**Title**

**Fruits and Vegetable waste: A potential source of nutraceutical compounds for the mitigation of adverse effects of food insecurity.**

Abdullah Maqbool1, Aleena Iqbal2

1Institute of energy and environmental engineering, University of the Punjab

2Department of Botany, Lahore College for Women University, Lahore, Punjab, Pakistan.

Corresponding author:

aleenaiqbal012@gmail.com

Abstract:

Fruits and vegetables are enriched with essential nutrients that are required for proper functioning of the human body. To meet the increasing requirement of rapidly rising population and changes in dietary preferences, the production of vegetable and fruit has increased. Lack of proper infrastructure and handling techniques, has led to deterioration of large amounts of fresh commodities, as well as their residues, by-products and parts. This loss in commodities impacts negatively on nutrition, the environment, and the economy. According to Food and Agriculture Organization of United Nations (FAO) fruits and vegetable losses are among the leading food losses and are expected to increase 60%. Up to 25-30 % of the waste is generated by fruits and vegetable processing industries, which includes mainly peels, seeds, rind and pomace. These by-products of food industry are enriched with bioactive compounds (dietary fibers, vitamins, polyphenols, enzymes, essential oils, carotenoids, etc.). The forthcoming food insecurity issues can be mitigated by utilization of nutrient-enriched waste products of the food industry. For promotion of good health exploration and utilization of plant-based Nutraceuticals has grown increasingly important keeping with the world’s paradigm shift towards an ecofriendly and sustainable solution to treat malnutrition. This chapter had highlighted the importance of food waste resources, the effective production of Nutraceuticals of by-products, their health benefits and to prevent pollution.

* 1. **Introduction**

Plants are important for well-being of mankind. The concept of the use of plants as medicine and their importance in Maintaining good health is a subject of increasing concern [1]. Thus plant-based foods are sources of essential macro and micronutrients required by the human body for proper functioning and thus prevent body from chronic ailments [2]. Plants bearing fruits and vegetables play a significant role in human dietary habits. FVs are enriched with protein, carbohydrates, minerals, vitamins, amino acids, fatty acids, dietary fibers, electrolytes and various bioactive components (figure 1) [3,4]. They exhibit health promoting properties, as, appropriate consumption has been linked epidemiologically with decrease risk of various non-communicable diseases. Nowadays, the essential function of antioxidants is mainly focused. Antioxidants acts as scavengers in eradicating free radicals before they have adverse effects on body [5].

In the present era, all people around the globe are dealing with various chronic health issues. In addition, developing countries are facing disorders related to nutritional deficiency. Dietary recommendations from several nations suggested a plant-based diet particularly fruits and vegetables as the foundation of healthy life for all age groups [6]. Around the globe, approximately 2 billion people suffer from nutrient deficiency (hidden hunger). Hidden hunger exhibits negative effects on productivity, immune system, cognition, economy, growth, and development [7]. United Nations anticipated that the world population on earth will increase up to 9.3 billion by 2050 [8], therefore, there is a need to increase the production of food by 70-100 % more than it is today [9]. Agricultural production and human population possess a complex relationship. Consumer demand fresh FVs for a healthy life. Agriculturists, farmers, and researchers have created ways for the production and maintenance of large amounts of crop varieties [10]. Due to changes in climate, poor infrastructure, lack of high-tech equipment, and industrial consequences increased demand for food production will impose a significant burden on the earth [11]. Indirect pathways link food access with climate change. Various factors viz, increase in population, consumerism trends and modernization of food industries have resulted in the creation of huge amounts of waste. Agro-food supply chain produces a significant amount of various types of waste, particularly organic waste that influence the environment negatively [12]. The increase in population growth confers a challenge in providing appropriate food for all the habitants at the right time. Food insecurity is among the major issues around the world, mainly in undeveloped countries. A large amount of food is wasted in production, processing, and consumption time. From an environmental and economic standpoint, agro-waste poses substantial management challenges. Among the food waste, 25-30% is made up of fruits and vegetables. FVs are perishable products, sensitive to mechanical damage and susceptible to microbial attack. To ensure food security, and reduce food loss there is a need to explore new ways for alternative uses of agro-food waste [9]. The present chapter explored the solutions to utilize the nutraceutical compounds present in agro-food waste.

