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Biodiversity-Driven Functional Food Innovation: Harnessing Underexplored Native Crops for Human Health

Hirvita Bhatt[1], Abhiraj Malhotra[2], Priyamathi T[3], Shivam Chandra[4], Anusha K[5], Thilagavathi T[6], Nafisa Turaeva[7]

[1]Department of Pharmacognosy, Parul Institute of Pharmacy, Parul University, Vadodara, Gujarat, India, hirvita.bhatt40020@paruluniversity.ac.in
[2]Centre for Research Impact & Outcome, Chitkara University Institute of Engineering and Technology, Chitkara University, Rajpura, Punjab 140401, India, abhiraj.malhotra.orp@chitkara.edu.in
[3]Department of Public Health, School of Allied Health Sciences, VIMS Hospital, Salem Campus, Vinayaka Mission's Research Foundation (DU), Tamil Nadu, India, drpriyamathit@gmail.com
[4]School of Pharmacy and Research, Dev Bhoomi Uttarakhand University, shivamchandra303@gmail.com
[5]Pharmaceutics, Meenakshi College of Pharmacy, Meenakshi Academy of Higher Education and Research, anushakpharmacy@maher.ac.in
[6]Department of Nutrition and Dietetics, Meenakshi College of Arts and Science, Meenakshi Academy of Higher Education and Research, thilaga@maher.ac.in
[7]Department of Pediatrics No. 3 and Medical Genetics, Samarkand State Medical University, Samarkand, Uzbekistan, turayevanafisa444@gmail.com

ABSTRACT: Highly vulnerable to climate change, biodiversity loss, malnutrition, and supply chain disruptions, global food systems rely on a few staple crops. Underexplored native crops such as minor millets, native legumes, pseudocereals, traditional leafy vegetables, roots and tubers, oilseeds and fruits with climate resilience are valuable raw materials for developing sustainable functional foods. The current review discusses the potential of crop biodiversity in functional food innovation and its impact on human health. Native crops are rich in a variety of high-quality proteins, complex carbohydrates, dietary fibre, resistant starch, essential fatty acids, vitamins, minerals, polyphenols, carotenoids, phytosterols, bioactive peptides, and other specialized phytochemicals. These constituents can have antioxidant, anti-inflammatory, antidiabetic, cardioprotective, lipid-regulatory, immunomodulatory, neuroprotective, and gut-microbiome-modulatory effects. Their biological activity is, however, genotype-dependent, culture media-dependent, dependent on maturity, processing, interactions with food matrix, bioaccessibility, and individual host factors.

The nutritional quality, sensory acceptability, stability, safety and bioavailability are expected to be enhanced by conventional and emerging technologies, such as germination, fermentation, extrusion, high-pressure processing, ultrasound-assisted extraction, freeze drying and microencapsulation. Several factors remain to be addressed to expand the use of commercial translation, including limited compositional databases, inconsistent standardization, lack of clinical evidence, poor seed and processing systems, regulatory uncertainty, and low consumer awareness. Future innovations need to combine

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conservation and knowledge of crop varieties, standardized nutritional profiling, sustainable processing, clinical validation, health claims (with responsibility), equitable benefit sharing, and inclusive value chain development. Utilization of under-exploited local crops can diversify nutrition, increase food system resilience, boost rural livelihoods, preserve agrobiodiversity, and facilitate production of functional foods with proven benefits for eating habits and public health, which helps in the prevention of chronic diseases.

1. INTRODUCTION

Food systems around the world rely heavily on a limited range of commodity crops that have the advantage of having short food chains but whose dominance exposes them to climatic risks, pests and diseases, soil erosion and nutritional boredom. Biodiversity in agriculture provides a practical counterweight as diversity among the crops, varieties and production landscapes spreads out ecological risk and also aids in pollination, in soil functioning, in a variety of diets, and with locally adapted livelihoods. Thus, the loss of diversity of crops is not only a conservation issue, but a food system issue associated with food system fragility and missed opportunities for mitigating micronutrient deficiencies. (2) Functional foods represent a key translational link between biodiversity and health, offering physiological benefits beyond nutritional benefits through the naturally occurring or specifically added bioactive compounds in the food. They are becoming increasingly important as diet-related noncommunicable diseases are becoming prevalent alongside undernutrition, and consumers are looking for minimally processed foods that offer scientifically supported health benefits and are culturally relevant. Low-resilient native crops, such as climate-smart fruits and roots, traditional leafy vegetables, indigenous legumes and minor millets, are underutilized and have desirable mixes of fibre, quality protein, minerals, vitamins, essential fatty acids and phytochemicals but are under-researched, underrepresented in formal markets and in dietary guidelines. (5) Reintegration of these crops can also diversify farming and food systems, bolster local value chains and preserve indigenous and farmers' knowledge. Smallholder producers may also gain more flexibility in their choices and reduce external-input reliance due to their local adaptation (6). Figure 1 shows that innovation, based on biodiversity, must be enabled by a seamless pathway from crop identification and participatory cultivation to compositional characterization, safe processing, product development, clinical validation, commercialization, and measurable human-health outcomes. In this review, this pathway is critically explored by summarizing the nutritional and bioactive properties of those underutilized native foods, the potential health effects and mechanisms, the necessary processing technologies, the commercialization possibilities, and the ongoing research gaps. It also highlights the need for innovation to be environment-friendly, culturally appropriate, economically accessible and compliant with access and benefit-sharing principles to make biodiversity a long-term pillar of healthier food systems. (7)

