Sustainable novel extraction of bioactive compounds from fruits and vegetables waste for functional foods: a review

Sumaya Kainat, Muhamad Sajid Arshad, Waseem Khalid, Muhammad Zubair Khalid, Hyrije Koraqi, Muhammad Faizan Afzal, Sana Noreen, Zaira Aziz, and Ammar Al-Farga

Department of Chemistry, University of Engineering and Technology, Lahore, Pakistan; Department of Food Science, Government College University, Faisalabad, Pakistan; Faculty of Food Science and Biotechnology, UBT-Higher Education Institution, Pristina, Kosovo; University Institute of Diet and Nutritional Sciences, The University of Lahore, Lahore, Pakistan; General Medicine, Pakistan institute of Medical Sciences, Islamabad, Pakistan; Department of Food Science, Faculty of Agriculture, Ibb University, Ibb Yemen

ABSTRACT

The current review has been considered to extract the bioactive compounds from different fruits and vegetable waste using novel extraction techniques. Among all horticultural crops, fruits and vegetables are the most consumed. Due to a rising population and changing dietary patterns, the production and processing of horticultural commodities, particularly fruits and vegetables, has expanded dramatically in order to meet rising demand. Food waste is the by-product of numerous industrial, agricultural, domestic, and food operations sector that is steadily increasing as these activities rise. Seeds, skin, rind, and pomace make up the majority of the waste, which is rich in bioactive substances such as carotenoids, polyphenols, dietary fibers, vitamins, enzymes, and oils. Waste can be used to make a variety of vital bioactive components, which is an important step toward long-term development. For the extraction of bioactive compounds, various extraction technologies are being used, including supercritical fluid extraction, subcritical water extraction, enzyme assisted extraction, ultrasound and microwave assisted extraction. The sustainable extracts attained using different technologies are valuable in the formation of functional food. Conclusively, new technologies manage waste in a meaningful way that is collected from fruits and vegetables. However, these bioactive compounds that are attained from wastes are valuable in the formation of food products.

Introduction

The agri-food business generates a substantial amount of waste in the form of shells, skins, stems, seeds, and pulps, among other things, during the transformation of raw materials. Nonetheless, due to their low cost, abundance, and ease of availability, agri-food waste products may include health-beneficial substances with definite market potential. Large losses and waste of these key food commodities, as well as their components, by-products, and residues, have resulted from increased production and expansion, as well as a lack of suitable handling procedures and infrastructure. In all aspects of the handling and supply chain, harvesting, transportation to packing markets or houses, sorting and marketing, storage, grading, and treating the waste can occurs. Losses occur at every point of the supply chain, from production to postharvest to consumption. They are an unexpected consequence of the institutional and regulatory framework in which food production and supply systems operate. Losses very commonly occur in developing countries because of a lack of proper
handling techniques, whereas waste material is more common in advanced and well-off societies in emerging countries. Food waste is frequently caused by technical limits in handling and infrastructure, such as packaging, packing, storage, and marketing, but food loss is frequently caused by neglect or a deliberate decision to discard food. Table 1 depicts the types of fruit and vegetable losses and waste.

According to Emana et al. [9] almost all vegetables and fruits produced around the world are lost or wasted during post-harvest (omitting pre-harvest losses and waste after delivery to the customer). Waste generated after a product reaches the user is very important, particularly in prosperous countries. In the United States, post-harvest losses range from 2% to 23%, and they are usually dependent on the service, with a 12-percentage-point average. [9] A random range of post-harvest waste in the UK is 9%, and the products left in the field are not included in this because they do not meet the quality and acceptability criteria. [10] According to Rohm et al. [11] the general value of vegetables and fruit sold at the wholesale and retail levels in the US in 2008 was $42.8 billion, or $141 per person. According to FAO, 2017, [12] the production, packing, distribution, and consumption of fruits and vegetables alone generates approximately 55 MMT (Million Metric Tons) of fruit and vegetable waste (FVW) in developed.

Horticultural waste is a major source of bioactive substances that could be used in a variety of ways. Horticulture by-products have not always been recognized as valuable resources, but that is changing now that FVWs may be used to extract highly valuable biomolecules. Among other things, dietary fiber, organic acids, phenolic compounds, pigments, sugar by-products, and minerals are abundant in horticultural by-products. Antibacterial, anticancer, antiviral, antimutagenic, and cardioprotective properties are among the properties of several of these bioactive chemicals. [13] Fruits and vegetables such as oranges, pineapples, peaches, apples, potatoes, carrots, green peas, onions, artichokes, and asparagus are among those used for juice or pulp extraction, jams, and frozen pulp, resulting in massive waste. [14]

Additional technological advancements include the loss of bio-compounds due to insufficient processing in traditional extraction processes (maceration, shaking, Soxhlet, among others). [15] To extract bioactive molecules, traditional extraction procedures use chemicals or solvents to lyse or disrupt the cells or tissues. Acid extraction, alkali extraction, and solvent extraction are examples of these procedures. The majority of soluble dietary fiber (SDF) extraction procedures necessitate high temperatures, the use of strong acids or alkalis, a considerable incubation time, and residues in the finished product. These procedures also use a lot of chemicals and aren’t very environmentally friendly. [16] Ultrasound assisted extraction (UAE), microwave assisted extraction (MAE), accelerated solvent extraction (ASE), pulse electric field (PEF), high pressure processing and colloidal gas aphrons (CGAs), Ultrasound and microwave assisted extraction (UMAE), and subcritical and supercritical fluid extraction are some of the newer SDF extraction methods. These procedures can be used

| Commodity   | Waste Nature          | Typical waste and losses (%) | Reference |
|-------------|-----------------------|------------------------------|-----------|
| Apple       | Pomace, peel, and seeds | –                            | [4]       |
| Banana      | Peel                  | 35                           | [4]       |
| Dragon fruit | Seeds, Rind           | 30 to 45                     | [5]       |
| Mango       | Peel, stone           | 45                           | [4]       |
| Grapes      | Skin, stem, and seeds | 20                           | [4]       |
| Papaya      | Rind, seeds           | 10 to 20                     | [6]       |
| Citrus      | Rag, peel, and seeds  | 50                           | [4]       |
| Guava       | Peel, core, and seeds | 10                           | [4]       |
| Pineapple   | Core, skin            | 33                           | [7]       |
| Jackfruit   | Rind, seeds           | 50 to 70                     | [8]       |
| Onion       | Outer leaves          | –                            | [4]       |
| Peas        | Shell                 | 40                           | [4]       |
| Tomato      | Core, skin, and seeds | 20                           | [4]       |
| Potato      | Peel                  | 15                           | [4]       |

Note: (–) Data not available
separately, as a pre-treatment, or in combination to provide the highest yield at the lowest cost. Thermolable chemicals like polyphenols have been successfully extracted using ultrasound assisted extraction (UAE). The UAE improves heat and mass transmission while facilitating the release of extractable bio-compounds, making it a repeatable, selective, productive, and environmentally friendly method.

The food business is increasingly focusing on the development and production of functional and nutraceutical items. Because of the rising customer interest in "healthy" food, this new category of food products has gotten a lot of attention in the food market. As a result, both the pharmaceutical and food industries are interested in discovering new natural bioactive components that can be employed as medications, functional food ingredients, or nutraceuticals. Bio-actives can be isolated from food waste and used in the production of nutraceuticals and functional foods (Figure 1). These substances interact effectively with proteins, DNA, and other biological components to achieve desired outcomes, which can subsequently be exploited to develop natural medicines. Food bio-actives that have favorable effects on human body in terms of health promotion and disease risk reduction are gaining popularity among consumers. In order to obtain optimal functional food items, detailed knowledge regarding food bio-actives is required. This study discusses the many extraction processes used to extract bio-actives and nutraceuticals from food waste, as well as their applications in the prevention of chronic and lifestyle diseases (Figure 1).

