Vegetable Wastes and Byproducts

Subjects: Agriculture, Dairy & Animal Science
Contributor: Rajeev Bhat

Agri-food industries generate enormous amounts of fruit and vegetable processing wastes, which opens up an important research area aimed towards minimizing and managing them eciently to support zero wastes and/or circular economy concept. These wastes remain underutilized owing to a lack of appropriate processing technologies vital for their ecient valorization, especially for recovery of health beneficial bioactives like dietary fibers. Dietary fiber finds wide applications in food and pharmaceutical industries and holds high promise as a potential food additive and/or as a functional food ingredient to meet the techno-functional purposes important for developing health-promoting value-added products. Based on this, the present review has been designed to support 'zero waste' and 'waste to wealth' concepts. In addition, the focus revolves around providing updated information on various sustainability challenges incurred towards valorization of fruit and vegetable wastes for extraction of health promoting dietary fibers.

Keywords: Keywords: dietary fiber ; agri-food wastes ; by-products ; valorization ; health benefits

---

1. Abstract

Agri-food industries generate enormous amounts of fruit and vegetable processing wastes, which opens up an important research area aimed towards minimizing and managing them efficiently to support zero wastes and/or circular economy concept. These wastes remain underutilized owing to a lack of appropriate processing technologies vital for their efficient valorization, especially for recovery of health beneficial bioactives like dietary fibers. Dietary fiber finds wide applications in food and pharmaceutical industries and holds high promise as a potential food additive and/or as a functional food ingredient to meet the techno-functional purposes important for developing health-promoting value-added products.

2. Introduction

Higher production rate coupled with inappropriate handling technologies have led to the generation of enormous amounts of wastes in the food industries, particularly those from fruit and vegetable processing. This has opened up an important research area aimed towards minimizing and managing industrial wastes more efficiently to support zero wastes concept. Besides, food loss and waste reduction/management remain integral parts of the circular economy. As per the Food and Agriculture Organization (FAO) of the United Nations, annually about one-third of the global food production (~1.3 billion metric tons) is wasted [1]. Nevertheless, it is estimated that nearly half of the horticultural produce (fruits, vegetables, and root crops) is wasted globally, reaching up to 60% [2][3][4]. Earlier, Monier et al. [5] have quantified the amount of food wastes generated in the European Union, estimated to be ~180 kg of annual food loss per person. Further, recent estimation of food wastes by European Commission has estimated ~160 kg of food to be wasted per person [6]. According to Kader [7], around one-third of all fruits and vegetables produced globally is lost during postharvest process. Additionally, as much as 50% of the cultivated fruits and vegetables are wasted even before reaching the consumption stage [8][9].

Fruit and vegetable wastes generated in food industries post processing remain as underutilized owing to lack of appropriate processing technologies essential for their efficient valorization [8]. These vegetal wastes and/or by-products generated are a well-established source of bioactive compounds and include health beneficial dietary fibers. The health promoting potential of dietary fiber includes lowering of blood cholesterol and sugar levels, improving cardiovascular health, and much more [9]. Nevertheless, dietary fiber holds high promise as a potential food additive or as a functional food ingredient, which can meet the techno-functional purposes required for developing health-promoting value added products [9]. In this view, as per the authors' knowledge, there is no single review providing in-depth information and discussing on the dietary fiber obtained from fruit and vegetable wastes. In the present-day scenario, sustainable utilization and management of food industrial wastes and/or by-products is vital to minimize pollution created by landfills. Keeping this as the background, the main aim of this review was to introduce novel concepts for effective reuse, recyclability, and maximal utilization of wastes and by-products for value addition as well as to boost the economic value.

This review also supports ‘zero waste’ and ‘waste to wealth’ concepts, with the main focus relying on providing updated information on various sustainability challenges incurred towards utilizing fruit and vegetable wastes for extraction of dietary fiber, which is envisaged to find potential applications in various food industries.

3. Data, Model, Applications and Influences

3.1. Agri-Food Waste Valorization

Valorization technology involves sustainable conversion of agri-food wastes to value-added products. In the majority of the instances, agri-food wastes remain underutilized and find potential application only as bio-compost or as bio-fuel. Nevertheless, if left untreated for a long period, they can pose serious environmental stress, producing foul smells and pollution.

