canned juices market segment. Changing lifestyles and altering consumer eating patterns resulted in an increased intake of affordable, healthy and quick sources of nutrition, such as packaged fruit juices, thereby catalyzing the growth of the market.

The cost of producing ultra-fresh juice is significantly higher than that of conventional juice. Producing these drinks is, therefore, an expensive choice for people concerned about pricing. Because these items have a short shelf life, their storage is particularly challenging. To prevent product quality from being impacted, most of these products must be refrigerated. Thus, the consumers' adoption of these juice products is impacted by the short shelf life. Additionally, a significant amount of pulp waste is produced throughout the manufacturing process. Processing such production-related by-products can be quite challenging. This raises the producers' processing costs even more when producing these juice goods [3].

In conjunction with the population's increasing consumption habit, the food losses and processing waste intensify every year all over the world. In 2019, the total waste exceeded 931 million tons, according to the UN Environment Programme's Food Waste Index Report from 2021 [8], and overall represented approximately 17% of the global food production. The waste generated from the food service accounted for 26% of the entire quantity (following household waste) and was composed mainly of vegetable parts [9]. In addition to the USD 400 billion annual value of food loss estimated by The Food and Agricultural Organization (FAO) [10], the COVID-19 pandemic may have caused an extra 83 to 132 million people to experience chronic hunger in 2020 after a period in which - the Prevalence of Undernourishment Index remained essentially unchanged for five years [11].

Since small-scale food producers are usually in need and frequently live in subsistence-level conditions, the income of these units has an impact on the overall poverty as well. On average, their revenues are less than half as high as those of larger food producers mainly due to lower productivity and unstable cashflow, varying from roughly USD 300 in Malawi, Mozambique and Niger to more than USD 3000 in Albania, Guatemala, Iraq or Serbia [12]. Similar circumstances apply to small-scale processors because the isolation restrictions severely reduced their client segments and numbers.

Consequently, the private agri-food sector needs to be incorporated into a local Triple Helix Partnership (university, government and industry) and provided with solutions that are integrated into their core business in order to resolve the existing problem. Fortunately, the 2030 Agenda for Sustainable Development, approved in September 2015 by the United

Nations General Assembly, transcends the COVID-19 pandemic and offers a window of opportunity to examine development models that are more inclusive and equitable and are supported by sustainable consumption and production in order to create a more resilient and long-lasting recovery [13].

The whole fruits and vegetables are full of compounds with a wide bioactivity spectrum and proved beneficial properties to human health, that are transferred in large amounts to their associated waste, thus creating a huge interest in their recovery and valorization, mainly since they represent a cheap resource and are available in high amounts [14]. Discarded fruit and vegetable peels, seeds, fibrous debris, or whole pieces which cannot be integrated into different technological processes are considered waste if they are not used as sources of by-products or be transformed further on into valuable products [15]. The literature study in the field reveals research focused on capitalizing on this high industrial waste generated by the concentrated and not-form-concentrated juices. The present research focuses on a fraction of the latter, namely the small scale ultra-fresh juice producers from the out-of-home markets where, practically, apart from the juice itself, everything else it's treated as waste. Therefore, we offer solutions to overcome economic difficulties and waste issues for the small-scale producers by providing sustainable methods to reduce their losses to a minimum and transform them into valuable products, with affordable equipment and techniques. Due to the rising trend in health products, the traceability of the bioactive compounds from the most frequently used raw materials was analyzed in each of the processing stages to help maximize their transfer into the final products.

Integrated into the circular economy concept, valorization of these vegetable residues can reduce the associated wasted resources such as land, water, services, energy and labor, on the entire agri-food chain, as well as the environmental issues associated with decomposing landfills and greenhouse gases emitted and should be addressed in compliance with the contemporaneous circular economy and environmental regulations [16–18].

Integrated into the Triple Helix model, the current research presents affordable opportunities and a guideline for the small-scale juice processors and adds a basis for future collaborations if the latter are willing to concentrate their resources on externalizing the R&D activities.

Innovative technologies are available outside the laboratory scale, in order to recover bioactive compounds from vegetable waste following the circular economy path, such as:

- microwave-assisted extraction (MAE) for pineapple waste [19], banana peel [20,21], apricot kernel skin [22], cabbage outer leaves [23];
- ultrasound-assisted extraction (UAE) for walnut green husks [24], lettuce leaves [25], acerola residues [26], capsicum and cabbage waste [27];
- supercritical fluid extraction (SFE) for blueberry waste [28];
- microwave hydro diffusion and gravity (MHG) for broccoli waste [29];
- deep eutectic solvents (DES) as emerging green solvents for Ginkgo biloba leaves [30], mango waste [31].

However, these need large-scale industrial extraction pilot plants closely linked to the waste generator partner to create a functional economic cycle and an integrated efficiency. So basically, a high investment loop and niche conditions are needed in this sector. Most of them are just emptying the bioactive part from waste and transferring the leftovers for bioprocessing to create a green chain.

As opposed to the industrial-scale production waste, the daily waste generated by the ultra-fresh juice local industry has no current means of valorization and is mostly just thrown away in the bin. Identification of an effective approach to harness these fruit and vegetable waste into by-products, analyze the traceability of bioactive compounds through the process and finally identify different accessible and sustainable methods to transform the latter into consumer products represent the main topics covered by our current research.

Bibiana Ramírez-Pulido et al. in 2021 compared different drying methods and their potential impact on bioactive compounds and their bio accessibility and concluded that hot air drying was a suitable technology for the valorization of solid wastes from plant matrices in the food industry due to its lower processing and investment the integral recovery of the biowastes [32]. On the other hand, freeze-drying could also be used for an integral valorization approach, and it provides high-quality products and powders which strongly preserve their functional properties; however, this technology has limited industrial applications due to its high operating costs, which are 4–8 times higher compared to air-drying [33]. The viability of these two methods for implementation in small businesses was taken as objective for this article.

2. Materials and Methods

The ultra-fresh juices sold regularly use a wide variety of fruits and vegetables. However, for the research phase, we surveyed five local sellers of different sizes from the metropolitan area of Cluj-Napoca, Cluj County, Romania. The survey indicated that they most commonly use apples, oranges, carrots, celery, and beets as ingredients for fresh juices. Thus, these were established as samples for the ongoing study. Except for oranges, all the samples had their origin in Romania and were bought from the same source used by the vendors. Fruits and vegetable content in bioactive compounds differ in composition depending on the genetic factor, various growth conditions and harvest maturity stage [34–36].

2.1. Samples Processing

For the present research, sample fruits, such as apples (*Malus Domestica*), oranges (*Citrus X Sinensis*) and vegetables, such as beetroot (*Beta vulgaris* subsp. *Vulgaris Sonditiva Group*), celery root (*Apium Graveolens*) and carrots (*Daucus Carota* subsp. *Sativus*) were purchased from a local supermarket (Cluj-Napoca, Romania) at commercial maturity. All materials followed a procedure similar to that in the economic process. They had foreign bodies and plant material removed, were weighted at approximately 5 kg each and processed as samples into three stages. In the first phase, the samples were washed with tap water, air dried and peeled manually, weighted again and then were processed using a Professional electric juicer J80 ULTRA, Robot Coupe, with a productivity of 120 L/h, an equipment frequently used by local economic agents that sell ultra-fresh juices on a regular base. The squeezed juice obtained was weighted and sent for analysis and the remaining pulp—the by-product, which is normally thrown away in the small juice industry was also weighted and further processed, in the second phase, by cold pressing using an electrical 2000 W PU 05 equipment. The latter is a press with a classic screw-type system, having a pressing chamber with a gear motor. In order to determine a comparative efficiency of the pressing process between all the fruits and vegetables, the process was timed and, due to the fact that the by-product samples had different weights, ranging from 1.4 to 2.5 kg, just 1 kg of the by-product of each was weighted and used. The resulting pressed juice was weighted and sent for analysis. In the last phase, the squeezed pomace (from step 1) and pressed pomace (from step 2) were also weighted in order to determine the process losses and, due to high moisture content and to avoid microbial degradation and quality loss until the analysis, were preserved by two methods: by vacuum sealing in polyethylene bags followed by freezing at −18 °C and by drying for 12 h at a mild temperature of 50 °C using a professional dehydrator (Hendi Profi Line, Utrecht, The Netherlands) and grinding with a professional laboratory mill (IKA A10, Staufen, Germany). These methods were chosen primarily because, according to other recent research studies [32,37,38], they retain most of the bioactive compounds and secondly, because they can later be implemented as low-tech techniques using the equipment provided by economic agents. The graphical rendering of the entire process is presented in Figure 1.