Bioactive compounds in fruits and vegetables waste

Phytochemicals are abundant in FVW, and their extraction of phenolic compounds, dietary fibers, and other beneficial components has been studied. Most people eat the flesh or pulp of most fruits and vegetables, but studies have found that the seeds, peels, and other sections of fruits and vegetables that aren’t eaten often contain significant amounts of phytochemicals and essential minerals. For example, the phenolic content of the peels of lemons, grapes, and oranges, as well as the seeds of avocados, jackfruits, longans, and mangoes, is more than 15% higher than that of the fruit pulp. It’s worth noting that FVW are prone to microbial deterioration, which might result in unpleasant odors and environmental issues.

Dietary fibers

Roughage, often known as dietary fiber, is the indigestible portion of plant foods. Fiber provides numerous health advantages, including lowering the risk of heart disease and type 2 diabetes. Dietary fibers are present in all layers of the onion, but in varying amounts. The 9.51, 9.94, 9.73, 10.30, and 9.35 g/100 g DM fibers were found in five Polish potato types. Potato peel contains 61.0 to 125 g/kg crude fiber in the DM (Dry Matter), according to Ncobela et al. Solid waste from potatoes was also shown to be an excellent source of fiber (27 to 35 g/100 g). The apple peel had more dietary fiber than the pulp. Insoluble and soluble dietary fiber percentages were 0.46% and 0.43%, respectively. Apple pomace is a waste product from the apple juice processing industry that is high in nutritional fiber. Total dietary fiber (TDF) in vacuum-dried pomace varied from 442 to 495 g/kg, and was not statistically different from freeze-dried pomace (480 g/kg), according to Zhao et al. Dietary fibers have been found in abundance in mango by-products. TDFs make about 51.2% of mango peel DM (32% DM insoluble fibers and 19% DM soluble fibers). The TDF content of mango peels was determined to be in the range of 40.6% to 72.5% by Serna-Cock et al. with galactose, glucose, and arabinose being the predominant neutral sugars in both insoluble and soluble dietary fibers. Orange peels were found to have 57% DW TDFs, with 9.41% DW being the soluble fraction and 47.6% DW being the insoluble fraction, and the main fiber components being cellulose and pectin. Lemon peels have 14 g/100 g DM of dietary fibers, which is substantially greater than peeled lemon (7.34 g/100 g DM). Insoluble fibers and soluble fibers were 9.04 g/100 g DM and 4.93 g/100 g DM, respectively.
Phenolic compounds

Fruits and vegetables have a lot of phenolic compounds in their rinds, peels, and seeds. In the case of vegetable wastes, potato peel has been identified as a good source of phenolic compounds, containing 50% of the total bioactive components.\cite{33} Friedman et al.\cite{34} found that the peel of the Korean potato variety “Superior” had a higher concentration of phenols (385 ± 50 µg/g DW chlorogenic acid, 21.9 ± 2.0 µg/g DW chlorogenic acid isomer II, and 103 ± 10 µg/g DW caffeic acid) than the cortex (107 ± 4 µg/g DW chlorogenic acid, 4.2 ± 1.2 µg/g DW chlorogenic acid isomer II, and 2.29 ± 0.51 µg/g DW caffeic acid) of the same. Cucumber peel has been touted as a low-cost source of flavonoids for use in industry. FVWs were found to be high in phenolic content in the following sequence, according to a study by Islam et al.\cite{35} olive leaves > tomato peel > cucumber peel > watermelon peel > potato peel.
Date seeds are a great source of antioxidants and phenolic compounds.\textsuperscript{[36]} Except for olives, the oil produced from the seeds has a higher phenolic content than most culinary oils.\textsuperscript{[37]}

Citrus trash is a rich source of phenolic compounds since citrus peel has a higher concentration of polyphenols than the edible portion of the fruit.\textsuperscript{[38]} Aside from citrus, the peels of other fruits have been discovered to have higher phenolic content than the edible sections. Banana pulp (\textit{Musa Cavendish}) was discovered to have 232 mg/100 g DM of phenolic compounds, which is only around 25\% of the amount found in the peel.\textsuperscript{[39]} The peels of pomegranates have 249.4 mg/g phenolic chemicals, whereas the pulp has 24.4 mg/g.\textsuperscript{[40]} The phenolic content of apple peels has been observed to be up to 3300 mg/100 g DM.\textsuperscript{[41]} Grape skins and seeds are high in mono-, oligo-, and polymeric pro-anthocyanidins (phenolics), which are by-products of the juice and wine industries.\textsuperscript{[42]}

**Organic acids**

Organic acids are biomolecules that are widely employed in the food, cosmetics, and chemical industries. The most significant acids for the food and pharmaceutical industries are citric and lactic acids. Fermentation with various molds, yeasts, and bacteria can create citric acid. However, \textit{Aspergillus Niger} continues to be a popular mold species for the manufacture of citric acid in the industrial sector.\textsuperscript{[43]} Cassava bagasse is an excellent substrate for producing large levels of citric acid.\textsuperscript{[44]} Apple pomace has also been used as a substrate material with \textit{A. Niger} to produce up to 80\% citric acid\textsuperscript{[45]} as above pineapple, mandarin, and mixed fruit waste, which yield 51.4\%, 50\%, and 46.5\%, respectively.\textsuperscript{[46]}

Lactic acid occupies a prominent position among the carboxylic acids since it has numerous applications in both the food and non-food industries. It is mostly employed as an acidulant and preservative in food items.\textsuperscript{[47]} According to Yazid et al.\textsuperscript{[48]} \textit{Lactobacillus delbrueckii} can convert all of the sugars in cassava bagasse to 99\% lactic acid using the SSF method. Various microbes can create lactic acid from by-products of fruits and vegetables. Potato peel, sweet corn, mango, orange, green peas, and cassava residue were employed as substrates for \textit{Lactobacillus casei}, \textit{Lactobacillus delbrueckii}, and \textit{Lactobacillus plantarum} to create lactic acid.\textsuperscript{[49]}

**Proteins**

Protein has been discovered in the non-edible parts of a variety of fruits and vegetables, as well as in their trash. Friedman et al.\textsuperscript{[50]} found that Korean “Superior” potato peel has a high protein content (10.6 ± 0.2 g/100 g and 1.80 ± 0.03 g/100 g). Matharu et al.\textsuperscript{[51]} used the Lowry method for protein analysis on the peels of various fruits and discovered substantial levels of protein content in the peels of papaya fruit, avocado, and kiwifruit were1.79\%, 1.57\%, and 1.55\%, respectively. Protein content ranged from 2.5\% to 9.0\% in citrus peels.\textsuperscript{[52]} There were 1109 proteins discovered in the proteome profiling of citrus fruit, with 46 in the peel and pulp and 366 in the peel.\textsuperscript{[53]} Different parts of fruits and vegetables contained protein in different concentrations such as apple pomace (4.45 g), Carrot pomace (10.06 g), green pea peels (13.27 g), mosambi peel (5.4 g), pineapple peel (8.7 g), mango peel (9.5 g), cabbage leaves (20.4 g), orange peel (5.97 g), banana peel (6.02 g), tomato solid waste (17 to 22 g), potato solid waste (3 to 5 g), and cauliflower (16.1 g).\textsuperscript{[54]} FWV was also used to separate diverse protein compounds, including actinidin from the kiwifruit seeds, leptin from jackfruit seed,\textsuperscript{[55]} and vicilin-like protein from watermelon seeds.\textsuperscript{[56]} Table 2 summarizes the concentrations of various bioactive chemicals in vegetables and fruit waste.