As per the available reports, agri-food wastes can be a good source of functional bioactive compounds [10]. Most of these bioactive compounds are proved to possess health beneficial properties such as antioxidant, antiviral, antibacterial, cardio-protective, anti-tumor, anti-obesity, etc. [11][12]. Because of post-processing extraction of the pulp (to produce juice, jams, purees), high amounts of wastes are generated [13].

Food processing industrial wastes include bioactives such as dietary fibers, pigments, essential minerals, fatty acids, antioxidant polyphenolic compounds, etc., and require green approaches to obtain these value added compounds [14]. Alkozai et al. [15] used powder obtained from pomace of pineapple, carrot, banana, orange peels, and mango kernel in preparation of cookies. Accordingly, cookies prepared with 10% of powder recorded higher acceptability scores on sensory evaluation. Reports are also available wherein apple pomace, apple fiber powder, apple skin, carrot pomace, orange pomace, and mango peels have been used to extract dietary fibers and used as a functional food ingredient in various bakery based products (cookies, crackers, cakes, muffins, biscuits, bun, wheat rolls, etc.) [16].

Principally, dietary fibers are carbohydrate polymers such as cellulose, hemicellulose, lignin and pectin, which provide structural rigidity to the plant cell wall. Depending on the water solubility, dietary fibers are categorized as soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). In Figure 1, details on different types and sources of agri-food based dietary fiber are depicted. Accordingly, dietary soluble fiber types include pectin (sugars from whole grain, legumes, etc.), gums (sugar monomers from beans, legumes, etc.), and mucilage (aquatic plants, cactus, aloe vera, okra, as well as glycoproteins from food additives). Whereas, insoluble dietary fiber types include cellulose (providing glucose monomers obtained from fruits, root vegetables, etc.), hemicellulose (complex sugars from cereal bran and grains), and lignin (aromatic alcohols from vegetables). With regard to extraction methods identified, dietary fiber fibers (soluble and/or insoluble) are obtained via dry and/or wet processing, chemical methods, enzymatic gravimetric methods, and microbial methods (with certain limitations). More recently, green extraction methods such as water extraction, ethanol extraction and steam extraction, pulsed electric field assisted extraction, ultrasonic assisted extraction, high hydrostatic pressure assisted extraction, and other combination techniques are also widely used for extraction purposes [17][18].

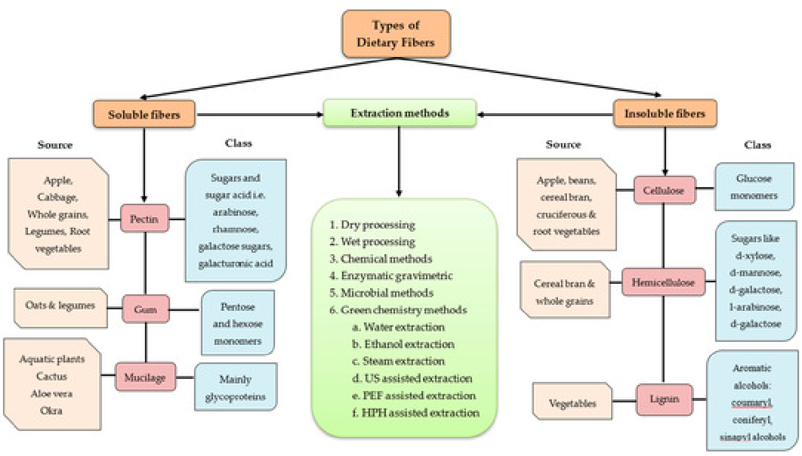

Figure 1. Agri-food based dietary fiber types, sources, and methods for their extraction.

To date, several techniques are recommended for dietary fibers extraction from plant resources. The techniques used for extraction like drying method, solvents extraction, and intensity of treatments were found to influence the composition and traits of obtained fibers [19]. Besides, selection of fiber extraction method can depend on the chemical nature of fiber, composition of particular fiber, presence of oligosaccharides, degree of polymerization, complexity, etc. [20]. Extraction method can also affect the behavior of dietary fiber in food applications as well as inside the human body [21]. Liquid to solid ratio, contact time, temperature, and selection of extraction method are some other factors that can influence the yield of dietary fiber [22]. Various treatment methods are reported to impart diverse effects on the structure of dietary fibers. Use of alkali and acid mediated extraction can damage the molecular structure of dietary fiber, however, enzymatic assisted extraction techniques can lead to incomplete extraction [17][23]. Alternatively, combined extraction methods (enzymatic and solvent) can also be useful for dietary fiber extraction. Further, modified wet-milling method has been recommended for better extractability, as these are cost-effective, capable of producing high purity fiber, and utilize minimal amounts of chemical and water than other routinely used methods. Purity of dietary fiber obtained by application of wet-milling technique is reported to be in the range of 50–90% [17].