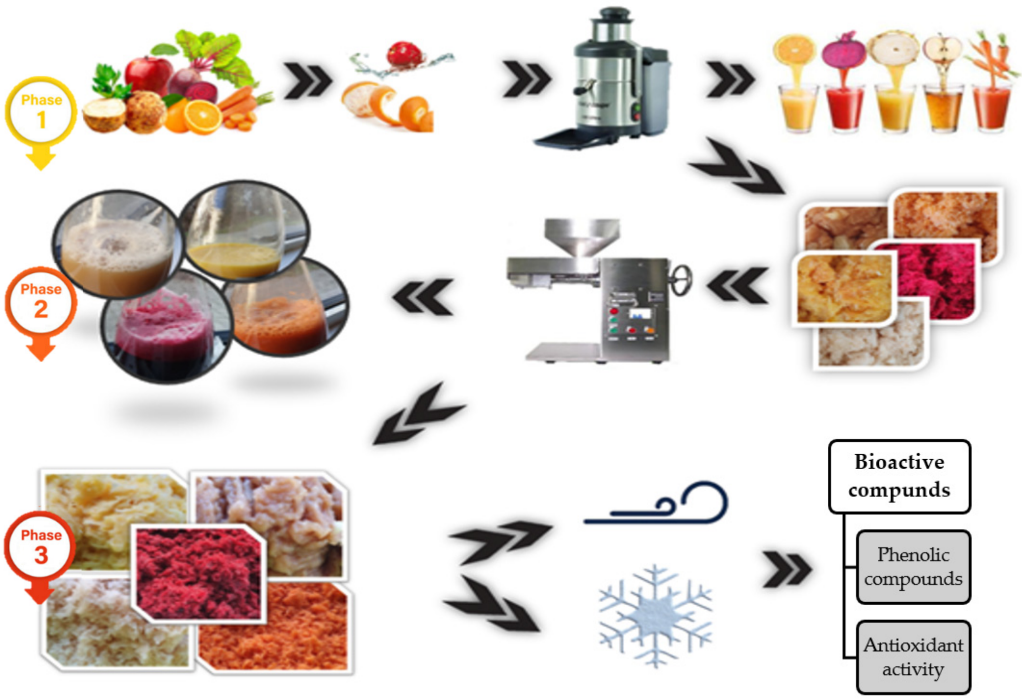


Figure 1. Research graphic design.

2.2. Evaluation of the Antioxidant Activity of Extracts and Quantification of Total Phenolics

2.2.1. Phenolic Compounds

Phenolic compounds were extracted according to the method reported by Abdel-Aal et al. [39] with some improvements. All the analyzed samples (1 g) were homogenized in methanol acidified with HCl (0.3%) using an ultraturax (Miccra D-9 KT Digitronic, Hünstetten, Germany) and then were centrifuged at 9000 rpm for 10 min (centrifuge with cooling, Universal 320 R, Hettich, Westphalia, Germany). The centrifugation process was repeated three times to maximize the degree of release of the compounds, and the resulting extracts (the supernatant) were concentrated at 45 °C under reduced pressure (Rotavap Laborata 4010 Digital, Heidolph, Schwabach, Germany), recovered in 5 mL methanol, filtered using 0.45 µm Millipore filters (Merck, Darmstadt, Germany), and stored at −18 °C for further analysis.

2.2.2. The Total Phenolic Compounds Assay

The Folin–Ciocalteu method estimates the total content of all phenolics present in the analyzed samples, anthocyanins, and non-flavonoid phenolic compounds [40,41]. Aliquots of 25 µL sample were mixed with 1.8 mL distilled water in a 24 wells microplate. An aliquot of 120 µL of Folin–Ciocalteu reagent was added and mixed, followed, after 5 min by the addition of 340 µL Na_2CO_3 (7.5% in water) to create basic conditions (pH ~10) for the redox reaction. After incubation for 120 min at room temperature, the absorbance was read at 750 nm using a microplate reader (BioTek Instruments, Winooski, VT, USA), against the blank, in which the standard or sample was replaced with methanol. Sample dilution was done when the recorded absorbance value exceeded the linear range of the gallic acid calibration curve. The results (expressed as gallic acid equivalents) were expressed as median results of triplicate analysis and presented in Figures 2 and 3.

2.2.3. Determination of DPPH Radical Scavenging Capacity

The DPPH scavenging activity assay was performed according to a method reported by Brand-Williams et al. [41]. This method is based on the ability of stable free radicals of 2,2-diphenyl-1-picrylhydrazyl to react with hydrogen donors. A DPPH solution (80 µM) was freshly prepared in 95% methanol. A volume of 250 µL of this solution was allowed to react with 35 μL of the sample. The chemical kinetics of the resulting solution was monitored at 515 nm for 30 min using a microplate reader BioTek Synergy HT, BioTek Instruments, Winooski, VT, USA. The antioxidant activity was calculated as follows:

$$\% \text{ DPPH scavenging activity} = (A0 - A1/A0) \times 100$$

where A0 was the absorbance of the control reaction and A1 the absorbance in the presence of the sample.

2.3. Statistical Analysis

All analyses were performed in triplicate. The results were statistically analyzed using Minitab 19.1 Statistical Software (Minitab Inc., State College, PA, USA), in order to detect significant differences among results by means of analysis of variance (ANOVA). The results from phases 1 and 2 were expressed as the mean of all the repetitions together with the standard deviation. A 95% confidence level was considered to determine significant differences in all cases.

3. Results and Discussion

3.1. By-Products Analysis

The processes involved in the research design and the by-products obtained are presented in Table 1. Analysis of the husks and impurities resulting just after the cleaning and peeling process show that these represent an initial loss for the merchant between 13 and 29%. These are usually transformed into waste and are not susceptible to being transformed into by-products through any small-scale processes, although composting them is a valuable and cheaper solution. To reduce the losses, some producers perform a rough cleaning with a hard brush instead of peeling.

Examining the fruit and vegetables squeezing process, it can be observed that, even when professional equipment is used, there is still little efficiency in the process, depending on their percentage of dry matter and fibre structure. Apples are processed efficiently by comparing all the samples, resulting in 61.28% juice, followed by oranges with 59.48% juice and beetroot with 57.35%, while the resulting squeezed pulp, approximately 40%, is usually thrown away. On the other hand, from carrots resulted 39.77% juice and from celery root just 33.72% juice, showing a high % of waste generated, reaching up to 66.28%. These percentages can be improved by selecting the appropriate variety of fruits, but generally these results are similar to those mentioned by five small local processors, previously questioned before starting this research. They use on average 45 kg of mixed fruits and vegetables daily, with emphasis on oranges and carrots and generate, on average, 20 kg of waste, so basically around 55% productivity on fresh juices. A 50% general thumb rule is used in the industry for calculating the gross profit, including raw material costs of their ultra-fresh products and the packaging, but not considering the other costs assimilated, such as human resources, utility expenses, etc., which are allotted to the whole production activity. The low productivity is also generated by the fact that oranges and carrots, which are used in larger quantities, also lost between 24.13 and 28.73% of the initial mass through cleaning and peeling. The vendors generally work 25 days a month, so we can approximate that they generate a minimum of 500 kg of waste monthly, of which around 300 kg could be smartly transformed into innovative products through different methods.