**Extraction of bioactive compounds from fruits and vegetables waste**

The most important stage in obtaining bioactive chemicals from FWV is extraction.\textsuperscript{[79]} The types and quantities of bioactive chemicals that can be extracted from FWV are determined by the best extraction procedures.\textsuperscript{[80]} Extraction procedures may differ depending on the bioactive chemicals to
be extracted. One of the most important aspects in determining the kind and amount of bioactive chemicals recovered is sample preparation. The comparison of different extraction techniques for the extraction of bioactive compounds is summarized in Table 3. Bioactive compounds from plant waste can be extracted using a variety of techniques, which can be split into two categories: conventional and novel techniques (Figure 2).

**Traditional extraction techniques**

For a very long time, these have been utilized as classical procedures are considered customary techniques. These processes are actually based on the solvent extraction power technique, and heat is applied, or a mixture of the two. Soxhlet extraction, hydro-distillation, and maceration are the three main traditional procedures. [79]

**Soxhlet extraction**

Soxhlet extraction is a well-known and commonly used technique for extracting valuable bioactive components from various plant sections, but it was originally designed primarily for lipid extraction. Essentially, a very small amount of dry material is retained in a thimble, which is then kept in a distillation flask containing the solvent of choice. A syphon aspirates the solution from the thimble-holder and returns it to the distillation flask when it reaches an overflow level. This solution holds the extract and transports it into the bulk liquid. The extracted solute remains in the distillation flask, and the solvent cycles back to the solid plant material. The procedure is repeated until the extraction is complete. [86]
Table 3. Comparison of different extraction techniques for the extraction of bioactive compounds.

| Bioactive component | Sources                  | Method | Optimum conditions | References |
|---------------------|--------------------------|--------|--------------------|------------|
| Anthocyanin         | Grape                    | Water  | 70°C               | [81]       |
|                     |                          | Ultrasons | 600 MPa             |            |
|                     |                          | HHP    | 35 kHz             |            |
|                     |                          | PEF    | 3 kV/cm²           | [82]       |
| Hesperetin          | Orange                   | LPT    | 70°C/30s           | [82]       |
|                     |                          | HPT    | 400 MPa/40°C/1 min |            |
|                     |                          | PEF    | 35 kV/cm³/750 ms   |            |
| Lutein              | Orange                   | LPT    | 70°C/30s           | [82]       |
|                     |                          | HPT    | 400 MPa/40°C/1 min |            |
|                     |                          | PEF    | 35 kV/cm³/750 ms   |            |
| Lycopene            | Tomato waste             | SFE    | 400 bar/80°C/4 g CO²/min/105 min | [83] |
| Naringenin          | Orange                   | LPT    | 70°C/30s           | [82]       |
|                     |                          | HPT    | 400 MPa/40°C/1 min |            |
|                     |                          | PEF    | 35 kV/cm³/750 ms   |            |
| Total phenolic      | Red grape pomace         | SE     | Refluxing for 2–3 h/96 | [84] |
| content             |                          | MAE    | 50°C/200 W/60 min 52,645 | |
|                     | Orange pomace (dry)      | SFE    | 25 MPa and 60°C 19.0 | [85] |
|                     | Orange pomace (fermented)| SFE    | 25 MPa and 60°C 19.0 | [85] |
| Zeaxantin           | Orange                   | LPT    | 70°C/30 s          | [82]       |
|                     |                          | HPT    | 400 MPa/40°C/1 min |            |
|                     |                          | PEF    | 35 kV/cm³/750 ms   |            |
| α-Carotene          | Orange                   | LPT    | 70°C/30 s          | [82]       |
|                     |                          | HPT    | 400 MPa/40°C/1 min |            |
|                     |                          | PEF    | 35 kV/cm³/750 ms   |            |
| α-Cryptoxanthin     | Orange                   | LPT    | 70°C/30 s          | [82]       |
|                     |                          | HPT    | 400 MPa/40°C/1 min |            |
|                     |                          | PEF    | 35 kV/cm³/750 ms   |            |

Hydro-distillation

Before dehydrating a plant sample, hydro-distillation is a traditional method for extracting key oils and bioactive chemicals from plant sources. The packing of the plant sample in a still compartment is the first stage in hydro-distillation. After that, a sufficient amount of water is added and the mixture is cooked. As an alternative, steam can be employed. The bioactive chemicals are effectively removed from plant cells using hot water and steam. Indirect water cooling condenses the vapor combination of oil and water. The condensed mixture is transferred from the condenser to a separator. Here, the beneficial chemicals and oil separate from the water on their own. Hydro-distillation is made up of three major physico-chemical processes: hydro-diffusion, hydrolysis, and heat decomposition. Heat-labile chemicals may be lost or damaged at the high extraction temperature.

Maceration

For a long time, maceration has been utilized in the home manufacture of tonics. It has gained popularity as a low-cost method of extracting bioactive chemicals and essential oils. It consists of multiple phases and is well-suited to low extraction rates. The first step is to completely grind plant samples into tiny particles in order to properly mix them with the solvent. The second stage involves pouring a suitable amount of the solvent, known as menstruum, into a closed vessel. The liquid is then discarded in the third phase, and a substantial amount of the prepared solution is obtained by pressing the solid residue left over from the extraction procedure. Finally, contaminants are removed from the crushed liquid via filtration. Shaking during maceration is sometimes used to boost extraction yield in two ways: to increase diffusion and to eliminate concentrated solution from the sample surface and replace it with a new solvent for optimum extraction yield.
Novel extraction technologies

Because of the limits of traditional procedures, novel techniques have been introduced. Traditional extraction methods are characterized by difficulty in obtaining high purity, the use of expensive solvents, lengthier extraction times, the potential degradation of heat-labile chemicals, and low extraction selectivity. Novel strategies have been developed to overcome these restrictions. For the extraction process, numerous unique and emerging approaches are now being used.

Supercritical fluid extraction

The extraction of bioactive chemicals from natural sources such as plants, food by-products, algae, and microalgae is usually done using supercritical fluid extraction, which is an environmentally beneficial technology. Because it is non-explosive, nontoxic, and affordable, supercritical carbon dioxide (SC-CO₂) is an appealing alternative to organic solvents. It possesses the ability to solubilize lipophilic substances and can be easily removed from the final products. Raw material is placed in an extraction container with temperature and pressure controllers to maintain the proper conditions during the extraction process. After that, a pump pressurizes the extraction container with the fluid. The products are collected by a tap positioned in the lower part of the separators once the fluid and

---

**Figure 2.** Various methods for extracting bioactive compounds from food waste, as well as their health benefits.
dissolved chemicals have been transferred to the separators. Finally, the fluid is recycled or discharged into the environment. The choice of supercritical fluids is vital to the process’s success, and a wide range of chemicals can be utilized as solvents in this method.\[92\]

Chai et al.\[93\] recovered polyphenols (gallic, protocatechuic, vanillic, syringic, ferulic, and p-coumaric derivatives) and flavonoids (quercetin and its derivatives) from Lees produced by the pisco-making process at 20 MPa and 313 K. Durante et al.\[94\] used SC-CO\(_2\) and Soxhlet extraction to extract oil from wheat bran, which is a rich source of antioxidants. During SC-CO\(_2\) extraction, pressure and temperature ranged from 10 to 30 MPa and 313.15–333.15 K, respectively. When compared to hexane extracted oil, oil obtained via SC-CO\(_2\) extraction demonstrated stronger resistance to oxidation and higher radical scavenging activity. Wenzel et al.\[95\] used SC-CO\(_2\) with an ethanol modifier to extract phenolic chemicals from black walnut (Juglans nigra) husks. Aryal et al.\[96\] described the supercritical approach as a viable alternative to traditional organic solvent extraction methods for obtaining biologically active chemicals. Another study was conducted on patè olive cake in which oil was extracted by using supercritical-CO\(_2\). The results showed that patè olive cake has rich in bioactive health-promoting compounds.\[97\]

