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Functional Food Development from Underutilized Plant Resources: Current Trends and Future Perspectives

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Abstract

Underutilized and neglected plant resources represent an important but insufficiently explored source of nutrients and bioactive compounds for functional food development. Many traditional crops, wild edible plants, local fruits, pseudocereals, pulses, seeds, and leafy vegetables possess substantial amounts of dietary fibre, proteins, minerals, vitamins, polyphenols, carotenoids, flavonoids, and other health-promoting constituents. Their wider utilization could contribute to dietary diversification, food security, biodiversity conservation, and sustainable agriculture. Recent advances in food processing, fermentation, germination, drying, extrusion, and encapsulation have created new opportunities for transforming these resources into functional ingredients and value-added foods. However, challenges related to seasonal availability, antinutritional factors, sensory properties, standardization, consumer acceptance, and scientific validation remain. This review summarizes major underutilized plant resources, their functional potential, emerging approaches for food development, and future opportunities for their integration into sustainable food systems.

Keywords: *Underutilized plants, functional foods, bioactive compounds, traditional crops, food security, phytochemicals, sustainable nutrition.*

1. Introduction

Modern food systems rely heavily on a relatively small number of major crops, including wheat, rice, maize, soybean, and potato. Although these crops are essential for global food production, excessive dependence on a limited number of species can reduce dietary diversity and agricultural resilience. Numerous locally adapted and traditionally consumed plants remain underutilized despite their nutritional and functional potential [1]. Underutilized plant resources include traditional cereals, pseudocereals, minor millets, indigenous fruits, wild edible plants, legumes, leafy vegetables, roots, tubers, and oilseeds. Examples include amaranth, buckwheat, finger millet, moringa, baobab, jackfruit, breadfruit, tamarind, lotus seeds, horse gram, and various traditional leafy vegetables. Many of these resources are naturally adapted to specific environmental conditions and may require fewer agricultural inputs than major crops. Their importance extends beyond nutrition. Underutilized crops can contribute to biodiversity conservation, provide income opportunities for rural communities, and support climate-resilient agriculture. Their incorporation into functional food products therefore represents an opportunity to connect nutritional improvement with sustainable agricultural development.

2. Nutritional and Functional Potential

Underutilized plants frequently contain diverse combinations of macronutrients and bioactive compounds. Minor cereals and millets can provide dietary fibre, minerals, phenolic compounds, and slowly digestible carbohydrates. Pulses such as horse gram and moth bean provide plant protein, fibre, minerals, and phytochemicals. Indigenous fruits may be particularly rich in vitamin C, carotenoids, anthocyanins, and polyphenols. Leafy plants such as moringa contain proteins, minerals, carotenoids, vitamins, and phenolic compounds and have consequently attracted considerable interest as functional ingredients [2]. Similarly, traditional pseudocereals such as amaranth and buckwheat provide proteins with favourable amino-acid profiles together with flavonoids and other phytochemicals.

Table 1. Selected underutilized plant resources and their functional potential

Plant resource	Important constituents	Potential functional applications
Finger millet	Fibre, calcium, polyphenols	Bakery foods, beverages, breakfast products
Amaranth	Protein, minerals, flavonoids	Protein-rich foods, gluten-free products
Buckwheat	Rutin, fibre, protein	Functional bakery products, beverages
Horse gram	Protein, fibre, phenolics	Snacks, pulses, protein formulations
Moringa leaves	Protein, carotenoids, minerals, polyphenols	Powders, beverages, supplements
Jackfruit	Fibre, carotenoids, phenolics	Flour, snacks, functional foods
Baobab fruit	Vitamin C, fibre, polyphenols	Beverages, nutritional formulations
Lotus seeds	Protein, starch, minerals	Snacks and functional flour

The health-promoting potential of these plants is generally associated with their antioxidant, anti-inflammatory, hypoglycaemic, hypolipidemic, and gastrointestinal effects. However, the biological activity of plant constituents depends on their concentration, chemical form, bioavailability, and interactions with the food matrix.

3. Emerging Approaches for Functional Food Development

3.1 Flour and Powder-Based Products

Drying and milling provide relatively simple methods for converting underutilized plant materials into stable functional ingredients. Leaf powders, fruit powders, seed flours, and millet flours can be incorporated into bakery products, snacks, beverages, soups, and complementary foods. However, high inclusion levels may alter colour, flavour, texture, and consumer acceptance. Optimization of formulation is therefore necessary to achieve nutritional improvement without compromising sensory characteristics.