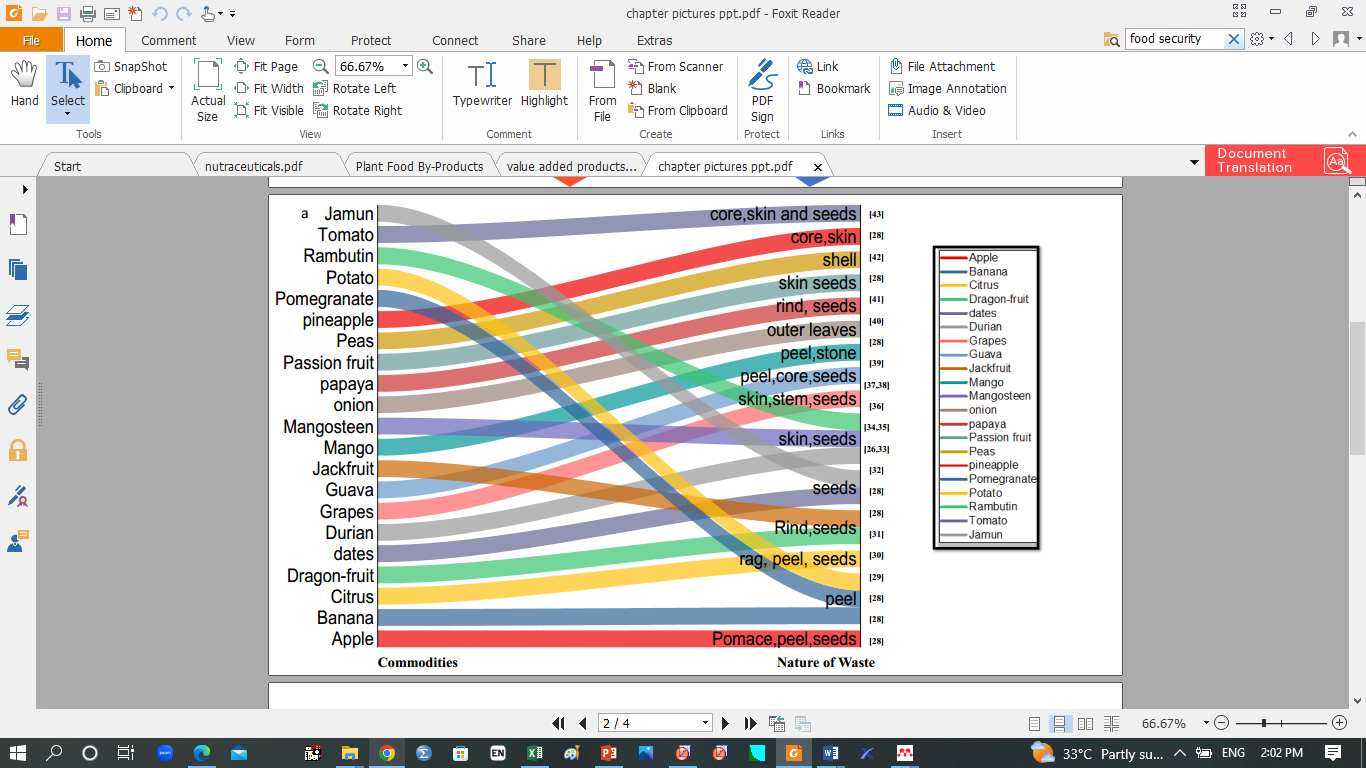
|  |
| --- |
|  |

C:\Users\Zainab\Downloads\chapter pictures ppt.tiff

Figure 1 Nutrient content of fruits and vegetables

1. **Fruits and vegetable waste production**

The unused and unconsumed parts of horticultural products (mainly fruits and vegetables) are recognized as Fruits and Vegetable losses and waste (FWL).  It is generated as a result of a lack of proper handling techniques, poor infrastructure, morphological quality or simply discarded for diverse reasons. A significant amount of FWL is also generated by FVs processing industries [12, 13]. Panouille *et al.*[13] documented that the type and quantity of FWL depend upon commodity and morphological parts (seeds, roots, stems, leaves, skin, tubers, stones, pomace, etc.). Some fruits and vegetables produce 25-30% waste that cannot be used further, mainly including peels (90-92 %), followed by pomace, core, rag, skin, shell, pods, stones, vine, and other materials [14, 15].  Among all the horticultural crops, FVs are most frequently consumed, because of the presence of bioactive compounds. Mostly processed, minimally processed, or raw FVs are consumed. With a rapid increase in population and change in dietary habits, the production and processing of FVs has been significantly enhanced.  Nutritional, environmental, and economic issues are emerging as a result of losses and waste of processing industries [16]. It is reported that in industrial countries FLW waste is primarily generated at the consumer and retail level, whereas, at the postharvest and processing level by developing countries [17]. The production of FLW is significantly higher in developed countries of the world. Approximately 198.9 kg of FLW is generated by developed countries annually by a person. It is estimated that FLW accounts for 40% of the whole food chain in the US [18]. 32% of the world FLW is produced in North Africa, Central and West Asia [19]. Whereas, 20 % (a third) of the world’s FLW is generated by the European continent, and 6 % by Latin America [20]. Hence the production of FLW imposes a significant effect on the environment and biodiversity [21]. FLW negatively influences food security and also causes a 60 % increase in greenhouse gas emissions [22]. Certain fruits and vegetables are not suitable for raw consumption and undergo processing to obtain the desired products [23] (Ayala-Zavala and others 2010,) like macadamia and coffee [24]. Slicing of apples generates 10.91% of seed and pulp upon 89.09% finished product. Papaya dicing generates 32% of the pulp (unusable), 8.5% of the peel, and 6.5% of seeds as a waste production of 53% final product. The peeling of mandarins accounts for 16% of the total waste and 84% of the final product generated [23, 25]. 5.5 MMT (million metric tons) of waste (including pomace) is produced during FVs juice production. Annually, approximately 5-9 MMT of solid waste are generated by grapes and wine processing industries [26,27]. Each year canning and freezing industries of FVs produced 6 MMT of solid waste containing of leaves, stalks and stems [13].