Table 1. Sample preparation and processing results in weight and percentage.

	Abbre-viations	U.m.	Oranges	Celery Root	Carrots	Beetroot	Apples		U.m.	Oranges	Celery Root	Carrots	Beetroot	Apples
Initial probe mass		kg	5.030 ± 0.25	5.013 ± 0.25	5.036 ± 0.25	5.020 ± 0.25	5.065 ± 0.25	Initial probe mass	%	100.00	100.00	100.00	100.00	100.00
Sample Preparation														
Cleaned and peeled probe		kg	3.56 ± 0.14	3.838 ± 0.12	3.785 ± 0.15	4.359 ± 0.04	4.0 ± 0.16	Cleaned and peeled probe	%	70.78	76.56	75.16	86.84	78.97
Husks		kg	1.445 ± 0.03	0.936 ± 0.037	1.215 ± 0.02	0.614 ± 0.025	1.055 ± 0.04	Husks	%	28.73	18.67	24.13	12.22	20.83
Impurities		kg	0.025 ± 0.001	0.239 ± 0.007	0.036 ± 0.002	0.047 ± 0.001	0.01 ± 0.001	Impurities	%	0.5	4.77	0.71	0.94	0.2
Sample to be analyzed		kg	0.01	0.01	0.01	0.01	0.01	Sample to be analyzed	%	0.2	0.2	0.2	0.2	0.2
Sample processed as fresh		kg	3.55 ± 0.14	3.828 ± 0.19	3.775 ± 0.15	4.349 ± 0.17	3.99 ± 0.20	Sample processed as fresh	%	100.00	100.00	100.00	100.00	100.00
Squeezing process														
Resulting juice (fresh)	FJ	kg	2.1120.11	1.2910.01	1.5010.06	2.4940.10	2.4450.12	Resulting juice (fresh)	%	59.48	33.72	39.77	57.35	61.28
Fresh pulp		kg	1.438 ± 0.01	2.537 ± 0.05	2.274 ± 0.09	1.855 ± 0.07	1.545 ± 0.08	Fresh pulp	%	40.52	66.28	60.23	42.65	38.72
Sample to be analyzed		kg	0.01	0.01	0.01	0.01	0.01	Sample to be analyzed	%	0.28	0.26	0.26	0.23	0.25
Marc to be pressed		kg	1	1	1	1	1	Marc to be pressed	%	100.00	100.00	100.00	100.00	100.00
Pressing process														
Press juice	PJ	kg	0.33 ± 0.01	0.462 ± 0.02	0.514 ± 0.02	0.447 ± 0.02	0.04 ± 0.02	Press juice	%	33.00	46.20	51.40	44.70	3.98
Pressed pulp	PP	kg	0.546 ± 0.03	0.427 ± 0.02	0.404 ± 0.02	0.469 ± 0.02	0.82 ± 0.04	Pressed Marc	%	54.60	42.70	40.40	46.90	81.96
Process losses		kg	0.124 ± 0.006	0.111 ± 0.005	0.082 ± 0.004	0.084 ± 0.004	0.82 ± 0.04	Process losses	%	12.40	11.10	8.20	8.40	14.06
Pressing Time		′, ″	23′15″ ±60″	14′11″ ±39″	6′40″ ±17″	6′30″ ±15″	6′4″ ±16″	Pressing Time	%	23′15″	14′11″	6′40″	6′30″	6′4″

Value presented is mean value (n = 3) ± standard deviation.

The proposed pressing process shows that the fruit and vegetable pulps (FP) resulting after the fresh juice production still have a high percentage of water that could be transformed into juice. Carrots, beetroot, and celery root marcs gave out another 0.51%, 46% and 45% pressed juice, respectively, 40%, 47% and 43% pressed pomace (PP) that shows us that the initial juicing process was not very effective, although using a professional equipment frequently sold in this sector. These results can be explained by their high fibre content that kept their available water bound which, through pressing, was able to be released by the force generated. Still, although they had similar results, by analyzing the time required for pressing, we can observe that the celery root process took more than twice the time, to about 14′11″ as opposed to 6′30″ and 6′40″ from the carrots and beetroot. This is important in determining the cost–benefit ratio correlated to the time variable that includes additional costs related (human and energy resources).

The orange FP released just 33% juice while 0.55% pomace remained and has potential to be capitalized theoretically, but because it took 23′15″ just to press 1 kg of orange marc and extrapolating it to the daily potential quantity, makes it not recommended for the pressing process. Table 1 also shows that the apple mark practically went through the press without being pressed, generating only 0.04% juice, 82% pulp and related losses. Correlating with the results of the previous pressing of the orange, leads to the conclusion that the low fibre content of these fruits inhibited the pressing process and generated more pulp than juice.

The juices generated by pressing the pulp (PJ) were sensory tested, subjectively, by the research team, each compared with the corresponding squeezed fresh juices (FJ). They had similar characteristics in terms of colour, aroma, and taste, with the difference that the PJ's were less sweet and more consistent than their equivalents.

This is explained by the fact that, through the squeezing process, most of the sugars (mainly fructose) were dissolved in the first juice (FJ) by molecular breakdown, and through the pressing of the pulp resulted (FP), it was possible to break the fibres and their transfer to the pressed juice (PJ) was favored. These facts also account for the high water content detected in the marcs and pomace and higher foaming capacity. Worth mentioning is that, according to the current regulations, while the first squeezed juiced can be sold as fresh juice, the second pressed juiced cannot be sold as fresh juice, so a different approach is needed to capitalize it, whereas as an isotonic or probiotic drink.

The pressing losses fluctuated between 8 and 14% due to the remnant of the debris on the surface of the press and work tools. In normal working conditions, with large quantities available, they would remain approximately the same quantitatively, but would represent a very small percentage of the whole batch. The losses could also be reduced by successive use for all the by-products mixed or separated, without sanitizing the equipment until the end. Process optimization can become a theme for future research in correlation with the structure of fruits and vegetables. Mixing them or using different varieties can lead to a better-composed structure that can reduce the time allotted for pressing and increase the yield in juices.

Literature studies on the selected fruit and vegetable reveal good antioxidant properties due to considerable amounts of phenolic compounds, such as gallic acid, caffeic acid, quercetin in beetroot, caffeic and ferulic acid in carrots and oranges, catechin, gallic acid, 3,4-dihydroxybenzoic acid and 1,2-dihydroxybenzene in celery root and hydroxycinnamates, phloretin glycosides, quercetin glycosides, catechins, procyanidins, epicatechin, chlorogenic acid, cryptochlorogenic acid in apples [42–49].

Their phenolic content varies during the development phase [50] and the antioxidant capacity depends on the exposure to factors such as light, temperature, water [51,52], nutritional deficiencies type of vegetable tissue, mechanical damage such as wounding, maturation stages [53,54], etc.

3.2. Results and Discussion Regarding the Total Phenolics and Antioxidant Activities

The content in total polyphenols of the analyzed samples and their by-products are presented in Figure 2. The concentration in total phenolics in the whole fruits (WF) varied between 77.38 mg GAE/100 g, respectively, 773.79 GAE/100 g reported as dry weight (d.w.) in apples to 160.87 mg GAE/100 g in WF and 1787.42 (DS) in oranges. For the vegetables analyzed, the total phenolic concentration varied from 63.13 to 189.38 mg GAE/100 g d.w. in WF to 631.25 to 1578.13 d.w., the lowest value reported for celery root and the highest for beetroot.