Further, modern day processing techniques such as pulsed electric field, ultrasonic, microwave, high hydrostatic pressure, ionizing radiations, etc., are reported to have certain advantages and drawbacks. The use of these innovative, sustainable, and green extraction technologies supports high quality extraction that is reproducible and easy to handle, with lower environmental impact [24][25]. Sun et al. [26] used ultrasonic assisted alkali extraction (as combination technique) for extraction of insoluble dietary from soybean residues. The results indicated yield of insoluble fiber to be 744 mg/g of raw soybean. Recently, Wen et al. [27] have investigated on the impact of ultrasonic-microwave assisted extraction on soluble dietary fiber from coffee wastes (silver skin of the seeds) and compared it with conventional solvent extraction technique. In their study, the highest recovery rate (42.7%) of soluble dietary fiber was achieved by ultrasonic-microwave extraction (as a combination extraction technique). This was 1.9, 1.5, and 1.2-fold of the recovery rates achieved by microwave assisted, ultrasonic assisted, and conventional solvent assisted extractions, respectively. Begum and Deka [28] extracted dietary fiber form culinary banana bract by using ultrasonic-assisted extraction. The yield of soluble, insoluble, and total dietary fibers was 4.65, 78.7, and 83.9 g/100 g, respectively. In a similar study, hemicellulose and phenolic compounds were extracted from bamboo 'bast fiber' powder by application of ultrasonic assisted extraction technique. Analysis revealed that a combination of ultrasonic extraction and hot water treatment lead to an increase in the extraction efficiency to 2.6-fold. In addition, it also contributed to higher amounts of polyphenolic compounds, hemicellulose, and molecule of lignin biosynthesis [29]. Further, three different combination techniques, i.e., microwave-ultrasonic, microwave-sodium hydroxide, and microwave-enzymatic treatments, were compared for the extraction of soluble dietary fiber from peels of grapefruit. Results of this study revealed the yield of soluble, insoluble, and total fibers for microwave assisted extraction to be 7.9, 55.8, and 63.4 g/100 g, and for microwave-sodium hydroxide treatment it was 17.2, 46.2, and 63.9 g/100 g. For microwave-enzymatic treatment, the values were 9.2, 53.2, and 63.4 g/100 g; and for microwave-ultrasonic treatment it was 8.6, 55, and 63.8 g/100 g [30]. In another study, pulsed electric field technique was applied for extraction of cellulose from 'Mendong' fiber. Pulsed electric field assisted extracted cellulose showed better crystalline index when compared to alkali extraction process. This process increased the crystallinity of extracted cellulose by 83–86% [31].

However, these modern-day extraction techniques have certain drawbacks. For example: The main disadvantage can include high-energy consumption (as in microwaves), separation issues (as in ultrasonic extraction), and lack of user friendliness (as in pulsed electric field extraction technique) [25]. Hence, from our point of view, wet milling can be considered as an ideal extraction method due to its affordability and ability to produce high quality pure fiber.

Currently, on a global platform, food-processing industries are continuously exploring novel avenues to obtain dietary fiber from underexplored plant resources, to be used as a value-added healthy ingredient. Generally, dietary fibers are obtained from cereals and/or their by-products. Garcia-Amezquita et al. [32] have reviewed on various aspects relevant to processing of plant by-products to obtain fiber-rich concentrate. Besides, various aspects relevant to evaluation of functional properties and technological functionalities of selected fruit and vegetable by-products are covered. Overall, in their article, the authors have detailed more on dietary fiber concentrates from fruits and vegetable by-products, whereas, in this article, we have covered all of the available information in more than 45 fruits and vegetables not only for SDF, IDF, and TDF, but also for pectin, cellulose, hemicellulose, and lignin. In addition, the main focus of the present review is to provide updated information on valorization opportunities of wastes/by-products derived from processing of various types of fruits and vegetables in a global context, the role of dietary fiber in health management, and finally the contribution to circular economy.