**Subcritical water extraction**

Subcritical water extraction is becoming a popular method for extracting phenolic chemicals from a variety of foods. Water at a temperature of between 100 and 374°C and a pressure high enough to keep it liquid is referred to as subcritical water (below the critical pressure of 22 MPa). Gbashi et al.\[98\] investigated the use of subcritical water extraction (SWE) for extracting polyphenolic compounds from Terminalia chebula Retz. fruits and discovered that the amount of extracted gallic acid and ellagic acid increased as the subcritical water temperature increased up to 180°C, while the highest amount of corilagin was recovered at 120°C. Kathiman et al.\[99\] used subcritical water extraction to extract mangiferin, a pharmacological active component from Mahkota Dewa at temperatures ranging from 323–423 K and pressures of 0.7–4.0 MPa, with extraction durations varying from 1 to 7 hours.

Using subcritical water, Beya et al.\[100\] recovered eight phenolic compounds from potato peel (gallic acid, chlorogenic acid, caffeic acid, protocatechuic acid, syringic acid, p-hydroxybenzoic acid, ferulic acid, and coumaric acid). The most phenolic compounds were recovered at 180°C and a 30-minute extraction time (81.83 mg/100 g fresh wt.). The primary phenolic chemicals recovered from potato peel at 180°C were chlorogenic acid (14.59 mg/100 g) and gallic acid (29.56 mg/100 g). To get phenolic chemicals from potato peel, subcritical water at 160–180°C, 6 MPa, and 60 min was shown to be a good substitute for organic solvents (such as methanol and ethanol).

Temperatures ranged from 100 to 220°C for 20 minutes, and reaction times at 160°C ranged from 10 to 50 minutes. Kim et al.\[101\] improved the generation of specific phenolic compounds by subcritical water hydrolysis in pumpkin leaves. The main phenolic chemicals found in the hydrolyzate of pumpkin leaves were caffeic acid, p-coumaric acid, ferulic acid, and gentisic acid. Mayanga-Torres et al.\[102\] used subcritical water and semi-continuous flow conditions to extract total phenolic components from two common coffee waste leftovers (powder and defatted cake). At 200°C and 22.5 MPa, the maximum total phenolic chemicals (26.64 mg GAE/g coffee powder) were recovered.

**Enzyme assisted extraction**

Enzyme-aided extraction is acknowledged as a more environmentally friendly approach for extracting bioactive substances and oil because it uses water as a solvent rather than organic solvents.\[103\] The recovery of lycopene from the peel fraction of tomato processing waste was greatly improved by the use of mixed enzyme preparations with cellulytic and pectinolytic activities, as well as the comparatively low cost of commercial food-grade enzyme preparations, which could be implemented on an industrial scale, according to Prokopov et al.\[104\] Costa et al.\[103\] investigated enzyme-assisted extraction of the bioactive component sativoside from plant sources, with a focus on food and nutraceutical applications. Reshmitha et al.\[105\] used
cellulase (20 units/g) and pectinase (30 units/g) to extract lycopene-rich extracts from tomato peel at 50°C for 60 minutes. According to these investigations, the release of bioactive chemicals from plant cells by cell disruption and extraction can be enhanced by utilizing enzyme preparations alone or in mixtures. Enzyme-assisted extraction has the potential to be a viable alternative to traditional solvent-based extraction procedures. It is based on enzymes’ capacity to catalyze reactions in aqueous solutions under mild processing conditions.\textsuperscript{106}

\textit{Extraction using ultrasounds}

When it comes to extracting bioactive components from natural goods, ultrasound-assisted extraction is thought to be a simpler and more successful method than standard extraction methods. Depending on the type of the plant material to be extracted, ultrasonic frequency has a significant impact on extraction yield.\textsuperscript{107} For simultaneous determination of the target chemicals in the respective extracts, high-performance liquid chromatography.

Kaleem et al,\textsuperscript{108} used an ultrasound-assisted extraction approach to extract anthocyanins and phenolic compounds from grape peel. Carreira-Casais et al,\textsuperscript{109} used ultrasound-assisted extraction to optimize and evaluate the extraction of stilbenes from grape canes. Stilbenes in grape canes were extracted for 10 minutes using this procedure, which used an extraction temperature of 75°C and ethanol (60%) as the extraction solvent. Grape cane by-products were discovered to be potential sources of bioactive chemicals of interest to the pharmaceutical and food sectors. Aguiló-Aguayo et al,\textsuperscript{110} investigated the influence of ultrasonic technology in extracting water-soluble polysaccharides from dried and milled \textit{Agaricus bisporus} by-products. β-Glucan was extracted from mushroom by-products in proportions of 1.01 and 0.98 g/100 g dry mass, with particle sizes of 355–250 and 150–125 μm, respectively. The highest extraction yield of 4.7% was obtained with a 15-minute extraction time, a 100 m amplitude, and 1 hour of precipitation in 80% ethanol.

\textit{Microwave assisted extraction}

Microwave-assisted extraction (MAE) is a revolutionary extraction technique that incorporates both microwave and solvent extraction. The fundamental advantage of MAE over ultrasonic aided extraction and Soxhlet extraction is that plant metabolites can be extracted in less time.\textsuperscript{111} Sonar & Rathod,\textsuperscript{112} used microwave assisted extraction conditions using water as a solvent to extract mangiferin from \textit{Mangifera indica} leaves. With a 5-minute extraction period, a solid to solvent ratio of 1:20, and a microwave power of 272 W, the maximum extraction yield of 55 mg/g was attained.

In a fascinating study (\textit{Ocimum basilicum} L), Filip et al,\textsuperscript{113} modified MAE using a response surface approach to improve the extraction of polyphenols from basil. The best extraction conditions were 50% ethanol, a microwave power of 442 W, and a time of 15 minutes. The basil liquid extract produced under these circumstances contains 4.299 g GAE/100 g total polyphenols and 0.849 g catechin equivalents/100 g total flavonoids. As a result, it can be inferred that the microwave assisted method has numerous advantages over other methods, including increased extraction efficiency, reduced extraction time, less labor, and high extraction selectivity, making it a preferred method for bioactive component extraction.\textsuperscript{114}

\textit{Extracted component from fruits and vegetables waste use in food application}

Food demand is rising all over the world, necessitating the development of new meals or the improvement of existing ones.\textsuperscript{115} Food development employing food wastes or byproducts from various agro-industries is a fantastic way to create secondary food products. Many, if not all, of these goods are abandoned, and they can be enhanced to make foods such as cookies or cereal bars. Not all agro-industrial wastes can be utilized as an ingredient in a newly formed food, and it can’t be any kind
of food; often, agro-industrial wastes are used in the development of flour-based foods. Some wastes are used to enhance the nutritional value of some foods. For example, adding defatted soybean powder to a tortilla raises the protein level. Soy flour has also been used to increase the protein and amino acid content of spaghetti. In order to produce a larger yield of nutritional fiber and some minerals like calcium, magnesium, or potassium, king palm flour was utilized in the making of cookies and gluten-free cookies.