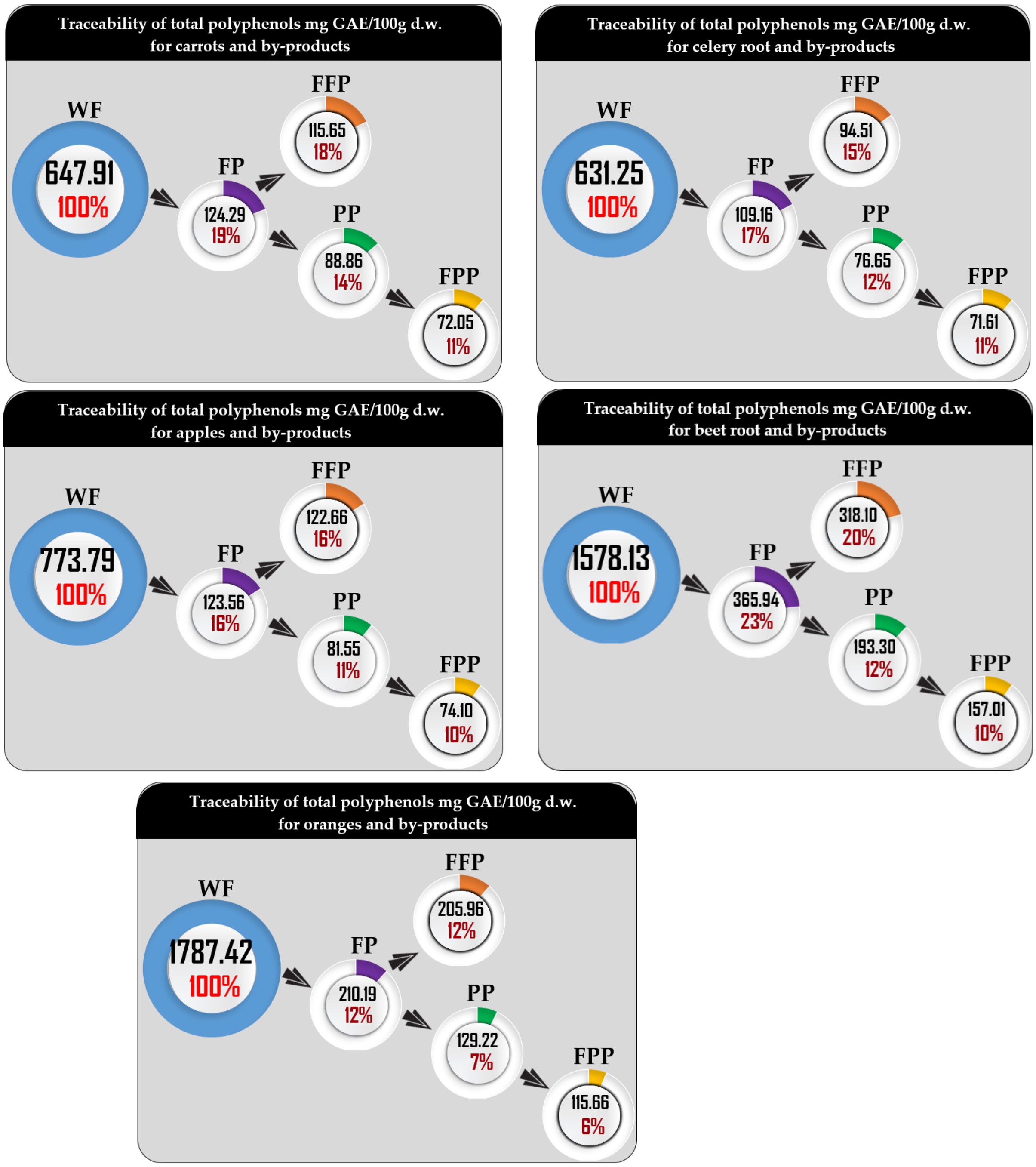


Figure 2. Transferability of total polyphenols from the raw materials to their by-products.

Analyzing the amount of polyphenols in the resulting juices, we can see that a considerable part of the total polyphenols in fruits and vegetables are transferred to juices and some to by-products. The squeezed juices contain between 20.61 mg GAE/100 g, in the case of celery root and 79.42 mg GAE/100 g in the case of beetroot. The values of polyphenols fluctuated in pressed juices between 10.18–50.91 mg GAE/100 g, the lowest value corresponding to celery root and the highest in the case of beetroot, variations similar to those present in squeezed juices. Comparing them as a percentage, the values of 100% representing the initial values in the samples, then between 30 and 40% of the total polyphenols are transferred to the squeezed juices, and between 16 and 28% are transferred to the pressed juices, representing together between 48 and 69% of the initial value.

Analyzing the amount of polyphenols in the resulting by-products, namely FP and PP, in order to identify the polyphenolic traceability, we observed values between 109.16 mg GAE/100 g in the case of celery root marc and 365.94 mg GAE/100 g in the case of beetroot marc and values between 76.65 mg GAE/100 g in the case of celery root pomace and 193.30 mg GAE/100 g in the case of beetroot pomace. Generally, the amount of polyphenols of FP and PP, of the same kind, are similar when analyzed as such. However, it should be noted that the FP has an average of extra 10% humidity determined, meaning that the values reported to the dry substance are lower, as presented. If we compare them as a percentage, the values of 100% representing the initial values in dry substance in the samples, between 11.76 (orange) and 23.19% (beetroot) of the total polyphenols are transferred to the FP and between 7.23% (orange) and 13.72% (carrots) are transferred to the PP.

Comparing the flours obtained from dehydrating the FP and PP, namely FFP and FPP, we observe similar data in terms of humidity and dry matter content. However, the FFP presented polyphenols quantities ranging from 94.51 mg GAE/100 g in the case of celery root to 287.12 mg GAE/100 g in the case of Beetroot analyzed as such and between 94.51 and 318.1 mg GAE/100 g d.w. As expected, the lowest values for the total phenolic content were obtained for the pomace flour samples, with the lowest content retrieved in the celery root sample (65.16 mg GAE/100 g as such and 71.6 mg GAE/100 g D.W.) and the highest in beetroot (140.93 mg GAE/100 g as such and 157.01 mg GAE/100 g D.W.). High levels of phenolic content are probably due to the improved extraction of intracellular content and hydrolysis of polysaccharides promoted by heat treatment [9].

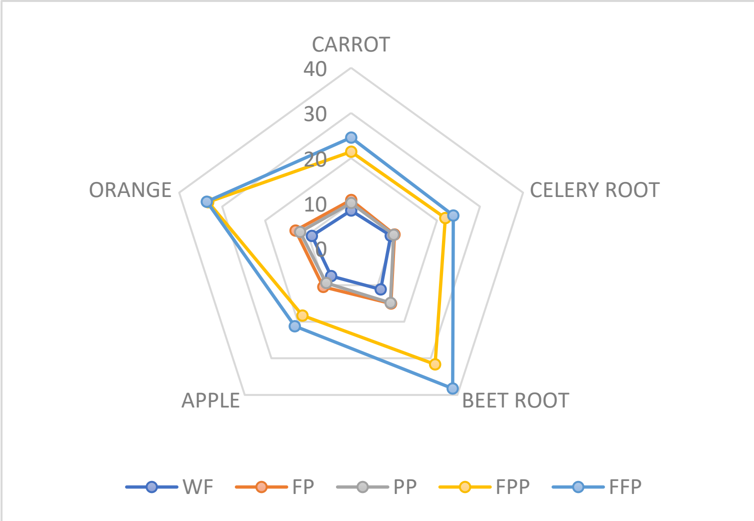
Study limitations: when analyzing the phenolic content, it should be considered that, there was no parallel process, just a continuous process in accordance with the research plan, and, due to the time required to press all the pulps, some additional oxidation has occurred in all the samples.

