Transforming By-Products of Food Industry into Dietary Fibre Treasures for Health and Sustainability

***Gouthami Shivaswamy[2], Abarna S[2], Ramakrishna A[2], Ranjani M[2], and Shalini Gaur Rudra[1]**
[1]Senior Scientist, Division of Food Science and Postharvest Technology, Indian Agricultural Research Institute, New Delhi (110 012), India
[2]Research Scholar, Division of Food Science and Postharvest Technology, Indian Agricultural Research Institute, New Delhi (110 012), India
*Corresponding Author: gouthamisiari@gmail.com

Fruits and vegetables stand out as the most commonly used commodities within the realm of horticulture crops. Currently, a significant portion, up to one-third, of fruits and vegetables, including seeds, pods, peels, pomace, hulls, husks, stems, and skins, are often discarded during preparation and processing, constituting a form of 'waste' (Ben-Othman et al., 2020). This not only results in the actual wastage of these parts but also diminishes the maximum nutritional potential of the respective fruit or vegetable. Researchers are actively exploring innovative applications for making use of such 'waste' components as potential by-products.

Worldwide, food processing industries generate substantial quantities of by-products constituting approximately 25 %–30 % of the entire commodity group (Sagar et al., 2018) and are rich source of dietary fibres, antioxidants, pigments, pectin, etc. But scanty efforts have been made to derive value-added products from these by-products resulting in significant portion remaining unused and often discarded as waste (Maurya et al., 2015). Since these by-products are recognized as potential reservoirs of various bioactive compounds, including dietary fibres, the prospect of harnessing these food processing by-products for dietary fibre, serves as functional and novel fibre in the production of various human foods, presenting a substantial opportunity for waste reduction and also indirect income generation (Sharma et al., 2020).

In recent decades, there has been a growing awareness among individuals regarding their diet and overall health. Dietary recommendations emphasize the importance of incorporating a substantial number of fruits and vegetables into one's diet for a healthy lifestyle. Nutritionists recommend consumption of low-fat foods that offer fewer calories while being rich in antioxidants and dietary fibre. Antioxidants and dietary fibre have gained popularity because of their substantial contributions in reducing cholesterol levels, preventing cardiovascular diseases and constipation (Pop et al., 2021).

Dietary fibre is composed of a diverse mixture of non-starch polysaccharides, including cellulose, hemicellulose, pectin, hydrocolloids, and lignin, which are resistant to hydrolysis by human digestive enzymes but are considered essential for maintaining good gut health. By-products containing dietary fibres encompass a significant array of colorants, antioxidant compounds, and other substances that confer notable health benefits (Popoola-Akinola et al., 2022).

Classification of dietary fibre

Based on origin

a) Plant origin

Plant-based dietary fibre refers to the type of fibre derived from plants, specifically from the cell walls, seeds, skins, and other structural components of fruits, vegetables, whole grains, nuts, seeds, and legumes. Plant-based fibres, such as cellulose, hemicellulose, pectin, and gums, are well-known for their ability to resist digestion in the human gastrointestinal tract, contributing to various health benefits, including improved digestion and gut health.

Ex: Fruits: found in the skins of fruits such as apples, pears, and berries; Vegetables: abundant in vegetables like carrots, broccoli, and leafy greens; Whole Grains: present in foods like oats, barley, brown rice, and quinoa; Legumes: found in beans, lentils, and peas; Nuts and Seeds: abundant in almonds, flaxseeds, and chia seeds.

b) Animal origin

Dietary fibre from animal sources is less common and is often referred to as functional or specialty fibres. These substances may share some characteristics with dietary fibre but are not as prevalent in the typical human diet as plant-based fibres. Eg: Chitin and Chitosan: derived from the exoskeletons of shellfish, crustaceans, and insects. Gelatin: obtained from animal collagen, often used as a gelling agent.

Based on solubility in water

a) Soluble Fibre

Soluble fibre dissolves in water and forms a gel-like substance. This type of fibre can help lower blood cholesterol and glucose levels. It is found in fruits, vegetables, legumes, and some grains. Eg: Pectins: found in fruits like apples, berries, and citrus fruits, as well as in some vegetables; Gums: present in seeds, beans, and certain types of seaweed; Beta-Glucans: commonly found in oats and barley; Inulin: found in chicory root, artichokes, and onions; Psyllium: derived from the seed husks of Plantago ovata, commonly used as a dietary supplement.

b) Insoluble Fibre

Insoluble fibre does not dissolve in water and adds bulk to the stool, aiding in the movement of food through the digestive system. It is commonly found in whole grains, nuts, seeds, and the skin of fruits and vegetables. Eg: Cellulose: abundant in whole grains, vegetables, and fruits; Hemicellulose: found in whole grains and cereal brans; Lignin: present in the woody parts of plants, particularly in the stalks and stems of vegetables; Resistant starch: resists digestion in the small intestine and is found in green bananas, raw potatoes, and some legumes.