Basri et al. combined the pineapple core with additional ingredients such as soybean extracts and broken rice to create a new cereal bar that is high in protein, dietary fiber, and minerals while being low in calories. Díaz-Vela et al. used pineapple peel flour to improve the physicochemical properties of cooked sausages, and they achieved excellent results, but pineapple peel flour was not determined to be superior to cactus pear peel flour. It helps sausages retain water and reduces oxidative rancidity. Mango skin is a good source of dietary fiber. The mango peel flour can be used to make pasta (macaroni), bakery items (bread, cakes, and cookies), dairy products (cheese, yogurt, and ice cream), and extruded foods. All of these food items are quite important in the global food market. Lenucci et al. showed that different fractions of mango fruits are a good source of bioactive compounds. However, green, novel biorefinery technologies may offer eco-friendly and profitable solutions, allowing the recovery of several more profitable by-products.

The extraction of various chemicals from accumulating food wastes and byproducts opens up new possibilities for using these extracts in the food industry to improve food quality. Some wastes can improve the nutritional properties of current foods, such as fiber content or protein, and are rich in the concentrations of minerals that are vital to health. Paté Olive Cake (POC) is a new by-product derived from recently introduced new decanters in the olive oil production process. There were no changes that occurred in total levels of triterpenic acids, carotenoids, and tocopherol. Sensory parameters were observed to improve after fermentation due to the increase of superior alcohols, esters, and acids. Olive paste (OP) is a novel by-product of the olive mill industry that is a rich source of bioactive compounds. These characteristics make OP particularly suitable as a functional ingredient for the food industry, as well as for the formulation of nutraceutical products. Furthermore, enriched taralli maintained a low amount of saturated fatty acids and high levels of polyphenols for up to about 90 days.

Three distinct apple wastes were tested by Waterhouse et al. They discovered that the three wastes from three distinct apples had a significant amount of polypeptide. The three separate sections of the apples that were assessed can be utilized to generate new culinary products. All food wastes and byproducts have a significant chance to be used in the creation of a variety of foods with improved nutritional properties. Several chemicals found in food residues or waste are better digested in the human system than others. The proper use of these biomaterials can promote human health, progress the food industry, and eliminate many of the environmental issues caused by the disposal of these wastes.

Bioactive compounds extracted from fruits and vegetables have health benefits

Bioactive chemicals, as health-related substances, are known to reduce the risk of developing diseases such as cancer, Alzheimer’s, cataracts, and Parkinson’s disease, among others (Figure 3). These positive benefits have been related to their antioxidant and radical scavenging properties, which can delay or prevent DNA, protein, and lipid damage. Indeed, these chemicals have antibacterial properties, and they play a significant role in protecting fruits against harmful agents by penetrating microorganisms’ cell membranes and producing lysis. Oxidative stress is caused by an imbalance between the generation of reactive oxygen species (ROS) and their elimination by our bodies’ defense mechanisms. Our body’s antioxidant mechanisms detoxify reactive intermediates, resulting in a reduction in oxidative stress. For sustaining health and preventing aging and age-related disorders, there should be interaction between free radicals, antioxidants, and co-factors. Oxidative damage occurs when the production of free radicals exceeds the protective effects of antioxidants and
some co-factors, resulting in aging and chronic diseases like cancer, cardiovascular disease, neurological disorders, and other lifestyle diseases.\textsuperscript{129}

Pharmaceutical preparations such as pills, capsules, tablets, powder, and vials are commonly used to take nutraceuticals.\textsuperscript{130} Mangiferin (1,3,6,7-tetrahydroxyxanthone-C2 – d-glucoside), a natural bioactive xanthonoid found in many plant species including the mango tree (\textit{Mangifera indica} L), has drawn the interest of research groups around the world for cancer treatment, according to Delgado-Hernández et al.\textsuperscript{131} Aside from its antioxidant and anti-

\textbf{Figure 3.} Major bioactive compounds from fruits and vegetables and their benefits against different diseases.
inflammatory qualities, mangiferin has been demonstrated to have potential benefits in brain, lung, cervix, breast, and prostate cancers, as well as leukemia, when given alone or in combination with recognized anticancer chemicals. By-products of the meat industry, including as brains, nervous systems, and spinal cords, are a source of cholesterol, which is extracted and utilized to make vitamin D3.\[132\] The health effects of flavonoids and saponins from black bean seed coatings were investigated by Leyva-Soto et al.\[133\]

The addition of flavonoids and saponins from black bean seed coat to whole wheat bread formulation resulted in the preservation of more than 90% of the added flavonoids and saponins, as well as 80% of anthocyanins in the bread after baking. The consumption of these health-promoting compound-rich breads could have serious health repercussions. The phenolic chemicals obtained from natural sources, such as benzoin, catechin, chlorogenic acid, and ferulic acid, when added with the other components prior to extrusion in the preparation of rolled oats, may result in products that are more resistant to oxidation (retardation of hexanal formation). Although processing resulted in a 24–26% reduction of the amount of the phenolic compounds added.\[134\] According to Lozano-Sánchez et al.,\[135\] an olive by-product known as “pâté,” which is produced using a contemporary two-phase centrifugal processing technique, can be exploited as a natural source of bioactive compounds. It was distinguished by the presence of hydroxytyrosol, β-hydroxy-verbascoside, oleo-side derivative, luteolin, and other possible nutraceutical or feed industry constituents such as hydroxy-tyrosol, β-hydroxy-verbascoside, oleoside derivative, and luteolin.

**Conclusion**

It is concluded that novel extraction technologies can be used to produce sustainable bioactive compounds from fruit and vegetable waste. Different parts (peel, seed, etc.) are waste that is produced from fruits and vegetables. These fruits and vegetable waste are composed of different bioactive compounds such as dietary fibers, phenolic compounds, and antioxidants. Different novel techniques are being used to extract bioactive compounds from waste. These sustainable extracts are added to different food products as functional ingredients. However, these food products play a valuable role in human health.

**Disclosure statement**

The authors have no relevant financial or non-financial interests to disclose.

**References**

[1] Jiménez-Moreno, N.; Esparza, I.; Bimbela, F.; Gandía, L. M.; Ancín-Azpilicueta, C. Valorization of Selected Fruit and Vegetable Wastes as Bioactive Compounds: Opportunities and Challenges. *Critical Reviews in Environmental Science and Technology*. 2020, 50(20), 2061–2108. DOI: 10.1080/10643389.2019.1694819.

[2] Schaefer, D.; Cheung, W. M. Smart Packaging: Opportunities and Challenges. *Procedia CIRP*. 2018, 72, 1022–1027. DOI: 10.1016/j.procir.2018.03.240.

[3] Burllea-Schiopoiu, A.; Ogarca, R. F.; Barbu, C. M.; Craciun, L.; Baloi, I. C.; Mihai, L. S. The Impact of COVID-19 Pandemic on Food Waste Behaviour of Young People. *J. Clean. Prod*. 2021, 294. DOI: 10.1016/j.jclepro.2021.126333.

[4] Biswal, S.; Ray, M. Fermentation of Agro–Based Waste and Residues from Different Sectors: A Reviewl. *Int. J. Agric. Sci*. 2017, 7(2), 425–432. www.tjprc.org

[5] Cheok, C. Y.; Mohd Adzahan, N.; Abdul Rahman, R.; Zainal Abedin, N. H.; Hussain, N.; Sulaiman, R.; Chong, G. H. Current Trends of Tropical Fruit Waste Utilization. *Crit. Rev. Food Sci. Nutr*. 2018, 58(3), 335–361. DOI: 10.1080/014048398.2016.1176009.