3.3. Determination of 2,2-Diphenyl-1-Picrylhydrazyl (DPPH) Radical Scavenging Capacity

As presented in Figure 3, the DPPH radical scavenging value in the initial samples fluctuates between 7.51% (apple) and 11.15% (Beetroot), while the d.w. varied between 9 and 12%, showing good antioxidant activity. The FP and PP have higher values, with DPPH values between 10.1% (celery) and 15% (Beetroot) for FP and fluctuating between 9.39% and 14.84%, the lowest result corresponding to apples and la highest to beetroot PP. In the case of FP, the d.w. content varied between 16.76% (oranges) and 19.66% (carrots) and for PP the d.w. content varied between a minimum of 24.97% (apples) and a maximal value of 30.55% (beetroot). Compared to the initial samples, these results show that these by-products have a good radical scavenging capacity.

The flour presented higher DPPH values per se due to the high dry matter content. Apple FFP presented the lower value of 21.21%, while the beetroot, 38.24%, being the highest value of the five group samples. The flour from fresh pulp (FPP) presented slightly lower values ranging from 18.31% in the case of the apple to 31.63% in the case of beetroot FPP. In the case of all the flours, the d.w. ranged in the 90% area, ±2%.

The scavenging activity potential presented in Figure 3 shows excellent opportunities to exploit the antioxidant bio content of the analyzed by-products. In terms of comparison, the FPP and FFP have similar valuers through self-comparison, as well as PP and FP. However, overall, the highest DPPH potential in by-products is contained in the flours, with values that are double compared to FP and PP and more than triple in some cases compared with the whole fruit.



Raw Materials	*WF%*	*FP%*	*PP%*	*FPP%*	*FFP%*
Carrot	8.42	10.75	10.09	21.44	24.57
Celery root	9.22	10.1	9.92	21.9	23.75
Beetroot	11.15	15	14.84	31.63	38.24
Apple	7.51	10.48	9.39	18.31	21.21
Orange	9.14	12.94	11.87	33.26	33.6

Figure 3. The DPPH radical scavenging activity potential from WF to by-products.

Results show that DPPH free radical activity is found in each of the by-products in considerable amounts generated by the large number of polyphenols transferred from the raw materials. The latter can be used as cheap raw material to develop new functional products, instead of being thrown away. By analyzing the five selected raw materials, we can conclude that all of them have a high potential in bio-waste valorization. The dehydrated form of fresh pulp and pressed pulp have, on average, almost double the bioactive potential per se but between 6 and 11% when considering the dry substance content. The polyphenols are transferred in smaller amounts to by-products, but still in quantities that cannot be overlooked. The highest quantities were determined in the FP.

4. Literature Review for Easy-to-Implement Solutions Using Small Investment for Capitalizing on the By-Products

In recent years, the interest in reusing materials of agro-industrial processes (peels, husks, pomace, seeds, etc.) increased significantly due to the huge amount and availability of these food residues, the disposal problem associated and the identified value of the by-products through contemporary research as a source of bioactive compounds (polysaccharides, fibres, phenolic compounds, vitamins, minerals, etc.) [55].

The research carried out in the last decade suggested a wide range of possible industrial applications for capitalizing the fruit and vegetable residues, many focused on extraction. The latter depends on several factors, such as the extraction technique, raw materials, and the extraction solvent used [56]. Furthermore, the techniques can be classified into conventional or non-conventional. Conventional techniques require the use of organic solvents, temperature, and agitation. Examples of this type of technique include Soxhlet, maceration, and hydrodistillation. Modern or non-conventional techniques are considered green or clean techniques due to reduced use of energy and the implementation of organic solvents, which are beneficial to the environment [56,57].

Unprocessed extracts and compounds with specific active ingredients extracted from agro-industrial residues show significant application potential in developing value-added functional, nutraceutical and cosmeceutical products and industrial food applications. However, most are inaccessible to small businesses, come with high costs and insufficient return on investment, and cannot be implemented efficiently locally. Thus, the present research focuses on more budget-friendly solutions, easier to apply in the economic environment.

Most peels (high content in antioxidants), seeds, and solid waste from producing fresh fruits are transformed into garbage. However, accompanied by an entrepreneurial effort or adequate specific policies, these residues can easily be used as compost, enriching the local agricultural soil with phenolic compounds and antioxidants. Residues obtained after cleaning, such as shells, seeds and dirt, will most likely take this path. Even so, these could generate some small savings from the related costs of disposing of them as waste. After a thorough washing, the peels and seeds can be used to obtain glazed sauces for culinary purposes. The FP have a high content of fibre and water and can be used in the pastry industry (cakes, pancake, jam and pies), promoting nutritional enrichment [58] or the sweets industry, such as candies, jellies and glacier sweets [42,59], in the culinary industry for pasta and marinating sauces, in the pastry recipes by carefully replacing the percentage of water in the recipe. The flour made from fruit and vegetable residues is utilized in the production of biscuits, muffins, cereal bars, and cookies with high levels of dietary fibre [60] and improves the nutritional properties as shown in [58,61] and other bread and pastry specialties. Due to the vast amounts of available fruits and vegetables, literature research was conducted with a focus on waste recovery methods that are easy to implement for the analyzed fruits and vegetables, as presented in Table 2.

Table 2. Waste recovery methods for the analyzed fruits and vegetables in the food industry.

Raw Material	Waste Form	Domain	Benefits	Ref
Carrots	Pomace (FP) powder 2–10% *w*/*w*	Pasta	Better cooking loss and firmness	[58]
Carrots	Pomace (FP) powder 3, 6, 9% *w*/*w*	Biscuits	Gluten-free rice crackers with higher dietary fibre and minerals	[62]
Carrots	Pomace (FP) powder 10, 20% *w*/*w*	Biscuits	Biscuits with a reduced glycemic index	[60]
Carrots	Pomace (FP) powder 3, 6, 9% *w*/*w*	Dairy	Yogurt with increased gelatinization pH and shortened fermentation time	[63]
Carrots	Pomace (FP) powder 3–5% *w*/*w*	Dairy	Butter with enhanced physicochemical, textural, and sensory properties	[63]
Carrots	Pomace (FP) powder 10, 20, 30% *w*/*w*	Biscuits	High fibre biscuits with no negative sensory characteristics	[62]
Carrots	Pomace (FP) powder 6.5% carrot	Beverages	Isotonic beverage	[42]
Orange	5.5% orange	Beverages	Isotonic beverage	[42]
Orange	powder 25–30% *w*/*w*	Biscuits	Biscuits rich in fibre and minerals.	[42]
Orange/ carrots	powder 75% *w*/*w*	Snacks	Cereal bars rich in fibre and minerals.	[42]
Orange	Pomace (FP) powder 3–5% *w*/*w*	Dairy	Butter with enhanced physicochemical, textural, and sensory properties	[63]
Celery root	Pomace (FP) powder 3–5% *w*/*w*	Dairy	Butter with enhanced color, textural, and sensory properties and higher dietary fibre	[63]
Celery root	Pomace (FP) powder 1–5% *w*/*w*	Bakery	Dough with increased water absorption and significant improvement of its antioxidant properties	[64]
Beetroot	Pomace (FP) powder 5% *w*/*w*	Bakery	Gluten-free and high fibre cookies	[65]
Beetroot	Pomace (FP) powder 2%, 4%, 6% and 8% *w*/*w*	Pasta	Pasta with higher dietary fibre content	[66]
Apple	Pomace (FP) powder up to 20% *w*/*w*	Confectionary	Bakery products with reduced energy content and increased fibre content	[67]