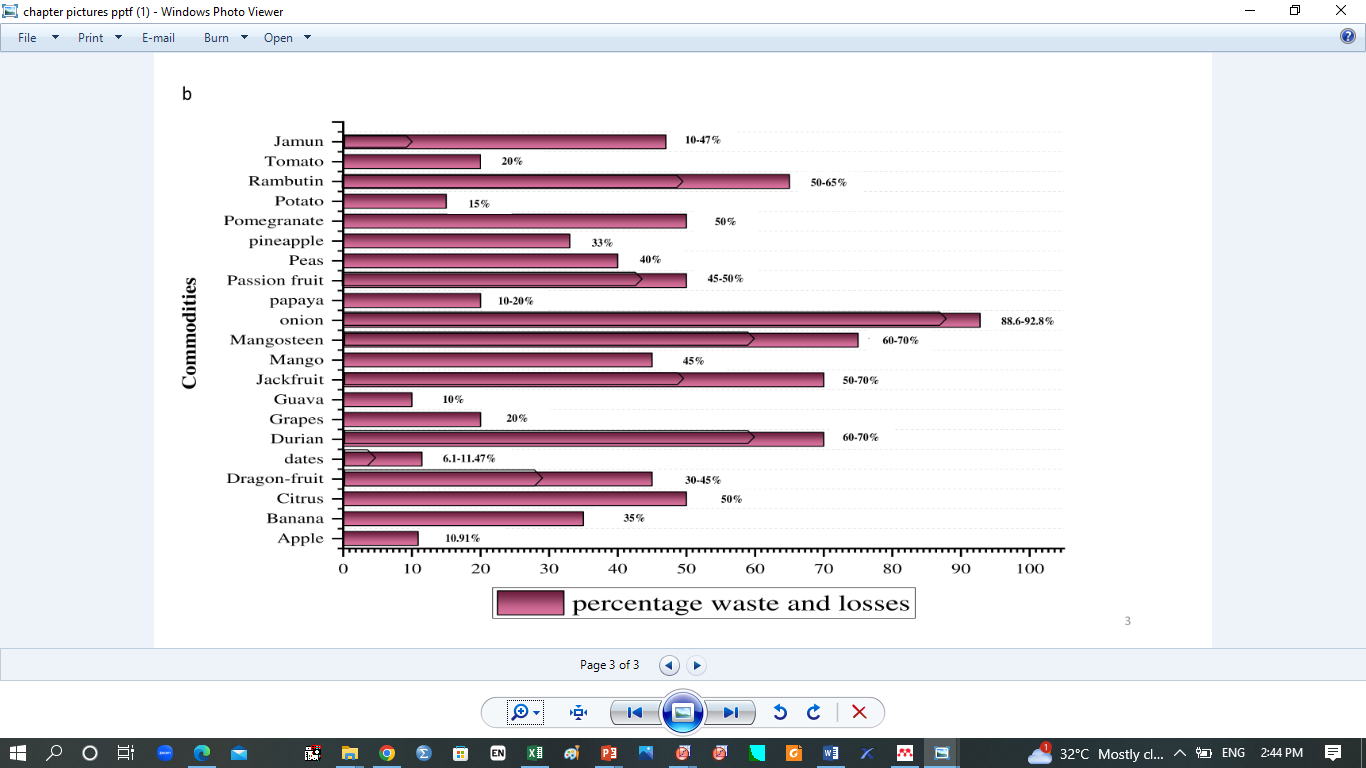


Figure 2. Fruit and vegetable waste and losses nature (a) and percentage (b)

1. **Effect of FLW on environment and economy**

According to FAO [45] FLW can be determined quantitatively and qualitatively. A reduction in the amount of consumable food is known as quantitative FLW. whereas FLW signified before the food item is wasted is qualitative FLW. Qualitative FLW can be identified as the decrease in consumer acceptability, nutritional and economic value. In spite of the beneficial role of qualitative FLW, it is hard to quantify and assess. A wide range of manufacturing operations are included in the agricultural food supply chain, which generates a large amount of various waste, mainly organic waste that can negatively influence the environment [15]. Agricultural food waste management is among the leading challenges around the globe. Moreover, FLW cause a significant loss of valuable of resources (food, fuel, bioactive compounds, etc.). In the field of waste management environmental sustainability is one of the most frequently discussed topics. Zero-emission systems, greener production, waste prevention and minimization are some eco-friendly approaches for waste management [45]. Agri-food productions require land preparation, application of fertilizers and many other costs. Hence FLW is also a huge economic loss [46-48]. FLW can increase the rate of poverty in developing nations. FLW can reduce the farmer’s income and enhance the price, as the decrease in quality, causes a reduction in the quantity of commodities that can be sold [48;49]. Food and Agriculture Organization [50] reported that the direct economic cost of FLW is 1.3 billion tonnes which are approximately USD 1 trillion/year excluding environmental damage which is projected to be almost USD 700 billion and externalities which cost around USD 900 billion.  It is documented that every year production of FLW consume 173-250 km3 of water [51;52] and 198 million hectares of fertile land [47]. Decrease in FLW production will ultimately cause decrease in environmental pollution, less use of resources (water, land and fertilizers) [48]. Various environmental issues can be upraised by organic waste as a result of climate change, susceptibility to microbial damage and due to high biological and chemical oxygen demand. Generation of greenhouse gases (CO2), variation in pH and chemical composition. Increase in accumulation rate that reduces the amount of available fertile land for disposal are among the leading environmental pollution raised by organic waste [53]. In 2009, Worldwide FLW produces almost 3,300-5600 million tonnes of CO2. Cereals waste generated approximately 34% of greenhouse gases, around the globe [52, 54].

* 1. **Fruits and Vegetable waste: A sustainable source of nutraceutical compounds**

Over the coming decades, the world will face significant issues regarding food security, economic growth, and environmental externalities. The rapid growth of the global population will elevate the likelihood of food insecurity. So ensuring food security for the entire global population in a sustainable manner is imperative. Although various global organizations had worked on food security, but they have not yet succeeded in eradicating hunger. Using the best alternative approaches and reducing FLW are the two sustainable methods to enhance global food security. For sustenance of global community improvement in the supply chain, inclusive agriculture and a compromise among government industries, and consumers are required. To ensure food security, it is necessary to decrease and repurpose the waste produced by the food industry. [9]. Global report on food crises (GRFC) for the year 2023 highlighted an increase in the number of people facing food insecurity. It is also documented that because of economic shock and the Ukraine war, a quarter of a billion people are suffering malnutrition. The report also indicated that approximately 258 million people in 58 territories are affected by food insecurity. In the GRFC’s seven years of history, this is the highest number [55].