[6] Madhuvanthi, S.; Selvapriya, K.; Nirmala, R. A.; Agalya, A.; Jeya, N. Extraction and Characterization of Pectin Derived from Underutilized Papaya Seeds as a value-added Product. *J. Nat. Appl. Sci*. 2022, 141, 127–132. DOI:10.31018/jans.v14i1.3269.
[30] Serna-Cock, L.; García-Gonzales, E.; Torres-León, C. Agro-industrial Potential of the Mango Peel Based on Its Nutritional and Functional Properties. Food Rev. Int. 2016, Vol. 32. 4. 364–376. Taylor and Francis Inc. 10.1080/87559129.2015.1094815

[31] Bender, A. B. B.; Speroni, C. S.; Salvador, P. R.; Loureiro, B. B.; Lovatto, N. M.; Goulart, F. R.; Lovatto, M. T.; Miranda, M. Z.; Silva, L. P.; Penna, N. G. Grape Pomace Skins and the Effects of Its Inclusion in the Technological Properties of Muffins. J. Culin. Sci. Technol. 2017, 15(2), 143–157. DOI: 10.1080/15428052.2016.1225535.

[32] Ashok, B.; Thundil Karuppa Raj, R.; Nanthagopal, K.; Krishnan, R.; Subbarao, R. Lemon Peel Oil – A Novel Renewable Alternative Energy Source for Diesel Engine. Energy Convers. Manag. 2017, 139, 110–121. DOI: 10.1016/j.enconman.2017.02.049.

[33] Azizi, A. F.; Sethi, S.; Joshi, A.; Singh, A. M.; Raigond, P.; Singh, M. K.; Yadav, R. K. Biochemical and Functional Attributes of Raw and Boiled Potato Flesh and Peel Powders for Suitability in Food Applications. J. Food Sci. Technol. 2020, 57(11), 3955–3965. DOI: 10.1007/s13197-020-04424-3.

[34] Friedman, M.; Kozukue, N.; Kim, H. J.; Choi, S. H.; Mizuno, M. Glycoalkaloid, Phenolic, and Flavonoid Content and Antioxidative Activities of Conventional Nonorganic and Organic Potato Peel Powders from Commercial Gold, Red, and Russet Potatoes. J. Food Compos. Anal. 2017a, 62, 69–75. DOI: 10.1016/j.jfca.2017.04.019.

[35] Islam, M. A.; Shahriar, S.; Hossain, T.; Sikdar, K. Y. K.; Al Hossain, A. M.; Sarkar, M. R.; Ali, M. S. In Vitro Antioxidant and in Vivo Analgesic Properties of Citrullus Lanatus Rind and Flesh Extract: A Comparison. Bangladesh Pharm. J. 2022, 251, 67–72. DOI: 10.3329/bpj.v251i1.57842.

[36] Idowu, A. T.; Igiehon, O. O.; Adekoya, A. E.; Idowu, S. Dates Palm Fruits: A Review of Their Nutritional Components, Bioactivities and Functional Food Applications. AIMS Agric. Food. 2020, 54, 734–755. DOI: 10.3934/agrfood.2020.4.734.

[37] Tafti, G.; Dahdavian, S.; Ardakani, Y. Physicochemical Properties and Applications of Date Seed and Its Oil. Int. Food Res. J. 2017, 24(4).

[38] Castrica, M.; Rebuffi, R.; Giromini, C.; Tretola, M.; Cattaneo, D.; Baldi, A. Total Phenolic Content and Antioxidant Capacity of Agri-food Waste and by-products. Ital. J. Anim. Sci. 2019, 18(1), 336–341. DOI: 10.1080/1828051X.2018.1529544.

[39] Navghare, V. V.; Dhwale, S. C. In Vitro Antioxidant, Hypoglycemic and Oral Glucose Tolerance Test of Banana Peels. Alexandria J. Med. 2017, 53(3), 237–243. DOI: 10.1016/j.ajme.2016.05.003.

[40] Abd El-khalik, T.; M. D.; Fath Omar, E. M. Effect of Olive Oil and Pomegranate Peels on Rats Suffering from Chronic Injury in the Liver. J. Home Econ. 2018. 28. 2. http://homeEcon.menofia.edu.eg

[41] Bitalebi, S.; Nikoo, M.; Rahmanifarah, K.; Noori, F.; Ahmadi Gavlighi, H. Effect of Apple Peel Extract as Natural Antioxidant on Lipid and Protein Oxidation of Rainbow Trout (Oncorhynchus Mykiss) Mince. Int. Aquat. Res. 2019, 11(2), 135–146. DOI: 10.1007/s40071-019-00224-y.

[42] Concencio, F. I. G. R.; Brotto, G. F.; Nora, L. Grape Wine and Juice: Comparison on Resveratrol Levels. Int. J. Adv. Eng. Res. Sci. 2019, 64, 378–386. DOI:10.22161/ijers.6.4.44.

[43] Saber, D.; Alghanti, A. H.; Ahmed, E. M.; Felemban, B. F.; Ali, H. T.; Megahed, M.; El-Aziz, K. Enhancement of Barrier and Mechanical Performance of Steel Coated with Epoxy Filled with Micron and Nano Alumina Fillers. Mater. Res. 2021, 25.

[44] Bapurao Khandagale, A.; Chandrakant Gangavane, S.; Yogendra Kulkarni, G.; Suhas Mandle, G.; Jagdish Upadhye, V. Comparative Analysis Of Citric Acid Production By Aspergillus Niger Using Different Media. Plant Cell Biotechnol. Mol. Biol. 2021, 22(4), 77–85.

[45] Chaudhary, N.; Dangi, P. Fruit and Vegetable Waste: A Taste of Future Foods. In Edible Food Package: Springer Singapore: 2022; pp 115–147. doi:10.1007/981-16-2383–7_6

[46] Pushpa, R. As. Random UV Mutagenesis Stimulated over Production of Citric Acid by Aspergillus Niger. Int. J. Recent Sci. Res. 2018.

[47] Martínez, O.; Sánchez, A.; Font, X.; Barrena, R. Valorization of Sugarcane Bagasse and Sugar Beet Molasses Using Kluyveromyces Marxianus for Producing value-added Aroma Compounds via solid-state Fermentation. J. Clean. Prod. 2017, 158, 8–17. DOI: 10.1016/j.jclepro.2017.04.155.

[48] Yazid, N. A.; Barrena, R.; Komilis, D.; Sánchez, A. Solid-state Fermentation as A Novel Paradigm for Organic Waste Valorization: A Review. Sustainability (Switzerland). 2017, 9(2). MDPI. 10.3390/su9020224

[49] Aim, H. B. U.; Saed, F.; Barrow, C. J.; Dunshea, F. R.; Suleria, H. A. R. Food Processing Waste: A Potential Source for Bioactive Compounds. Bioact. Compd. Underutilized Fruits and Nuts. 2020, 625–649.

[50] Friedman, M.; Kozukue, N.; Kim, H. J.; Choi, S. H.; Mizuno, M. Glycoalkaloid, Phenolic, and Flavonoid Content and Antioxidative Activities of Conventional Nonorganic and Organic Potato Peel Powders from Commercial Gold, Red, and Russet Potatoes. J. Food Compos. Anal. 2017b, 62, 69–75. DOI: 10.1016/j.jfca.2017.04.019.

[51] Matharu, A. S.; de Melo, E. M.; Houghton, J. A. Food Supply Chain Waste: A Functional Periodic Table of bio-based Resources. Waste Biorefinery: Potential and Perspectives. 2018, 219–236. Elsevier., .DOI: 10.1016/B978-0-444-63992-9.00007-0.
[52] Negro, V.; Ruggeri, B.; Fino, D. Recovery of Energy from Orange Peels through Anaerobic Digestion and Pyrolysis Processes after d-Limonene Extraction. Waste Biomass Valorization. 2018, 9(8), 1331–1337. DOI: 10.1007/s12649-017-9915-z.