Based on health benefits

a) Common or Conventional Fibres

Common fibres are typically found in everyday use and are widely consumed as plant-based foods. This includes fruits, vegetables, whole grains, seeds, and legumes. These fibres often have well-known structures and have been extensively studied because of their health benefits like regular bowel movements, aiding in digestion, and contributing to overall gut health. Eg: Cellulose, hemicellulose, pectin, gums, beta-glucans.

b) Novel or Specialty Fibres

Novel fibres are often derived from less common or unconventional sources, including certain plant extracts, by-products, and even animal sources in some cases. These fibres may have unique structures or properties that distinguish them from conventional fibres. Novel fibres offer specific health benefits, like prebiotic effects, improved mineral absorption, and potential effects on blood sugar levels. Eg: Inulin, resistant starch, chitin, chitosan, fructo-oligosaccharides (FOS), arabinoxylan (Pathania and Kaur, 2022).

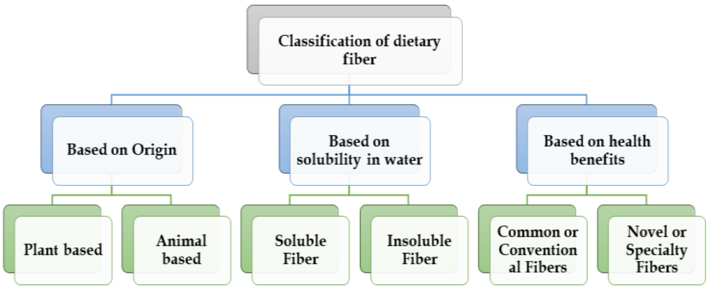

Fig. 1: Classification of dietary fibre

Extraction methods

1. Dry processing methods

Dry processing methods for the extraction of dietary fibre involve techniques that do not rely on the use of solvents or liquids. These methods are generally employed to separate and concentrate dietary fibre from plant sources.

Milling and Air Classification

Seeds or plant materials are mechanically disintegrated using milling equipment, breaking them into smaller particles. Air classification is then applied to separate these particles based on size and density. This method is effective for crops where starch is the primary storage material, such as peas, faba beans, baby lima beans, and cowpeas. It requires reduced energy and water consumption compared to wet processing methods. However, repeated air classification may decrease product recovery.

Grinding and Sieving

In this method, plant materials are ground into a fine powder using grinding equipment, and the resulting powder is then sieved to separate different particle sizes. It is simple and cost-effective method. However, it may not be as efficient as air classification in separating different components.

Extrusion

In this method, plant materials are subjected to high pressure and temperature through an extruder, resulting in a continuous flow of processed material. Mainly used for producing high-fibre snacks and cereals. This method is rapid and continuous process, with potential for creating novel fibre-rich products (Maphosa and Jideani, 2016).

2. Wet processing methods

Conventional wet milling

Conventional wet milling involves only water to extract dietary fibre. Raw plant materials are initially soaked to soften them, followed by grinding to break them down into smaller particles. Screening separates various particle sizes, and centrifugation separates solid and liquid phases. Washing removes soluble components, and optional enzyme treatments aid in cell wall breakdown. Dewatering reduces water content, and the dietary fibre is then dried. The final product undergoes quality control. This method is effective in obtaining high-quality fibre, but consumes large amount of water and has energy-intensive drying.

Alkali wet milling

In this method, alkaline solutions like Sodium hydroxide (NaOH) or Potassium hydroxide (KOH) is used. Alkali treatment helps solubilize hemicellulose, facilitating the separation of fibre from other components. Alkali wet milling is particularly effective in extracting fibre from materials with high lignin content, such as cereal brans.

Enzymatic wet processing

This method employs enzymes for the extraction of dietary fibre. Enzymes like amylases and cellulases are employed as they help break down complex carbohydrates, cell walls, and other structural components, facilitating the release of fibre. This method is particularly suitable for producing high-quality dietary fibre from various plant sources while minimizing the use of harsh chemicals and preserving the natural attributes of the fibre.

Modified wet milling

Mainly used for food applications. This method combines either conventional, alkali or enzymatic methods to extract dietary fibre from plant materials (Garcia-Amezquita et al., 2018).

Physical methods

This method maintains the structural integrity of the fibres and prevent substantial damage to the polymer chain. Consequently, the extracted fibres exhibit a high cation exchange capacity, as the side chain group remains nearly intact.

3. Microbial methods

This method involves fermenting of fibre through the use of microorganisms and enzymes. High-purity enzymes are frequently employed to selectively eliminate oligosaccharides and polysaccharides like galactans, fructans, mannans, and arabinans. This method helps in preserving the undistorted structure of the fibres and avoiding significant loss of hemicelluloses and soluble fibres. But there are concerns that microbial fermentation might generate harmful substances, potentially rendering the extracted fibres unsuitable for use in food applications.