Phyto-active constituents of the FWL can be a source of nutraceuticals and an ingredient for the preparation of functional food [56; 57]. The word nutraceutical coined by Dr. Stephen DeFelice, derived from the combination of two words “nutrition” and “pharmaceutical” in 1989 [58]. Zeisel [59] defined nutraceutical as a dietary supplement that delivers a concentration form of bioactive food component in a nonfood matrix and maintains a good health. Nutraceutical can also be defined as any substance whose nutritional content is known [60], usually sold in medical form (capsules or pills). A dietary substance that provides nutrition, energy, regulates various physiological processes and lowers the risk of diseases is known as functional food. [61]. Functional food differs from nutraceuticals in that it supplies one or more active substances inside the food matrix. The waste generated by food industries is enriched with various functional food ingredients like dietary fibers, fatty acids, amino acids, phenolic compounds, probiotics, minerals, carotenoids, minerals and various other bioactive components. These functional food ingredients can prevent serious ailments. The popularity of functional foods (functional beverages) is increasing rapidly nowadays. The by-products and waste produced by food industries can serve as economically viable sources of functional food ingredients. Moreover, it results in generation of new jobs and reduces environmental pollution caused by food industrial waste [62]. Researchers around the world are working in utilization of dietary fibers present in the fruits and vegetables. These dietary fibers improve sugar absorption, intestinal motility and bulking mediators [63]. Nutraceutical industries uses polyphenols (diverse bioactive compounds) [64]. Polyphenols mainly flavonoids, phenolic acids, phenyl paranoids, tannins quinones and lignin plays an active role in scavenging free radicals, reduction of cardiovascular and chronic degenerative ailments. Sir Elkhatim et al. [65] docuemted that waste products of fruits and vegetables can be a high source of phenolic compounds and hence can be used as a supplements.

Ajikumar *et al.* [66] documented that the bioactive compounds can treat and prevent various chronic ailments, by interacting with DNA, proteins and various biomolecules. Currently, as per consumer demands for healthy and nutritional food items food industries are working on the formation of nutraceutical products. Total phenolic compounds (TPC) and dietary fibers exhibit cardio-protective, anticancer and antimicrobial potential. FWL is enriched with these valuable bioactive compounds. Pulp or juice of citrus fruits (oranges, lime, lemon and grapefruit) are usually consumed. Citrus fruits processing, generates 50% of the waste consisting of pulp, peels and seeds [67]. Citrus fruits seeds and peels are enriched with antioxidant compounds mainly pectins, flavonoids, fibers, naringin, hesperidin, narirutin, eriocitrin and limonene [68]. Dijlas et al., [69] documented that limonoids (Limonin, nomilinic and nimolin) present in the citrus fruit peels exhibit antimicrobial potential.

*Mangifera indica* L. (Mango) is a commonly available seasonal fruit that is typically utilized in the production of items such as pickles, purees, juices, and canned products. By-products (unused) of mango comprises of kernels (9-40 %) and peels (7-24 %) are enriched with various bioactive compounds. Amino acids (leucine, valine and lysine) and phenolic compounds are present in mango kernels. Functional compounds viz; polyphenolic, hydrolysable tannis, xanthanoids, catechins, flavonoiods, carotenoids, dietary fibers, vitamins C and E are present in mango seeds [70-72]. BenOthman et al., [72] reported that mango peel and seeds are enriched with Mangiferin (a bioactive compound that showed antioxidant, antimicrobial and immunomodulatory potential). Bananas are characterized as second largest tropical fruit. Banana peels (a waste product) make up 40% of the overall fruit weight. Various antioxidant bioactive compounds, proteins and dietary fibers are present in banana peels. Banana peels are used in animal feed, in formation of banana powder and chips [73; 74]. In spite of this, a large amount of banana peels is discarded which is hazardous for the environment. Therefore, there is a need of formation of valuable food products. Apple juice yields pomace which constitutes 30 % of the fruit. Apple pomace contains 2-4 % seeds, 1 % stem and 95% peels. It is an essential source of phenolic compounds (naringenin, epicatechin, quercetin, phloridzin, catechin, etc.) and antioxidants [75-76]. Grape wine industry produced pomace (by product), which constitutes 15-20 % of the total weight of the grapes. Grape pomace consists of stems, seeds, pulp and skins. Grape by-products are an essential source of anthocyanins, flavonols ( quercetin-3-O-glucoside, kaempferol-3-O-glucoside, myricetin, quercetin), flavanols (proanthocyanidins), stilbenes (piceid, resveratrol, astringin), phenolic acids (ferulic, gallic, p-coumaric, vanillic, p-hydroxybenzoic and caffeic) [77]. Liu et al., [78] documented that cabbage external leaves are principle waste product which are removed before processing. For the extraction and utilization of essential phyto-active constituents from cabbage waste products efforts are being made. Flesh, crown, and peels are the waste products of beet root (*Beta vulgaris*). Strong antioxidant compounds Betalains (red betacyanins yellow beta-xanthins) are the main valuable compound present in flesh (14%), crown (32%) and peels (54%) of beet root [79]. Onion skin is enriched with quercetin, flavonoids, phenolics, aglycone, fructans, dieatary fibers, and alkenyl cysteine sulfoxides. These bioactive compounds observed to have antidiabetic, antispasmodic, antimicrobial activities [80]. Kallel et al., [81] reported that garlic husk is abundant in polyphenolic compounds, cellulose, hemicellulose, and lignin, making it a valuable source of these components.

* 1. **Extraction of value-added compounds from Phytowaste**

Proliferation in diet related health issues enhances the need of dietary supplements. Fruits and vegetables are enriched with bioactive active compounds and essential oils. Nutraceutics serve as dietary supplements that prevents or treat human ailments and are formulated from food items. Waste from fruits and vegetables can serve as a potential source for the development of nutraceuticals. [82]. Extraction of bioactive compounds without affecting their chemical and structural properties is challenging. A variety of traditional extraction methods, such as solvent extraction and maceration, along with non-thermal techniques like microwave-assisted extraction, ultrasound-assisted extraction, electric pulse field, high-voltage electric discharge, and subcritical fluid extraction, have been assessed. [83;84].