Table 2. *Cont.*

Raw Material	Waste Form	Domain	Benefits	Ref
Apple	Pomace (FP) powder 5–10% *w*/*w*	Bakery	Bread (wheat, rye and mixed) with reduced energy content and manufacturing costs	[68,69]
Apple	Pomace (FP) powder 50% *w*/*w*	Bakery	Wheat bran muffin with better sensorial characteristics.	[68,70]
Apple	Pomace (FP) flakes 40% *w*/*w*	Confectionary	Cookies with better sensorial characteristics.	[71]
Apple	Pomace (FP) powder 50% *w*/*w*	Bakery	Pie fillings and oatmeal cookies with reduced manufacturing costs	[72]
Apple	Pomace (FP) powder 2, 4, 6, and 8% *w*/*w*	Meat	Buffalo Sausage with higher fibre content	[72]

The data presented previously show a lot of individual application examples, due to their unique characteristics and research-specific area, that could be easily extrapolated to the other analyzed by-products. However, also, the similarities found in the by-products (high fibre content and antioxidant capacity) suggest many potential applications in different types of food enrichment (volume replacement, stabilizers and emulsifiers, thickening or texturizing, caloric or dietary fibre substitute) in high-consumption products such as beverages, soups, sauces, desserts, dairy products, cookies, pasta, and bread [61,66–72]. The principle for incorporation should be related to the desired physical, chemical, or sensory characteristics of the particular food and by-product availability [73].

More research on biocomposite traceability related to mixing different conservation methodologies and further on the technological processes involved to obtain high value-added products needs to be pursued to create specific easy to implement and accessible methods. The immediate use of vegetable waste in pastry products remains a good research topic. Adding the dried pulps back to freshly pressed juices accompanied by a sensory analysis could also represent a future research direction. Ultimately, it is up to the entrepreneur to calculate the cost/benefit efficiency for implementing different waste reuse solutions, corroborate his specific activity, and create a balance between consumer requirements, business specifics, profit and product functionality.

5. Discussion

Methods to develop innovative products using the fruit and vegetable waste from small-scale restaurants or bistros are scarce since these are very perishable raw materials and must be used immediately. The proposed press equipment costs around 2000 Euro and the dehydrator around 1000 Euro, so these are affordable for any local vendor and their return on investment is high, considering the considerable amount of waste that could be capitalized on a regular basis.

Results show that the low-temperature heat treatment used for obtaining the flours helped preserve the antioxidant activity and could be efficiently used in small-scale processes to ensure conservability due to the fact that generated polyphenol losses (including manipulation, freezing and drying) were between 1 and 14%. Still, in terms of efficiency, the FFP its more cost-effective and in terms of the total polyphenols, the FPP has, on average just half of the FFP.

Since each of the by-products requires further technological processes to be valorized, which implies more resources and associated costs, it will remain on the economic agent's choice to identify (alone or in a research partnership) the feasibility of the implementation process.

For example, by analyzing data from Table 1, we can deduce that in terms of juice efficiency, the oranges, beetroot, and apple show great juicing potential but generate lower amounts of marc (FP) compared to celery and root. So, one can stop here and just use the waste for pastries or other purposes. If we analyze the pressing process, we can deduce that although celery and oranges generate from 33 to 46% of new pressed juices from marc (PP), their pressing time required will probably generate in time more costs than profits for the implementer. To the same extent, beet and carrots generate almost 50% juice from FP, potentially creating new beverages high in DPPH and polyphenols, as Figure 3 shows. Nevertheless, apple pomace used in the process shows just 4% juice after pressing, so the process should be stopped at the juicing process and the apple pomace be used as a by-product.

The data obtained presents a lot of potential for further research, in order to optimize the processes, for example, by modifying the pressing screw power, temperature, mixing between vegetable matrixes, testing different fruit/vegetable varieties in order to obtain a more specific result and also by generating a detailed cost efficiency sheet for each of the by-products, also taking into account the depreciation of equipment, specific consumption and man-hour, etc.

6. Conclusions

The content of apples, carrots, oranges, beetroot and celery root in total polyphenols and antioxidant capacity was assessed and compared with the composition of their equivalent by-products. Results show a DPPH potential almost double in value in pulps and up to triple in flours per se, compared with the raw material, but the high dry substance content must be accounted for. Total polyphenols transferred to the by-products in considerable amounts, up to 23%, emphasizing the importance and the opportunities of reusing this agro-industrial waste as a reliable source of bioactive compounds.

Contemporary research for obtaining affordable, low-tech solutions that could generate for vendors added sustainable value through the development of innovative functional products, were analysed and completed with an innovative processing solution.

Author Contributions: Conceptualization, A.B., L.C.S. and M.V.M.; methodology, L.C.S.; software, M.M.; validation, A.C.F. and M.V.M.; investigation, M.M. and A.C.F.; resources, A.B.; data curation, A.C.F.; writing—original draft preparation, A.B., L.C.S. and M.V.M.; writing—review and editing, A.C.F. and A.B.; supervision, A.B. and L.C.S. All authors have read and agreed to the published version of the manuscript.

Funding: The APC was funded by the Romanian Ministry of Education and Research—project FDI-0040.

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

Abbreviations

WF	whole fruit
FJ	fresh fruit
FP	fresh pulp
PP	pressed pulp
PJ	pressed juice
FFP	flour from fresh pulp
FPP	flour from pressed pulp
D.W.	reported as dry weight
AA	antioxidant activity
GAE	gallic acid equivalents
DPPH	2,2-Diphenyl-1-picrylhydrazyl

References

1. Fruit Juice Market: Global Industry Trends, Share, Size, Growth, Opportunity and Forecast 2022–2027. Available online: https://www.imarcgroup.com/fruit-juice-manufacturing-plant (accessed on 21 March 2022).
2. Consumer Markets Non-Alcoholic Drinks. Available online: https://www.statista.com/outlook/cmo/non-alcoholic-drinks/juices/worldwide#revenue (accessed on 3 August 2022).
3. Available online: https://www.fortunebusinessinsights.com/cold-pressed-juice-market-106647 (accessed on 4 August 2022).
4. United Nations. *World Population Prospects 2019: Highlights*; Report No. ST/ESA/SER.A/423; United Nations, Department of Economic and Social Affairs, Population Division: New York, NY, USA, 2019.