References

1. Food and Agriculture Organization (FAO). Definitional Framework of Food Losses and Waste; FAO: Rome, Italy, 2014. Available online: http://www.fao.org/3/a-at144e.pdf (accessed on 2 March 2020).

2. Gustavsson, J.; Cederberg, C.; Sonesson, U.; Van Otterdijk, R.; Meybeck, A. Global Food Losses and Waste: Extent, Causes and Prevention. In A Study Conducted for International Congress “Save Food” At Inter. FAO, Dusseldorf, Germany, 2011; Food and Agriculture Organization of the United Nations: Rome, Italy, 2011. Available online: http://www.fao.org/3/a-i2697e.pdf (accessed on 27 February 2020).
3. Imbert, E. Food waste valorization options: Opportunities from the Bioeconomy. Open Agric. 2017, 2, 195–204.
4. Gupta, N.; Poddar, K.; Sarkar, D.; Kumari, N.; Padhan, B.; Sarkar, A. Fruit waste management by pigment production and utilization of residual as bioadsorbent. J. Environ. Manag 2019, 244, 138–143.
5. Monier, V.; Mudgal, S.; Escalon, V.; O’Connor, C.; Gibon, T.; Anderson, G.; Montoux, H.; Reisinger, H.; Dolley, P.; Ogilvie, S.; et al. Preparatory Study on Food Waste across EU 27. Report for the European Commission [DG ENV-Directorate C]; European Commission, France: 2010. Available online: https://ec.europa.eu/environment/eussd/pdf/bio_foodwaste_report.pdf (accessed on 22 February 2020).
6. Stenmarck, Â.; Jensen, C.; Quested, T.; Moates, G.; Buksti, M.; Cseh, B.; Juul, S.; Parry, A.; Politano, A.; Redlingshofer, B. Estimates of European Food Waste Levels; IVL Swedish Environmental Research Institute: Stockholm, Sweden, 2016. Available online: https://www.eu-fusions.org/phocadownload/Publications/Estimates%20of%20European%20food%20waste%20levels.pdf (accessed on 28 February 2019).
7. Kader, A.A. Increasing food availability by reducing postharvest losses of fresh produce. Acta Hort. 2004, 682, 2169–2176.
8. Elik, A.; Yanik, D.K.; Istanbullu, Y.; Guzelsoy, N.A.; Yavuz, A.; Gogus, F. Strategies to reduce post-harvest losses for fruits and vegetables. Strategies 2019, 5, 29–39.
9. 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.
10. Ben-Othman, S.; Jõudu, I.; Bhat, R. Bioactives From Agri-Food Wastes: Present Insights and Future Challenges. Molecules 2020, 25, 510.
11. Takshak, S. Bioactive compounds in medicinal plants: A condensed review. SEJ Pharm. Nat. Med. 2018, 1, 13–35.
12. Yahia, E.M. The contribution of fruit and vegetable consumption to human health. In Fruit and Vegetable Phytochemicals- Chemistry and Human Health, (Edition2); De La Rosa, L.A., Alvarez-Parrilla, E., González Aguilar, G.A., Eds.; Wiley-Blackwell: Hoboken, NJ, USA, 2010; pp. 3–51.
13. Wadhwa, M.; Bakshi, M.; Makkar, H. Wastes to worth: Value added products from fruit and vegetable wastes. CAB Rev. 2015, 43, 1–25.
14. Banerjee, J.; Singh, R.; Vijayaraghavan, R.; MacFarlane, D.; Patti, A.F.; Arora, A. Bioactives from fruit processing wastes: Green approaches to valuable chemicals. Food Chem. 2017, 225, 10–22.
15. Akozai, A.; Alam, S. Utilization of Fruits and Vegetable Waste in Cereal Based Food (Cookies). Int. J. Eng. Res. Technol. 2018, 7, 383–390.
16. Sahni, P.; Shere, D.M. Utilization of fruit and vegetable pomace as functional ingredient in bakery products: A review. Asian J. Dairy Food Res. 2018, 37, 202–211.
17. Maphosa, Y.; Jideani, V.A. Dietary fiber extraction for human nutrition—A review. Food Rev. Int. 2016, 32, 98–115.
18. Soquetta, M.B.; Terra, L.D.M.; Bastos, C.P. Green technologies for the extraction of bioactive compounds in fruits and vegetables. CyTA-J. Food 2018, 16, 400–412.
19. Fuentes-Alventosa, J.M.; Rodríguez-Gutiérrez, G.; Jaramillo-Carmona, S.; Espejo-Calvo, J.; Rodríguez-Arcos, R.; Fernández-Bolaños, J.; Guillén-Bejarano, R.; Jiménez-Araujo, A. Effect of extraction method on chemical composition and functional characteristics of high dietary fibre powders obtained from asparagus by-products. Food Chem. 2009, 113, 665–671.
20. Verma, A.K.; Banerjee, R. Dietary fibre as functional ingredient in meat products: A novel approach for healthy living—A review. J. Food Sci. Technol. 2010, 47, 247–257.
21. 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.
22. Al-Farsi, M.A.; Lee, C.Y. Optimization of phenolics and dietary fibre extraction from date seeds. Food Chem. 2008, 108, 977–985.
23. Ma, M.M.; Mu, T.H. Effects of extraction methods and particle size distribution on the structural, physicochemical, and functional properties of dietary fiber from deoiled cumin. Food Chem. 2016, 194, 237–246.