The extraction of bioactive compounds is a significant contributor to the economic growth of developing nations. For the successful scale-up cost effective and viable techniques plays an important role in extraction and identification of these beneficial compounds. The countries like Africa and Sub-Saharan region lacks the technology to recover the maximum amount of nutrients and development of beneficial products. There is a need to explore the appropriate solvent and collaboration of international agro-industries for the generation of maximum amount of nutrients from the fruits and vegetables waste products [85]. Fruits and vegetable waste can enhance the flavor of food products. Pineapple cannery waste, which contains a high concentration of ferulic acid, is recognized as the precursor for the production of vanillic acid and vanillin [86]. 4-hydroxy-3-methoxy benzaldehyde (vanillin) is the main constituent present in vanilla beans. *Aspergillus niger* I-1472 is reported in transformation of ferulic acid into vanillic acid, whereas *Pycnoporus* *cinnabarinus* MUCL 39533 converts vanillic acid to vanillin [87]. Lalou and Mantzouridou [88], extracted flavoring compounds like ethyl octanoate, isoamyl acetate, phenyl ethyl acetate, ethyl do decanoate, ethyl decanoate and ethyl decanoate by cultivation of yeast VitilevureMT (S.cerevisiae) on orange peel waste using solid state fermentation. Whereas, pectin, L-ascorbic acid, and carotenoids were the by-products produced through this process. Biotransformation of apple pomace by fungus *Tyromyces chioneus* results in formation of flavoring compounds viz; acetic acid, benzyl alcohol, 3-phenyl-1-1propanol, benzaldehyde and 3-phenulpropanal [89]. Cinnamic acid enhances 10 times the production of 3-phenylpropanal and 3-phenul-2-propanol. Extraction of bioactive compounds using micro-organisms and enzymes enhance valorization of waste. However, enzymatic extraction and solid state-fermentation significantly enhances a variety of bioactive compounds if trials like volatility and environmental compassion should be addressed properly. Optimizing the fermentation process can minimize the escape of volatile compounds from the reactor.The efficacy of extraction can be improving by the use of hybrid technologies [90].

**Conclusion**

Fruits and vegetables enriched with essential nutrients that are required for healthy life. A diet high in fruit has been linked to a lower risk of chronic diseases. World population is increasing rapidly and is expected to reach 9.6 billion in 2050. Food production has been increased to meet the increasing demand of food. A large amount of fruits and vegetable waste and loss is generated because of poor infrastructure, mishandling, and processing. The affinity of plants to replace chemicals and nutraceuticals is of interest of food industries. In pursuit of greater sustainability in productivity and global food security, waste generated during the cultivation, harvesting, and processing of fruit and vegetable biomass is presently regarded as the most favorable alternative source of nutraceuticals.

References:

1. T. Moses; and A. Goossens, A. 2017. Plants for Human Health: Greening Biotechnology and Synthetic Biology. *J. Exp. Bot.* 2017, 68, 4009–4011.
2. D.P. Roberts; and A.K. Mattoo, Sustainable Crop Production Systems and Human Nutrition. Front. Sustain. *Food Syst.* 2019, 3, 72.
3. T. Alzate-Yepes, L. Pérez-Palacio, E., Martínez, and Osorio, M. Mechanisms of Action of Fruit and Vegetable Phytochemicals in Colorectal Cancer Prevention. *Molecules,* 2023, 28(11), 4322.
4. Slavin, J., and Lloyd, B. (2012). Health Benefits of Fruits and Vegetables. *Advances in Nutrition*, **3**(4): 506-516. doi: 10.3945/an.112.002154
5. Kaur, C., & Kapoor, H. C. (2001). Antioxidants in fruits and vegetables–the millennium’s health. *International journal of food science & technology*, *36*(7), 703-725.
6. National Institute of Nutrition, Indian Council of Medical Research; *Dietary guidelines for Indians:* *A manual*. Hyderabad: NIN; 2011.
7. Micronutrient Initiative. *Investing in the future: A united call to action on vitamin and mineral deficiencies*. Ottawa, Canada: Micronutrient Initiative; 2009.
8. J. Charles; H. Godfray; J. R. Beddington; I.R. Crute, L. Haddad; D. Lawrence; J.F. Muir; S. Robinson; S.M. Thomas; and C. Toulmin, Food Security: The Challenge of Feeding 9 Billion People. *Science*, 2010, 327 (5967), 812–818.
9. Hanson, C. Food Security, Inclusive Growth, Sustainability, and the Post-2015 Development Agenda. *Background Research Paper Submitted to the High Level Panel on the Post-2015 Development Agenda, World Resource Institute,* 2013.
10. Tscharntke, T.; Clough, Y.; Wanger, T. C.; Jackson, L.; Motzke, I.; Perfecto, I.; Vandermeer, J.; Whitbread, A. Global Food Security, Biodiversity Conservation and the Future of Agricultural Intensification. Biol. Conserv. 2012, 151 (1), 53–59.
11. C. Ajila; S.K. Brar; M. Verma; U.P. Rao. Sustainable Solutions for Agro-Processing Waste  
    Management: An Overview. Environmental Protection Strategies for Sustainable Development; Springer: Berlin-Heidelberg, 2012; pp 65–109.
12. Sagar, N. A., Pareek, S., Sharma, S., Yahia, E. M., & Lobo, M. G. (2018). Fruit and Vegetable Waste: Bioactive Compounds, Their Extraction, and Possible Utilization. Comprehensive Reviews in Food Science and Food Safety, 17(3), 512–531. doi:10.1111/1541-4337.12330
13. Panouille M, Ralet MC, Bonnin E, Thibault JF. 2007. Recovery and reuse´of trimmings and pulps from fruit and vegetable processing. In: Waldron KW, editor. Handbook of waste management and co-product recovery in food processing. Cambridge: Woodhead Publishing Limited. p 417–47.
14. Ajila CM, Aalami M, Leelavathi K, Rao UP. 2010. Mango peel powder: a potential source of antioxidant and dietary fiber in macaroni preparations. Innov Food Sci Emerg Technol 11:219–24.
15. Ajila CM, Bhat SG, Rao UP. 2007. Valuable components of raw and ripe peels from two Indian mango varieties. Food Chem 102:1006–11.
16. Rodríguez, G., Lama, A., Rodríguez, R., Jiménez, A., Guillén, R., & Fernández-Bolanos, J. (2008). Olive stone an attractive source of bioactive and valuable compounds. Bioresource technology, 99(13), 5261-5269.
17. Arancon, R. A. D., Lin, C. S. K., Chan, K. M., Kwan, T. H., & Luque, R. (2013). Advances on waste valorization: new horizons for a more sustainable society. Energy Science & Engineering, 1(2), 53-71.
18. Ziolkowska, J.R. Economic and Environmental Costs of Agricultural Food Losses and Waste in the US. Int. J. Food Eng. 2017, 3. [Google Scholar] [CrossRef][Green Version]
19. Bilali, H.E.; El Bilali, H. Research on food losses and waste in North Africa. N. Afr. J. Food Nutr. Res. 2018, 2, 51–57. [Google Scholar]
20. Hoehn, D.; Laso, J.; Cristóbal, J.; Ruiz-Salmón, I.; Butnar, I.; Borrion, A.; Bala, A.; Fullana-i-Palmer, P.; Vázquez-Rowe, I.; Aldaco, R.; et al. Regionalized Strategies for Food Loss and Waste Management in Spain under a Life Cycle Thinking Approach. Foods 2020, 9, 1765. [Google Scholar] [CrossRef]
21. Brenes-Peralta, L.; Jiménez-Morales, M.F.; Freire Junior, M.; Belik, W.; Basso, N.; Polenta, G.; Giraldo, C.; Granados, S. Challenges and Initiatives in Reducing Food Losses and Waste: Latin America and the Caribbean; Burleigh Dodds Science Publishing: Cambridge, UK, 2020. [Google Scholar]
22. Beretta, C.; Stucki, M.; Hellweg, S. Environmental Impacts and Hotspots of Food Losses: Value Chain Analysis of Swiss Food Consumption. Environ. Sci. Technol. 2017, 51, 11165–11173. [Google Scholar] [CrossRef]
23. Ayala-Zavala JF, Rosas-Dom´ınguez C, Vega-Vega V, Gonzalez-Aguilar GA. ´ 2010. Antioxidant enrichment and antimicrobial protection of fresh-cut fruits using their own byproducts: looking for integral exploitation. J Food Sci 75:175–81.
24. Miljkovic D, Bignami G. 2002. Nutraceuticals and methods of obtaining nutraceuticals from tropical crops. U.S. Patent Application No. 10/067,569.
25. Joshi VK, Kumar A, Kumar V. 2012. Antimicrobial, antioxidant and phyto-chemicals from fruit and vegetable wastes: a review. Intl Food Ferm Technol 2:123–36.
26. Schieber A, Stintzing FC, Carle R. 2001. By-products of plant food processing as a source of functional compounds - recent developments. Trends Food Sci Technol 12:401–13.
27. Laufenberg G, Kunz B, Nystroem M. 2003. Transformation of vegetable waste into value added products: (A) the upgrading concept; (B) practical implementations. Bioresour Technol 87:167–98.
28. Gupta K, Joshi VK. 2000. Fermentative utilization of waste from food processing industry. In: Joshi VK, editor, Postharvest technology of fruits and vegetables: handling, processing, fermentation and waste management. New Delhi: Indus Pub Co. p 1171–93.
29. Cheok CY, Adzahan NM, Rahman RA, Abedin NHZ, Hussain N, Sulaiman R, Chong GH. 2018. Current trends of tropical fruit waste utilization. Crit Rev Food Sci Nutr 58(3):335–61.