5. Vollset, S.E.; Goren, E.; Yuan, C.-W.; Cao, J.; Smith, A.E.; Hsiao, T.; Murray, C.J.L. Fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100: A forecasting analysis for the Global Burden of Disease Study. *Lancet* **2020**, *396*, 1285–1306. [CrossRef]
6. Canudas-Romo, V.; Shen, T.; Payne, C.F. The Components of Change in Population Growth Rates. *Demography* **2022**, *59*, 417–431. [CrossRef] [PubMed]
7. Available online: https://es.statista.com/outlook/cmo/non-alcoholic-drinks/juices/worldwide (accessed on 21 March 2022).
8. Food Waste Index Report. 2021. Available online: https://wedocs.unep.org/bitstream/handle/20.500.11822/35280/FoodWaste.pdf (accessed on 21 February 2022).
9. Gowe, C. Review on potential use of fruit and vegetables by-products as a valuable source of natural food additives. *Food Sci. Qual. Manag.* **2015**, *45*, 47–61.
10. 2019 Food Loss Report and Database. Available online: https://www.fao.org/platform-food-loss-waste/flw-data/en/) (accessed on 3 August 2022).
11. Available online: https://www.fao.org/hunger/en/ (accessed on 3 August 2022).
12. Tracking Progress on Food and Agriculture-Related SDG Indicators 2021. A Report on the Indicators under FAO Custodianship. Available online: https://www.fao.org/sdg-progress-report/en/ (accessed on 3 August 2022).
13. Available online: https://www.fao.org/sustainable-development-goals/indicators/232/en/ (accessed on 3 August 2022).
14. Panzella, L.; Moccia, F.; Nasti, R.; Marzorati, S.; Verotta, L.; Napolitano, A. Bioactive phenolic compounds from agri-food wastes: An update on green and sustainable extraction methodologies. *Front. Nutr.* **2020**, *7*, 60. [CrossRef]
15. De Ancos, B.; Colina-Coca, C.; González-Peña, D.; Sánchez-Moreno, C. Bioactive compounds from vegetable and fruit by-products. *Biotechnol. Bioact. Compd. Sources Appl.* **2015**, 1–36. [CrossRef]
16. Venkat, K. The climate change and economic impacts of food waste in the United States. *Int. J. Food Syst. Dyn.* **2011**, *2*, 431–446.
17. Vilariño, M.V.; Franco, C.; Quarrington, C. Food loss and waste reduction as an integral part of a circular economy. *Front. Environ. Sci.* **2017**, *5*, 21. [CrossRef]
18. 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]
19. Kaavya, R.; Kalpana, L.; Kumar, A.A. Microwave methods for the extraction of bioactive components and enzymes from pineapple waste and its application in meat tenderization. *Int. J. Agric. Sci.* **2017**, *9*, 4612–4620.
20. Shengjiu, G.U.; Kaimei, Z.H.U.; Caizhen, L.U.O.; Jiang, Y.; Yourui, X.U. Microwaves-assisted Extraction of Polyphenols from Banana Peel. *Med. Plant* **2014**, *5*, 21–24.
21. Vu, H.T.; Scarlett, C.J.; Vuong, Q.V. Maximising recovery of phenolic compounds and antioxidant properties from banana peel using microwave assisted extraction and water. *J. Food Sci. Technol.* **2019**, *56*, 1360–1370. [CrossRef] [PubMed]
22. Han, Z.-P.; Liu, R.L.; Cui, H.Y.; Zhang, Z.Q. Microwave-assisted extraction and LC/MS analysis of phenolic antioxidants in sweet apricot (Prunus armeniaca L.) kernel skins. *J. Liq. Chromatogr. Relat. Technol.* **2013**, *36*, 2182–2195. [CrossRef]
23. Chaisamlitpol, S.; Hiranvarachat, B.; Srichumpoung, J.; Devahastin, S.; Chiewchan, N. Bioactive compositions of extracts from cabbage outer leaves as affected by drying pretreatment prior to microwave-assisted extraction. *Sep. Purif. Technol.* **2014**, *136*, 177–183. [CrossRef]
24. Tabaraki, R.; Shahrbanoo, R. Comparison between conventional and ultrasound-assisted extractions of natural antioxidants from walnut green husk. *Korean J. Chem. Eng.* **2014**, *31*, 676–683. [CrossRef]
25. Plazzotta, S.; Manzocco, L. Effect of ultrasounds and high pressure homogenization on the extraction of antioxidant polyphenols from lettuce waste. *Innov. Food Sci. Emerg. Technol.* **2018**, *50*, 11–19. [CrossRef]
26. Rezende, Y.R.R.S.; Pedreira Nogueira, J.; 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-Food Sci. Technol.* **2017**, *85*, 158–169. [CrossRef]
27. Liang, J.L.; Yeow, C.C.; Teo, K.C.; Gnanaraj, C.; Chang, Y.P. Valorizing cabbage (Brassica oleracea L. var. capitata) and capsicum (Capsicum annuum L.) wastes: In vitro health-promoting activities. *J. Food Sci. Technol.* **2019**, *56*, 4696–4704. [CrossRef]
28. Paes, J.; Dotta, R.; Barbero, G.F.; Martínez, J. Extraction of phenolic compounds and anthocyanins from blueberry (Vaccinium myrtillus L.) residues using supercritical CO2 and pressurized liquids. *J. Supercrit. Fluids* **2014**, *95*, 8–16. [CrossRef]
29. Ferreira, S.S.; Passos, C.P.; Cardoso, S.M.; Wessel, D.F.; Coimbra, M.A. Microwave assisted dehydration of broccoli by-products and simultaneous extraction of bioactive compounds. *Food Chem.* **2018**, *246*, 386–393. [CrossRef]
30. Cao, J.; Chen, L.; Li, M.; Cao, F.; Zhao, L.; Su, E. Efficient extraction of proanthocyanidin from Ginkgo biloba leaves employing rationally designed deep eutectic solvent-water mixture and evaluation of the antioxidant activity. *J. Pharm. Biomed. Anal.* **2018**, *158*, 317–326. [CrossRef]
31. Pal, C.B.T.; Jadeja, G.C. Microwave-assisted extraction for recovery of polyphenolic antioxidants from ripe mango (Mangifera indica L.) peel using lactic acid/sodium acetate deep eutectic mixtures. *Food Sci. Technol. Int.* **2020**, *26*, 78–92. [CrossRef] [PubMed]
32. Ramírez-Pulido, B.; Bas-Bellver, C.; Betoret, N.; Barrera, C.; Seguí, L. Valorization of vegetable fresh-processing residues as functional powdered ingredients. A review on the potential impact of pretreatments and drying methods on bioactive compounds and their bioaccessibility. *Front. Sustain. Food Syst.* **2021**, *5*, 654313. [CrossRef]
33. Ratti, C. Hot air and freeze-drying of high-value foods: A review. *J. Food Eng.* **2001**, *49*, 311–319. [CrossRef]