4. Gravimetric methods

Nonenzymatic gravimetric method

This technique involves the use of hydrolytic or oxidative chemical breakdown, resulting in the retention of crude fibre. The approach is categorized into two main groups: acid-detergent and neutral detergent extractions. In the acid-detergent process, crude fibre is obtained as the combination of cellulose, lignin, and acid-insoluble hemicelluloses, leading to the substantial loss of most fibre components. Conversely, the neutral detergent procedure separates cellulose, lignin, and hemicelluloses insoluble in neutral detergent. However, this method is not suitable for plants with a high content of soluble fibre.

Enzymatic gravimetric methods

In this technique, enzymes are employed to break down complex carbohydrates, proteins, and other substances in food samples, facilitating the isolation and quantification of dietary fibre. This method provides more accurate and specific measurement of dietary fibre compared to traditional gravimetric techniques, as specific enzymes can be chosen to target particular components. Despite potential time constraints, this method stands out for its ability to enhance precision in dietary fibre analysis for nutritional and food research purposes.

5. Enzymatic-chemical methods

This technique involves enzymatic digestion of non-fibre fractions combined with the chemical extraction. Particularly, this approach eliminates starch enzymatically and utilize ethanol to separate the soluble fibre concentrate (Maphosa and Jideani, 2016).

Advantages of dietary fibre extraction from food waste

- They help in valorization of food waste *i.e.*, they recycle the food waste into some value-added products.
- Boosts new market in functional food industry.
- Modern diets made after processing of grains lack soluble dietary fibres and this creates an opportunity for their fortification and enrichment.
- They improve the quality of bakery products, extruded products and drinks with respect to their texture, water holding capacity and increased shelf-life (Dalal *et al*., 2020).

Conclusions

Extraction of dietary fibre from food waste represents a pivotal step towards both waste reduction and the creation of value-added products. Fruits and vegetables, being the most utilized commodities in horticulture crops, generate substantial by-products rich in dietary fibres, antioxidants, and other bioactive compounds. Classification of dietary fibres based on origin, solubility, and health benefits further emphasizes the diverse nature of these compounds. Notably, the extraction of dietary fibres from food waste offers several advantages, such as valorisation of waste, contributing to the functional food industry, fortification of modern diets, and improving the quality of various food products. This not only addresses environmental concerns but also aligns with the growing awareness of health-conscious individuals. Therefore, the pursuit of efficient and sustainable methods for dietary fibre extraction from food waste holds significant promise for both waste management and the development of healthier, value-added food products.

References

Ben-Othman, S., Jõudu, I. and Bhat, R., 2020. Bioactives from agri-food wastes: Present insights and future challenges. *Molecules*, 25(3): 510-532.

Dalal, N., Phogat, N., Bisht, V. and Dhakar, U., 2020. Potential of fruit and vegetable waste as a source of dietary fibre. *Int. J. Chem. Stud*, 8(1): 3085-3090.

Garcia-Amezquita, L.E., Tejada-Ortigoza, V., Serna-Saldivar, S.O. and Welti-Chanes, J., 2018. Dietary fibre concentrates from fruit and vegetable by-products: Processing, modification, and application as functional ingredients. *Food and Bioprocess Technology*, 11: 1439-1463.

Maphosa, Y. and Jideani, V.A., 2016. Dietary fibre extraction for human nutrition—A review. *Food Reviews International*, 32(1): 98-115.

Maurya, A.K., Pandey, R.K., Rai, D.I.P.T.I., Porwal, P.A.R.A.S. and Rai, D.C., 2015. Waste product of fruits and vegetables processing as a source of dietary fibre: A review. *Trends Biosci*, 8(19): 5129-5140.

Pathania, S. and Kaur, N., 2022. Utilization of fruits and vegetable by-products for isolation of dietary fibres and its potential application as functional ingredients. *Bioactive Carbohydrates and Dietary Fibre*, 27: 100295-100302.

Pop, C., Suharoschi, R. and Pop, O.L., 2021. Dietary fibre and prebiotic compounds in fruits and vegetables food waste. *Sustainability*, 13(13): 7219-7226.

Popoola-Akinola, O.O., Raji, T.J. and Olawoye, B., 2022. Lignocellulose, dietary fibre, inulin and their potential application in food. *Heliyon*, 8(8).

Sagar, N.A., Pareek, S., Sharma, S., Yahia, E.M. and 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.

Sharma, P., Gaur, V.K., Kim, S.H. and Pandey, A., 2020. Microbial strategies for bio-transforming food waste into resources. *Bioresource technology*, 299: 122580-122600.

* * * * * * * *