30. Habib, H. M., & Ibrahim, W. H. (2009). Nutritional quality evaluation of eighteen date pit  
    varieties. International Journal of Food Sciences and Nutrition, 60(sup1), 99–111
31. Siriphanich J, Yahia EM. 2011. Durian (Durio zibethinus Merr.). In: Yahia EM, editor. Postharvest biology and technology of tropical and subtropical fruits. Cambridge, GB: Woodhead Publishing. p 80–114
32. Saxena A, Bawa AS, Raju PS. 2011. Jackfruit (Artocarpus heterophyllus Lam.). In: Yahia EM, editor. Postharvest biology and technology of tropical and subtropical fruits. Cambridge: Woodhead Publishing Lim Limited. p 275–98
33. Mitra SK, Pathak PK, Devi HL, Chakraborty I. 2013. Utilization of seed and peel of mango. Acta Hort 992:593–6.
34. Chen Y, Huang B, Huang M, Cai B. 2011. On the preparation and characterization of activated carbon from mangosteen shell. J Taiwan Inst Chem Engr 42:837–42.
35. Ketsa S, Paull RE, Saltveit ME. 2011. Mangosteen (Garcinia mangostana L.). In: Yahia E, editor. Postharvest biology and technology of tropical and subtropical fruits. London: Woodhead Publishing. p 1–30.
36. Chorolque, A.; Pellejero, G.; Sosa, M.C.; Palacios, J.; Aschkar, G.; García-Delgado, C.; Jiménez-Ballesta, R. Biological control of soil-borne phytopathogenic fungi through onion waste composting: Implications for circular economy perspective. Int. J. Environ. Sci. Technol. 2021, 1–10.
37. Lee WJ, Lee MH, Su NW. 2011. Characteristics of papaya seed oils obtained by extrusion–expelling processes. J Sci Food Agric 91:2348–54
38. Parni B, Verma Y. 2014. Biochemical properties in peel, pulp and seeds of Carica papaya. Plant Arch 14:565–8.
39. Esquivel P, Stintzing FC, Carle R. 2007. Comparison of morphological and chemical fruit traits from different pitaya genotypes (Hylocereus sp.) grown in Costa Rica. J Appl Bot Food Qual 81:7–14.
40. Choonut A, Saejong M, Sangkharak K. 2014. The production of ethanol and hydrogen from pineapple peel by Saccharomyces cerevisiae and Enterobacter aerogenes. Energy Proc 52:242–9.
41. Fahmy, H. A., & Farag, M. A. (2022). Ongoing and potential novel trends of pomegranate fruit peel; a comprehensive review of its health benefits and future perspectives as nutraceutical. *Journal of Food Biochemistry*, *46*(1), e14024.
42. Issara U, Zzaman W, Yang TA. 2014. Rambutan seed fat as a potential source of cocoa butter substitute in confectionary product. Intl Food Res J 21:25–31.
43. Al-Dhabi, N.A.; Ponmurugan, K. Microwave assisted extraction and characterization of polysaccharide from waste jamun fruit seeds. Int. J. Biol. Macromol. 2020, 152.
44. Ajila, C.; Brar, S. K.; Verma, M.; Rao, U. P. Sustainable Solutions for Agro-Processing Waste  
    Management: An Overview. Environmental Protection Strategies for Sustainable Development; Springer: Berlin-Heidelberg, 2012; pp 65–109
45. Food and Agriculture Organization (2014). Food Wastage Footprint-Full-Cost Accounting - Final Report. Rome: FAO.
46. Bahadur, K., Haque, I., Legwegoh, A. F., and Fraser, E. D. (2016). Strategies to reduce food loss in the global South. Sustainability 8:595. doi: 10.3390/su8070595
47. Kummu, M., Guillaume, J. H. A., de Moel, H., Eisner, S., Flörke, M., Porkka, M., et al. (2016). The world's road to water scarcity: shortage and stress in the 20th century and pathways towards sustainability. Sci. Report 6:38495. doi: 10.1038/srep38495
48. Shafiee-Jood, M., and Cai, X. (2016). Reducing food loss and waste to enhance food security and environmental sustainability. Environ. Sci. Technol. 50, 8432–8443. doi: 10.1021/acs.est.6b01993
49. Affognon, H., Mutingi, C., Sanginpa, P., and Borgemeister, C. (2015). Unpacking postharvest losses in Sub-Saharan Africa: a meta-analysis. World Dev. 66, 49–68. doi: 10.1016/j.worlddev.2014.08.002
50. Food and Agriculture Organization. (2015). The State of Food Insecurity in the World. Rome: FAO.
51. Mekonnen, M. M., and Hoekstra, A. Y. (2010). The green, blue and grey water footprint of crops and derived crop products. Value of Water Research Report Series No. 48. Delft: UNESCO-IHE. Available online at: <http://wfn.project-platforms.com/Reports/Report47-WaterFootprintCrops-Vol1.pdf>
52. Food and Agriculture Organization (2013). *Food Wastage Footprint: Impacts on Natural Resources*. Rome: FAO.
53. Lin, C. S. K.; Pfaltzgraff, L. A.; Herrero-Davila, L.; Mubofu, E. B.; Abderrahim, S.; Clark, J.
54. H.; Koutinas, A. A.; Kopsahelis, N.; Stamatelatou, K.; Dickson, F. Food Waste as a Valuable Resource for the Production of Chemicals, Materials and Fuels. Current Situation and Global Perspective. Energy Environ. Sci. 2013, 6 (2), 426–464.
55. Global Report on Food Crises 2023 | World Food Programme. (2023). Retrieved 28 July 2023, from <https://www.wfp.org/publications/global-report-food-crises-2023>
56. Baiano, A. (2014). Recovery of biomolecules from food wastes-a review. Molecules 19, 1482114842.
57. Mira, B., Blasco, M., Berna, A., Subirats, S. (1999). Supercritical CO2 extraction of essential oil from orange peel. Effect of operation conditions  
    on the extract composition. J. Supercrit. Fluid. 14, 95104.
58. Kalra, E.K. (2003). Nutraceutical-definition and introduction. AAPS PharmSci. 5 (3), 2728
59. Zeisel, S.H. (1999). Regulation of “nutraceuticals. Science 285, 18531855
60. Chauhan, B., Kumar, G., Kalam, N., Ansari, S.H. (2013). Current concepts and prospects of herbal nutraceutical: a review. J. Adv. Pharm.  
    Technol. Res. 4 (1), 4.
61. Nicoletti, M. (2012). Nutraceuticals and botanicals: overview and perspectives. Int. J. Food Sci. Nutr. 63 (sup1), 26.
62. Routray, W., Orsat, V. (2019). Agricultural and food industry by-products: source of bioactive components for functional beverages. Nutrients  
    Beverages. Elsevier, pp. 543589.