34. Deepa, P.; Sujathamma, P. Information source and consultancy pattern of different sericultural technologies at field level and technology adoption in the semi-arid conditions of Chittoor District in Andhra Pradesh. *Indian J. Seric.* **2007**, *46*, 86–88.
35. Vallejo, F.; Tomás-Barberán, F.A.; García-Viguera, C. Phenolic compound contents in edible parts of broccoli inflorescences after domestic cooking. *J. Sci. Food Agric.* **2003**, *83*, 1511–1516. [CrossRef]
36. Ho, C.-T. *Phenolic Compounds in Food: An Overview*; ACS Publications: Washington, DC, USA, 1992; pp. 2–7.
37. Fărcaș, A.C.; Socaci, S.A.; Chiș, M.S.; Dulf, F.V.; Podea, P.; Tofană, M. Analysis of Fatty Acids, Amino Acids and Volatile Profile of Apple By-Products by Gas Chromatography-Mass Spectrometry. *Molecules* **2022**, *27*, 1987. [CrossRef]
38. Polat, S.; Guclu, G.; Kelebek, H.; Keskin, M.; Selli, S. Comparative elucidation of colour, volatile and phenolic profiles of black carrot (Daucus carota L.) pomace and powders prepared by five different drying methods. *Food Chem.* **2022**, *369*, 130941. [CrossRef]
39. Abdel-Aal, E.-S.M.; Hucl, P. Composition and stability of anthocyanins in blue-grained wheat. *J. Agric. Food Chem.* **2003**, *51*, 2174–2180. [CrossRef]
40. Singleton, V.L.; Orthofer, R.; Lamuela-Raventós, R.M. Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. In *Methods in Enzymology*; Academic Press: Cambridge, MA, USA, 1999; Volume 299, pp. 152–178.
41. Brand-Williams, W.; Cuvelier, M.-E.; Berset, C.L.W.T. Use of a free radical method to evaluate antioxidant activity. *LWT Food Sci. Technol.* **1995**, *28*, 25–30. [CrossRef]
42. Brito, T.B.N.; Ferreira, M.S.L.; Fai, A.E.C. Utilization of agricultural by-products: Bioactive properties and technological applications. *Food Rev. Int.* **2020**, *38*, 1305–1329. [CrossRef]
43. Urbina, L.; Eceiza, A.; Gabilondo, N.; Corcuera, M.Á.; Retegi, A. Valorization of apple waste for active packaging: Multicomponent polyhydroxyalkanoate coated nanopapers with improved hydrophobicity and antioxidant capacity. *Food Packag. Shelf Life* **2019**, *21*, 100356. [CrossRef]
44. 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]
45. Li, W.; Yang, R.; Ying, D.; Yu, J.; Sanguansri, L.; Augustin, M.A. Analysis of polyphenols in apple pomace: A comparative study of different extraction and hydrolysis procedures. *Ind. Crops Prod.* **2020**, *147*, 112250. [CrossRef]
46. Ben-Othman, S.; Jõudu, I.; Bhat, R. Bioactives from agri-food wastes: Present insights and future challenges. *Molecules* **2020**, *25*, 510. [CrossRef]
47. Singh, J.P.; Kaur, A.; Shevkani, K.; Singh, N. Composition, bioactive compounds and antioxidant activity of common Indian fruits and vegetables. *J. Food Sci. Technol.* **2016**, *53*, 4056–4066. [CrossRef]
48. Ribarova, F.; Atanassova, M.; Marinova, D.; Ribarova, F.; Atanassova, M. Total phenolics and flavonoids in Bulgarian fruits and vegetables. *JU Chem. Metal* **2005**, *40*, 255–260.
49. Kays, S.E.; Barton, F.E.; Windham, W.R.; Himmelsbach, D.S. Prediction of Total Dietary Fibre by Near-Infrared Reflectance Spectroscopy in Cereal Products Containing High Sugar and Crystalline Sugar. *J. Agric. Food Chem.* **1997**, *45*, 3944–3951. [CrossRef]
50. Dixon, R.A.; Paiva, N.L. Stress-induced phenylpropanoid metabolism. *Plant Cell* **1995**, *7*, 1085–1097. [CrossRef]
51. Saltveit, M.E. Physical and physiological changes in minimally processed fruits and vegetables. In *Proceedings-Phytochemical Society of Europe*; Oxford University Press Inc.: Oxford, UK, 1996; Volume 41.
52. Sáyago-Ayerdi, S.G.; Arranz, S.; Serrano, J.; Goñi, I. Dietary fibre content and associated antioxidant compounds in roselle flower (Hibiscus sabdariffa L.) beverage. *J. Agric. Food Chem.* **2007**, *55*, 7886–7890. [CrossRef]
53. Reyes, L.F.; Villarreal, J.E.; Cisneros-Zevallos, L. The increase in antioxidant capacity after wounding depends on the type of fruit or vegetable tissue. *Food Chem.* **2007**, *101*, 1254–1262. [CrossRef]
54. Özgen, M.; Torun, A.A.; Ercisli, S.; Serçe, S. Changes in chemical composition, antioxidant activities and total phenolic content of Arbutus andrachne fruit at different maturation stages. *Ital. J. Food Sci.* **2009**, *21*, 65–72.
55. Dilucia, F.; Lacivita, V.; Conte, A.; Del Nobile, M.A. Sustainable use of fruit and vegetable by-products to enhance food packaging performance. *Foods* **2020**, *9*, 857. [CrossRef] [PubMed]
56. Tiwari, B.K. Ultrasound: A clean, green extraction technology. *TrAC Trends Anal. Chem.* **2015**, *71*, 100–109. [CrossRef]
57. Rodríguez-Pérez, C.; Quirantes-Piné, R.; Fernández-Gutiérrez, A.; Segura-Carretero, A. Optimization of extraction method to obtain a phenolic compounds-rich extract from Moringa oleifera Lam leaves. *Ind. Crops Prod.* **2015**, *66*, 246–254. [CrossRef]
58. Bianchi, F.; Tolve, R.; Rainero, G.; Bordiga, M.; Brennan, C.S.; Simonato, B. Technological, nutritional and sensory properties of pasta fortified with agro-industrial by-products: A review. *Int. J. Food Sci. Technol.* **2021**, *56*, 4356–4366. [CrossRef]
59. Göksel Saraç, M.; Dogan, M. Incorporation of dietary fibre concentrates from fruit and vegetable wastes in butter: Effects on physicochemical, textural, and sensory properties. *Eur. Food Res. Technol.* **2016**, *242*, 1331–1342. [CrossRef]
60. Kumari, S.; Grewal, R.B. Nutritional evaluation and utilization of carrot pomace powder for preparation of high fibre biscuits. *J. Food Sci. Technol.* **2007**, *44*, 56–58.
61. Wirkijowska, A.; Zarzycki, P.; Sobota, A.; Nawrocka, A.; Blicharz-Kania, A.; Andrejko, D. The possibility of using by-products from the flaxseed industry for functional bread production. *LWT* **2020**, *118*, 108860. [CrossRef]
62. Bielig, H.J.; Fischer-Ayloff-Cook, K.P. Bedeutung der Rheologie in der Lebensmitteltechnologie. *Z. Lebensm. Unters. Forsch.* **1984**, *179*, 364–370. [CrossRef]
63. Wang, H.J.; Thomas, R.L. Direct use of apple pomace in bakery products. *J. Food Sci.* **1989**, *54*, 618–620. [CrossRef]

64. Ferreira, M.S.L.; Santos, M.C.; Moro, T.; Basto, G.J.; Andrade, R.; Gonçalves, É.C. Formulation and characterization of functional foods based on fruit and vegetable residue flour. *J. Food Sci. Technol.* **2015**, *52*, 822–830. [CrossRef] [PubMed]
65. Wang, N.; Xu, Y.; Chao, H.; Zhang, M.; Zhou, Y.; Wang, M. Effects of celery powder on wheat dough properties and textural, antioxidant and starch digestibility properties of bread. *J. Food Sci. Technol.* **2020**, *57*, 1710–1718. [CrossRef] [PubMed]
66. Cobb, C.W.; Cobb, J.B.; Carson, C.S. *The Green National Product: A Proposed Index of Sustainable Economic Welfare*; University Press of America: Lanham, MD, USA, 1994; p. 343.
67. Younis, K.; Ahmad, S. Waste utilization of apple pomace as a source of functional ingredient in buffalo meat sausage. *Cogent Food Agric.* **2015**, *1*, 1119397. [CrossRef]
68. Thebaudin, J.Y.; Lefebvre, A.C.; Harrington, M.; Bourgeois, C.M. Dietary fibres: Nutritional and technological interest. *Trends Food Sci. Technol.* **1997**, *8*, 41–48. [CrossRef]
69. Crizel, T.D.M.; Rios, A.D.O.; Thys, R.C.S.; Flôres, S.H. Effects of orange by-product fibre incorporation on the functional and technological properties of pasta. *Food Sci. Technol.* **2015**, *35*, 546–551. [CrossRef]
70. Fissore, E.N.; Rojas, A.M.; Gerschenson, L.N.; Williams, P.A. Butternut and beetroot pectins: Characterization and functional properties. *Food Hydrocoll.* **2013**, *31*, 172–182. [CrossRef]
71. Figuerola, F.; Hurtado, M.L.; Estévez, A.M.; Chiffelle, I.; Asenjo, F. Fibre concentrates from apple pomace and citrus peel as potential fibre sources for food enrichment. *Food Chem.* **2005**, *91*, 395–401. [CrossRef]
72. Chauhan, S.; Rajput, H. Production of gluten free and high fibre cookies using beetrot waste powder and wheat flour husk. *The Pharma Innov. J.* **2018**, *7*, 556.
73. Pilnik, W.; Rombouts, F.M. Polysaccharides and food processing. *Carbohydr. Res.* **1985**, *142*, 93–105. [CrossRef]