24. Vieira, G.S.; Cavalcanti, R.N.; Meireles, M.A.A.; Hubinger, M.D. Chemical and economic evaluation of natural antioxidant extracts obtained by ultrasound-assisted and agitated bed extraction from jussara pulp (Euterpe edulis). J. Food Eng. 2013, 119, 196–204.

25. Chemat, F.; Rombaut, N.; Meullemiestre, A.; Turk, M.; Perino, S.; Fabiano-Tixier, A.S.; Abert-Vian, M. Review of green food processing techniques. Preservation, transformation, and extraction. Innov. Food Sci. Emerg. Technol. 2017, 41, 357–377.

26. Sun, J.; Zhang, Z.; Xiao, F.; Wei, Q.; Jing, Z. Ultrasound-Assisted Alkali Extraction of Insoluble Dietary Fiber from Soybean Residues. In Proccedings of the IOP Conference Series: Materials Science and Engineering, 22-24 June, 2018; Zhuai, China. IOP Publishing, England and Wales: 2018; p. 052005.

27. Wen, L.; Zhang, Z.; Zhao, M.; Senthamaraikannan, R.; Padamati, R.B.; Sun, D.W.; Tiwari, B.K. Green extraction of soluble dietary fibre from coffee silverskin: Impact of ultrasound/microwave-assisted extraction. Int. J. Food Sci. Technol. 2020, 55, 2242–2250.

28. Begum, Y.A.; Deka, S.C. Effect of processing on structural, thermal, and physicochemical properties of dietary fiber of culinary banana bracts. J. Food Process. Pres. 2019, 43, e14256.

29. Wang, C.; Tallian, C.; Su, J.; Vielnascher, R.; Silva, C.; Cavaco-Paulo, A.; Guebitz, G.M.; Fu, J. Ultrasound-assisted extraction of hemicellulose and phenolic compounds from bamboo bast fiber powder. PLoS ONE 2018, 13, 1–11.

30. Gan, J.; Huang, Z.; Yu, Q.; Peng, G.; Chen, Y.; Xie, J.; Nie, S.; Xie, M. Microwave assisted extraction with three modifications on structural and functional properties of soluble dietary fibers from grapefruit peel. Food Hydrocoll. 2020, 101, 105549.

31. Suryanto, H.; Fikri, A.A.; Permanasari, A.A.; Yanuhar, U.; Sukardi, S. Pulsed electric field assisted extraction of cellulose from mendong fiber (Fimbristylis globulosa) and its characterization. J. Nat. Fibers 2018, 15, 406–415.

32. Garcia-Amezquita, L.E.; Tejada-Ortigoza, V.; Serna-Saldivar, S.O.; Welti-Chanes, J. Dietary Fiber Concentrates from Fruit and Vegetable By-products: Processing, Modification, and Application as Functional Ingredients. Food Bioprocess. Technol. 2018, 11, 1439–1463.

Retrieved from https://encyclopedia.pub/entry/history/show/6956