[53] Xu, L.; Wei, L.; Shi, Q.; Cai, C.; Fu, H. Y.; She, Y. B. Non-targeted Detection of Multiple Frauds in Orange Juice Using Double water-soluble Fluorescence Quantum Dots and Chemometrics. Food Anal. Methods. 2019, 12(11), 2614–2622. DOI: 10.1007/s12161-019-01570-z/Published.

[54] Srivastava, N.; Srivastava, M.; Alhazmi, A.; Kausar, T.; Haque, S.; Singh, R.; Ramteke, P. W.; Mishra, P. K.; Tuohy, M.; Leitgeb, M., et al. Technological Advances for Improving Fungal Cellulase Production from Fruit Wastes for Bioenergy Application: A Review. Environ. Pollut. 2021, 287. DOI: 10.1016/j.envpol.2021.117370.

[55] John, O. D.; du Preez, R.; Panchal, S. K.; Brown, L. Tropical Foods as Functional Foods for Metabolic Syndrome. Food Funct. 2020, 11(8), 6946–6960. DOI: 10.1039/d0fo01133a.

[56] Faiaid, S. S.; Ethis, N.; Hajjee, Z.; M. J. Tikrit Journal for Agricultural Sciences (TJAS) (TJAS) (TJAS) Optimization for Extraction Proteins from Pulp of Watermelon Seed. Tikrit J. Agric. Sci. 2019, 19(2), 75–83. http://tujas.tu.edu.iq

[57] Matheus, J. R. V.; Andrade, C. J.; de, M.; F. R.; Fai, A. E. C. Persimmon (Diospyros Kaki L): Chemical Properties, Bioactive Compounds and Potential Use in the Development of New Products – A Review. Food Rev. Int. 2020. 10.1080/17450151.2020.1733597

[58] Kumar, D.; Shamim, M.; Arya, S. K.; Siddiqui, M. W.; Srivastava, D.; Sandhu, S. Valorization of By-products from Food Processing through Sustainable Green Approaches. In Challenges and Opportunities of Circular Economy in Agri-Food Sec; Springer, 2021; pp 191–226.

[59] Rairiprouhit, D. A Review: Food, Chemical Composition and Utilization of Carrot (Daucus Carota L) Pomace. Int. J. Chem. Sci. 2018, 6(3), 2921–2926. https://www.researchgate.net/publication/328450822

[60] Behiry, S. I.; Okla, M. K.; Alami, S. A.; EL-Hefny, M.; Salem, M. Z. M.; Alaraith, I. A.; Ali, H. M.; Al-Ghtani, S. M.; Monroy, J. C.; Salem, A. Z. M. Antifungal and Antibacterial Activities of Musa Paradisiaca L. Peel Extract: HPLC Analysis of Phenolic and Flavonoid Contents. Processes. 2019, 7(4). DOI: 10.3390/pr7040215.

[61] Vu, H. T.; Scarlett, C. J.; Vuong, Q. V. Effects of Drying Conditions on Physicochemical and Antioxidant Properties of Banana (Musa Cavendish) Peels. Dry. Technol. 2017, 35(9), 1141–1151. DOI: 10.1080/07373937.2016.1233884.

[62] Oh, J. H.; Chung, J. O.; Lee, C. Y.; Yun, Y.; Park, M. Y.; Hong, Y. D.; Kim, W. G.; Cha, H. Y.; Shin, K. S.; Hong, G. P., et al. Characterized Polysaccharides from Green Tea Inhibited Starch Hydrolysis and Glucose Intestinal Uptake by Inducing Microstructural Changes of Wheat Starch. J. Agric. Food Chem. 2021, 69(47), 14075–14085. DOI: 10.1021/acs.jafc.1c04274.

[63] Sharma, K. D.; Karki, S.; Thakur, N. S.; Attri, S. Chemical Composition, Functional Properties and Processing of carrot–A Review. J. Food Sci. Technol. 2012, 49(1), 22–32. DOI: 10.1007/s13197-011-0310-7.

[64] Nakicigojlu-Tas, E.; Otleš, S. Influence of Extraction Solvents on the Polyphenol Contents, Compositions, and Antioxidant Capacities of Fig (Ficus Carica L.) Seeds. An. Acad. Bras. Cienc. 2021, 93(1). DOI: 10.1590/0001-3765202120190526.

[65] Petropoulos, S. A.; Fernandes, ̀.; Natsi, G.; Petrokos, K.; Barros, L.; Ferreira, I. C. F. R. Nutritional Value, Chemical Characterization and Bulk Morphology of Greek Garlik Landraces. Molecules. 2018, 23(2). DOI: 10.3390/molecules23020319.

[66] Ma, Z. F.; Zhang, H. Phytochemical Constituents, Health Benefits, and Industrial Applications of Grape Seeds: Amini-review. Antioxidants. 2017, 6(3). MDPI. 10.3390/antiox06030071

[67] Safaei, N.; Babaei, H.; Azarfarin, R.; Jadati, A. R.; Yaghoubi, A.; Sheikhalizadeh, M. A. Comparative Effect of Grape Seed Extract (Vitis Vinifera) and Ascorbic Acid in Oxidative Stress Induced by on-pump Coronary Artery Bypass Surgery. Ann. Card. Anaesth. 2017, 201, 45–51. DOI:10.4103/0971-9784.197834.

[68] Schieber, A. Side Streams of Plant Food Processing as a Source of Valuable Compounds: Selected Examples. Annu. Rev. Food Sci. Technol. 2017, 8, 97–112.

[69] Sotiropoulou, E. I.; Liouni, M.; Calokerinos, A. C.; Nerantzis, E. Utilization of Grape Pomace for the Production of Microbial protein–A Review. In Proceedings of the 5th International Conference on Sustainable Solid Waste Management, Athens, Greece, 2017, 21–24.

[70] Ahmadi Kamazani, N.; Elhamirad, A. H.; Ghavami, M.; Moridi Farimani, M.; Armin, M. Ultrasound-Assisted Extraction of Antioxidant Extract from Lettuce (Lactuca Sativa L) Wastes and Evaluation of the Antioxidative Activity. J. Food Technol. Nutr. Sci. 2017, 14(2), 21–38.

[71] Kumari, K. Mushrooms as Source of Dietary Fiber and Its Medicinal Value: A Review Article. J. Pharmacogn. Phytochem. 2020, 9(2), 2075–2078. www.phytojournal.com.

[72] Masmoudi, M.; Yaich, H.; Borchani, M.; Mbarki, R.; Attia, H. Chemical, Physical and Sensory Characteristics of Biscuits Enriched with Jujube (Zizyphus Lotus L) Flour and Fiber Concentrate. J. Food Sci. Technol. 2021, 58(4), 1411–1419. DOI: 10.1007/s13197-020-04652-7.
[93] Chai, Y. H.; Yusup, S.; Kadir, W. N. A.; Wong, C. Y.; Rosli, S. S.; Ruslan, M. S. H.; Chin, B. L. F; Yin, C. L. Valorization of Tropical Biomass Waste by Supercritical Fluid Extraction Technology. *Sustainability (Switzerland)*. 2021. Vol. 13, 1–24. MDPI. 10.3390/su13010233

[94] Durante, M.; Lenucci, M. S.; Rescio, L.; Mita, G.; Caretto, S. Durum Wheat by-products as Natural Sources of Valuable Nutrients. *Phytochemistry Reviews*. 2012, 11, 255–262.