63. Garcia-Amezquita, L.E., Tejada-Ortigoza, V., Serna-Saldivar, S.O., Welti-Chanes, J.,  
    2018. Dietary fber concentrates from fruit and vegetable by-products: processing,  
    modifcation, and application as functional ingredients. Food Bioprocess Technol.  
    11, 1439–1463. <https://doi.org/10.1007/s11947-018-2117-2>.
64. Swallah, M.S., Sun, H., Affoh, R., Fu, H., Yu, H., 2020. Antioxidant potential overviews of  
    secondary metabolites (polyphenols) in fruits. Int. J. Food Sci. 2020 https://doi.org/  
    10.1155/2020/9081686
65. Sir Elkhatim, K.A., Elagib, R.A.A., Hassan, A.B., 2018. Content of phenolic compounds  
    and vitamin C and antioxidant activity in wasted parts of Sudanese citrus fruits. Food  
    Sci. Nutr. 6, 1214–1219. https://doi.org/10.1002/fsn3.660
66. Ajikumar, P.K., Tyo, K., Carlsen, S., Mucha, O., Phon, T.H., Stephanopoulos, G. (2008). Terpenoids: opportunities for biosynthesis of natural  
    product drugs using engineered microorganisms. Mol. Pharma. 5, 167190
67. Khao, T.H., Chen, B.H. (2013). Fruits and vegetables. In: Chandrasekaran, M. (Ed.), Valorization of Food Processing By-Products. Taylor and  
    Francis Group, Boca Raton, FL, pp. 517557. , Chapter 18.
68. Manthey, J.A., Grohmann, K., Guthrie, N. (2001). Biological properties of citrus flavonoids pertaining to cancer and inflammation. Curr. Med.  
    Chem. 8, 135153
69. Dijlas, S., Canadanovic, B.J., Cetkovic, G. (2009). By-products of fruit processing as a source of phytochemicals. Chem. Ind. Chem. Eng. 15,  
    191202.
70. Aslam, H.K.W., Raheem, M.I.U., Ramzan, R., Shakeel, A., Shoaib, M., Sakandar, H.A. (2014). Utilization of mango waste material (peel, kernel)  
    to enhance dietary fiber content and antioxidant properties of biscuit. J. Global Innovation Agric. Social Sci. 2 (2), 7681
71. Abdalla, A.E.M., Darwish, S.M., Ayad, E.H.E., El-Hamahmy, R.M. (2007). Egyptian mango by-product 1: compositional quality of mango seed  
    kernel. Food Chem. 103, 11341140.
72. Ben-Othman, S., Jo˜udu, I., Bhat, R. (2020). Bioactives from agri-food wastes: present insights and future xhallenges. Molecules 25, 510544.
73. Mohapatra, D., Mishra, S., Sutar, N. (2010). Banana and its by-product utilization: an overview. J. Sci. Ind. Res. 69, 323329
74. Anal, A.K. (2013). Food processing by-products. In: Tiwari, B., Brunton, N.P., Brennan, C.S. (Eds.), Handbook of Plant Food Phytochemicals:  
    Sources, Stability and Extraction. Wiley Science Publishers, Oxford, pp. 180192. , Chapter 8
75. Dhillon, G.S., Kaur, S., Brar, S.K. (2013). Perspective of apple processing wastes as lowcost substrates for bioproduction of high value products: a review. Renew. Sustain. Energy Rev. 27, 789805.
76. Bhushan, S., Kalia, K., Sharma, M., Singh, B., Ahuja, P.S. (2008). Processing of apple pomace for bioactive molecules. Crit. Rev. Biotechnol. 28  
    (4), 285296.
77. Machado, N.F.L., Domı ´nguez-Perles, R. (2017). Addressing facts and gaps in the phenolics Chem of winery by-products. Molecules 22 (2), 286.
78. Liu, D., Liu, D., Zeng, R.J., Angelidaki, I. (2006). Hydrogen and methane production from household solid waste in the two-stage fermentation  
    process. Water Res. 40, 22302236.
79. Vulic, J.J., ´ Cebovi ´ c, T.N., ´ Canadanovi ˇ c-Brunet, J.M., ´ Cetkovi ´ c, G.S., ´ Canadanovi ˇ c, V.M., Djilas, S.M., et al. (2014). In vivo and in vitro antioxi- ´  
    dant effects of beetroot pomace extracts. J. Funct. Foods 6, 168175
80. Marrelli, M., Amodeo, V., Statti, G., Conforti, F. (2019). Biological properties and bioactive components of Allium cepa L.: focus on potential  
    benefits in the treatment of obesity and related comorbidities. Molecules 24, 119.
81. Kallel, F., Driss, D., Chaari, F., Belghith, L., Bouaziz, F., Ghorbel, R., et al. (2014). Garlic (Allium sativum L.) husk waste as a potential source of  
    phenolic compounds: influence of extracting solvents on its antimicrobial and antioxidant properties. Ind. Crops Prod 62, 3441.
82. Wadhwa, M., Bakshi, M.P.S., Makkar, H.P.S., 2015. Waste to worth: fruit wastes and byproducts as animal feed. CAB Rev. Perspect. Agric. Vet. Sci. Nutr. Nat. Resour. 10
83. Kumar, K., Yadav, A.N., Kumar, V., Vyas, P., Dhaliwal, H.S., 2017. Food waste : a potential bioresource for extraction of nutraceuticals and bioactive compounds. Bioresour. Bioprocess. <https://doi.org/10.1186/s40643-017-0148-6>.
84. Sridhar, A., Ponnuchamy, M., Kumar, P.S., Kapoor, A., 2020. Food preservation techniques and nanotechnology for increased shelf life of fruits, vegetables, beverages and spices: a review. Environ. Chem. Lett. 2, 1–21. https://doi.org/ 10.1007/s10311-020-01126-2.
85. Ganesh, K. S., Sridhar, A., & Vishali, S. (2022). Utilization of fruit and vegetable waste to produce value-added products: Conventional utilization and emerging opportunities-A review. Chemosphere, 287, 132221.
86. Lun, O.K., Wai, T.B., Ling, L.S., 2014. Pineapple cannery waste as a potential substrate for microbial biotransformation to produce vanillic acid and vanillin 21 (3), 953–958
87. Mantzouridou, F.T., Paraskevopoulou, A., Lalou, S., 2015. Yeast ﬂavour production by solid state fermentation of orange peel waste. Biochem. Eng. J. 101, 1–8. <https://doi>. org/10.1016/j.bej.2015.04.013.
88. Lalou, S., Mantzouridou, F., 2013. Bioﬂavour Production from Orange Peel Hydrolysate Using Immobilized Saccharomyces cerevisiae 9397–9407. <https://doi.org/10.1007/> s00253-013-5181-6.
89. Bosse, A.K., Fraatz, M.A., Zorn, H., 2013. Formation of complex natural ﬂavours by biotransformation of apple pomace with basidiomycetes. Food Chem. 141, 2952–2959.
90. Vyas P, Chaudhary B, Mukhopadhyay K, Bandopadhyay R (2009) Anthocyanins: looking beyond colors. In: Bhowmik PK, Basu SK, Goyal A (eds) Advances in biotechnology. Bentham Science Publishers Ltd., Oak Park, pp 152–184