3.2 Germination and Fermentation

Germination can activate endogenous enzymes and modify the nutritional composition of seeds and grains. It may increase the availability of selected phenolic compounds and vitamins while reducing certain antinutritional factors [3].

Fermentation represents another promising approach. Microbial fermentation can improve digestibility, modify flavour, reduce undesirable compounds, and generate bioactive metabolites. Fermented products derived from traditional cereals and legumes may therefore provide both nutritional and functional advantages.

3.3 Extrusion and Novel Processing

Extrusion can convert underutilized grains and legumes into ready-to-eat snacks, breakfast cereals, and textured products. It offers simultaneous mixing, cooking, shaping, and stabilization. Properly controlled extrusion can improve digestibility and product functionality, although excessive processing temperatures may reduce heat-sensitive nutrients. Encapsulation and advanced drying technologies can further improve the stability of sensitive phytochemicals. These approaches are particularly relevant for incorporating plant extracts into beverages, functional foods, and nutraceutical formulations.

4. Current Trends

One of the major trends in functional food development is the transformation of traditional crops into modern convenience foods. Consumers increasingly seek products that combine nutritional value, natural ingredients, sustainability, and convenience. This has encouraged the development of millet-based snacks, plant protein products, functional beverages, fruit-based powders, and high-fibre bakery products. Another important trend is the utilization of plant-processing residues and traditionally discarded fractions. Seeds, peels, leaves, and stems may contain valuable compounds that can be recovered and incorporated into food formulations. Such approaches support circular food production and can increase the economic value of agricultural resources [4]. The development of gluten-free and plant-based foods has also increased opportunities for underutilized cereals and pseudocereals. Amaranth, buckwheat, quinoa, and millet can provide alternatives to conventional cereal ingredients while contributing additional nutrients and phytochemicals.

5. Challenges

Despite their potential, several factors restrict the large-scale commercialization of underutilized plant-based functional foods. Limited availability of standardized raw materials is a major challenge. Nutrient and phytochemical composition can vary according to genotype, geographical origin, cultivation practices, maturity, and storage. Some underutilized plants also contain antinutritional factors such as phytates, tannins, oxalates, and enzyme inhibitors. Appropriate processing can reduce these compounds, but excessive processing may simultaneously decrease desirable nutrients and phytochemicals. Sensory acceptance is another important limitation. Strong flavours, bitterness, unusual colours, or coarse textures may reduce consumer acceptance. Product formulation must therefore balance nutritional enhancement with taste, appearance, texture, shelf stability, and affordability. Furthermore, many claims regarding the health benefits of underutilized plants are based on laboratory or animal studies. More controlled human studies are required to establish effective intake levels, bioavailability, safety, and clinically relevant outcomes.

6. Future Perspectives

Future development should move from simple incorporation of underutilized plant materials toward scientifically standardized functional ingredients. Modern analytical techniques can assist in identifying key bioactive compounds and monitoring their stability during processing and digestion.

Breeding and biotechnology may also contribute to the development of varieties with improved nutritional characteristics, yield, processing quality, and resistance to environmental stress. Combining traditional knowledge with modern food science could accelerate the development of culturally appropriate functional foods. There is also considerable potential for digital technologies, precision agriculture, green extraction, fermentation, and encapsulation to improve the value chain. Establishing local processing facilities could reduce post-harvest losses while creating employment and income opportunities in rural communities.

7. Conclusion

Underutilized plant resources offer significant opportunities for developing nutritious, functional, and sustainable foods. Traditional cereals, millets, pulses, indigenous fruits, leafy plants, seeds, and pseudocereals provide diverse nutrients and bioactive compounds that can contribute to improved dietary quality. Advances in drying, germination, fermentation, extrusion, extraction, and encapsulation are enabling their conversion into modern functional food products. Nevertheless, greater attention is required to standardization, antinutritional factors, sensory quality, bioavailability, safety, and clinical validation. Integrating underutilized crops into functional food systems can simultaneously support nutritional diversification, biodiversity conservation, rural livelihoods, and sustainable food production.

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