[95] Wenzel, J.; Storer Samaniego, C.; Wang, L.; Burrows, L.; Tucker, E.; Dwarshuis, N.; Ammerman, M.; Zand, A. Antioxidant Potential of *Juglans Nigra*, Black Walnut, Husks Extracted Using Supercritical Carbon Dioxide with an Ethanol Modifier. *Food Sci. Nutr.* 2017, 5(2), 223–232. DOI: 10.1002/fsn3.385.

[96] Aryal, S.; Baniya, M. K.; Danekhu, K.; Kunwar, P.; Gurung, R.; Koirala, N. Total Phenolic Content, Flavonoid Content and Antioxidant Potential of Wild Vegetables from Western Nepal. *Plants*. 2019, 8(4). DOI: 10.3390/plants8040096.

[97] Durante, M.; Ferramosca, A.; Treppicione, L.; Di Giacomo, M.; Zara, V.; Montefusco, A.; Lenucci, M. S. Application of Response Surface Methodology (RSM) for the Optimization of Supercritical CO2 Extraction of Oil from Pate Olive Cake: Yield, Content of Bioactive Molecules and Biological Effects in Vivo. *Food Chem.* 2020, 332, 127405.

[98] Gbashi, S.; Adebo, O. A.; Piater, L.; Madala, N. E.; Njobeh, P. B. Subcritical Water Extraction of Biological Materials. *Sep. Purif. Rev.* 2017. Vol. 46. 1. 21–34. Taylor and Francis Inc. 10.1080/15422119.2016.1170035

[99] Kathiman, M. N.; Muralidhar, S. K. A.; Gimbin, J. Effect of Encapsulation Agents on Antioxidant Activity and Moisture Content of Spray Dried Powder from Mahkota Dewa Fruit Extract. *IOP Conference Series: Mater. Eng.* 2020, 991(1). DOI: 10.1088/1757-899X/991/1/012040.

[100] Beya, M. M.; Netzel, M. E.; Sultanbawa, Y.; Smyth, H.; Hoffman, L. C. Plant-based Phenolic Molecules as Natural Preservatives in Comminuted Meats: A Review. *Antioxidants*. 2021. Vol. 10. 2. 1–18. MDPI. 10.3390/antiox10020263

[101] Kim, D. S.; Kim, M. B.; Lim, S. Enhancement of Phenolic Production and Antioxidant Activity from Buckwheat Leaves by Subcritical Water Extraction. *Prev. Nutr. Food Sci.* 2017, 22(4), 345–352. DOI: 10.3746/pnf.2017.22.4.345.

[102] Mayanga-Torres, P. C.; Lachos-Perez, D.; Rezende, C. A.; Prado, J. M.; Ma, Z.; Tompsett, G. T.; Timko, M. T.; Forster-Carneiro, T. Valorization of Coffee Industry Residues by Subcritical Water Hydrolysis: Recovery of Sugars and Phenolic Compounds. *J. Supercrit. Fluids*. 2017, 120, 75–85. DOI: 10.1016/j.supflu.2016.10.015.

[103] Costa, J. R.; Tonon, R. V.; Cabral, L.; Gottschalk, L.; Pastrana, L.; Pintado, M. E. Valorization of Agricultural Lignocellulosic Plant Byproducts through Enzymatic and Enzyme-Assisted Extraction of High-Value-Added Compounds: A Review. *ACS Sustain. Chem. Eng.* 2020. Vol. 8. 35. 13112–13125. American Chemical Society. 10. 1021/acssuschemeng.oc02087

[104] Prokopov, T.; Nikolova, M.; Dobrev, G.; Taneva, D. Enzyme-assisted Extraction of Carotenoids from Bulgarian Tomato Peels. *Acta Aliment.* 2017, 46(1), 84–91. DOI: 10.1556/066.2017.46.1.11.

[105] Reshmitha, T. R.; Thomas, S.; Geethanjali, S.; Arun, K. B.; Nisha, P. DNA and Mitochondrial Protective Effect of Lycopene Rich Tomato (*Solanum Lycopersicum L.*) Peel Extract Prepared by Enzyme Assisted Extraction against H2O2 Induced Oxidative Damage in L6 Myoblasts. *Journal of Functional Foods*. 2017, 28, 147–156. DOI: 10. 1016/j.jff.2016.10.031.

[106] Yang, X.; Zhang, Y.; Pang, H.; Yuan, S.; Wang, X.; Hu, Z.; Zhou, Q.; He, Y.; Yan, Y.; Xu, L. Codisplay of Rhizopus Oryzae and Candida Rugosa Lipases for Biodiesel Production. *Catal.* 2021, 11(4). DOI: 10.3390/ catal11040421

[107] Chen, X.; Li, X.; Zhu, X.; Wang, G.; Zhuang, K.; Wang, Y.; Ding, W. Optimization of Extrusion and ultrasound-assisted Extraction of Phenolic Compounds from jizi439 Black Wheat Bran. *Processes*. 2020, 8(9), 1153. DOI: 10.1080/23433393.2019.1694819.

[108] Kaleem, M.; Ahmad, A.; Amir, R. M.; Raja, G. K. Ultrasound-assisted Phytochemical Extraction Condition Optimization Using Response Surface Methodology from Perlette Grapes (*Vitis Vinifera*). *Process*. 2019, 7(10). DOI: 10.3390/pr7100749.

[109] Carreira-Casais, A.; Carpena, M.; Pereira, A. G.; Chamorro, F.; Soria-Lopez, A.; Perez, P. G.; Otero, P.; Cao, H.; Xiao, J.; Simal-Gandara, J., et al. Critical Variables Influencing the Ultrasound-Assisted Extraction of Bioactive Compounds—A Review. *2021, 50. DOI: 10.3390/csa2021-10562.

[110] Aguilo-Aguayo, I.; Walton, J.; Viñas, I.; Tiwari, B. K. Ultrasound Assisted Extraction of Polysaccharides from Mushroom by-products. *LWT*. 2017, 77, 92–99. DOI: 10.1016/j.lwt.2016.11.043.

[111] Vinatourou, M.; Mason, T. J.; Calinescu, I. Ultrasonically Assisted Extraction (UAE) and Microwave Assisted Extraction (MAE) of Functional Compounds from Plant Materials. *TrAC - Trends Anal. Chem.* 2017, 97, 159–178.

[112] Sonar, M. P.; Rathod, V. K. Optimization Study of Marmelosin (Imperatorin) Extraction from Aegle Marmelos Using Three Phase Partitioning. *J. Biol. Act. Prod. Nat.* 2020, 105, 418–428. DOI: 10.1080/22311866.2020.1816215.
Antioxidant Effect, Improve Biochemical Parameters Related to Metabolic Syndrome, and Decrease Cellular Genotoxicity in Humans. *Food Res. Int.* 2021, 142. DOI: [10.1016/j.foodres.2020.110101](https://doi.org/10.1016/j.foodres.2020.110101).

[134] Moreno, C. R.; Fernández, P. C. R.; Rodríguez, E. O. C.; Carrillo, J. M.; Rochín, S. M. Changes in Nutritional Properties and Bioactive Compounds in Cereals during Extrusion Cooking. *Extrusion Metals, Polym. Food Prod* 2018, 104–124.

[135] Lozano-Sánchez, J.; Bendini, A.; Di Lecce, G.; Valli, E.; Gallina Toschi, T.; Segura-Carretero, A. Macro and Micro Functional Components of a Spreadable Olive by-product (Pâté) Generated by New Concept of two-phase Decanter. *Eur. J. Lipid Sci. Technol.* 2017, 119(1). DOI: [10.1002/ejlt.201600096](https://doi.org/10.1002/ejlt.201600096).