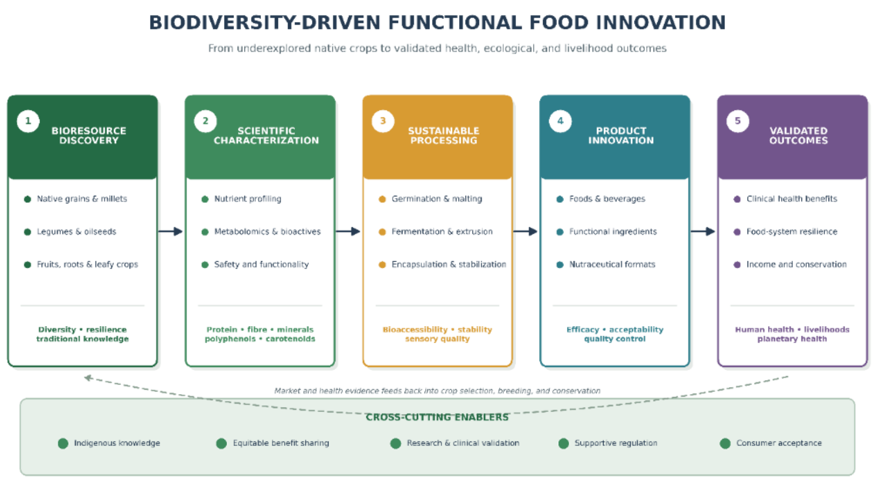

Figure 1. Biodiversity-driven pathway from underexplored native crops to functional foods and improved human health.

2. NUTRITIONAL AND BIOACTIVE POTENTIAL OF UNDEREXPLORED NATIVE CROPS

Underexplored native crops include cereals and pseudocereals which are well adapted to the local environment, pulses, oilseeds, roots and tubers, leafy vegetables, fruits and multipurpose trees that are important but have limited applications in some geographical areas. The distribution of their cultivation is reflective of their long-term association with regional climates and food cultures, with teff and fonio linked to Africa, amaranth and quinoa linked to the Americas, bambara groundnut and African yam bean associated with sub-Saharan Africa, minor millets with South Asia, and breadfruit and many indigenous fruits with tropical island and forest systems. (8) These species are capable of providing protein with desirable amino acid profiles, slowly digestible carbohydrate, resistant starch, dietary fibre, unsaturated lipids, and minerals like iron, zinc, calcium, magnesium and potassium to complement the major staple food crops. (9) Legumes not used to their full potential are particularly rich in protein, fibre, lysine, polyunsaturated fatty acids and phenolic compounds, but may have issues with antinutrients and cooking quality. Indigenous leafy vegetables are often a rich source of provitamin A carotenoids, folate, vitamin C, calcium and iron while coloured grains, fruits and seed coats contain anthocyanins, flavonoids, phenolic acids, tannins and other antioxidants. Other functional constituents include phytosterols, which can inhibit cholesterol absorption in the intestine, bioactive peptides produced during the course of digestion or fermentation, saponins, glucosinolates and molecules with technological value that are particular to each species and are responsible for the aroma or color. Table 1 summarizes the representative crops, origin, nutrients, bioactives and traditional uses. The composition is variable: There may be significant variation depending on genotype, soil, rain, altitude, maturity, season, post-harvest handling, and analytical method. Processing also has mixed effects, either through soaking, germination, fermentation or thermal treatment, phytate, tannins and enzyme inhibitors may be reduced, digestibility may be improved, but excessive heat, oxygen, light and water exposure may degrade the vitamins and phenolics. Therefore, it is important for compositional databases to provide not just a crop name, but the cultivar, location, processing status, and validated processing methods of the crop. The development of a standardized profiling tool which combines proximate composition, metabolomics, bioaccessibility, safety, and sensory characteristics will aid in the identification of promising materials to develop reproducible functionable ingredients from biodiversity. (14)

Table 1. Underexplored native crops, geographical origins, major nutrients, bioactive compounds, and traditional uses.

Crop	Geographical association	Major nutrients	Key bioactives	Traditional use
Finger millet (Eleusine coracana)	East Africa; South Asia	Calcium, fibre, slowly digestible starch	Phenolic acids, tannins	Porridge, flatbread, fermented beverages
Bambara groundnut (Vigna subterranea)	Sub-Saharan Africa	Protein, lysine, fibre, potassium	Flavonoids, phenolic acids	Boiled seeds, flour, snacks, milk analogue
Amaranth (Amaranthus spp.)	Central/South America; Africa; Asia	Quality protein, iron, magnesium, fibre	Squalene, rutin, betalains	Popped grain, porridge, leafy vegetable
Fonio (Digitaria spp.)	West Africa	Starch, sulfur amino acids, minerals	Phenolic compounds	Couscous, porridge, beverages
Baobab (Adansonia digitata)	Sub-Saharan Africa	Vitamin C, calcium, soluble fibre	Procyanidins, flavonols	Drinks, sauces, fruit powder
Breadfruit (Artocarpus altilis)	Pacific and tropical regions	Complex carbohydrate, fibre, potassium	Carotenoids, phenolics	Roasted, boiled, flour-based foods

Crop	Geographical association	Major nutrients	Key bioactives	Traditional use
Moringa leaves (Moringa oleifera)	South Asia; Africa	Protein, provitamin A, iron, calcium	Quercetin, chlorogenic acid, glucosinolates	Leaf vegetable, soups, powdered fortificant

3. HEALTH-PROMOTING PROPERTIES AND MECHANISMS OF ACTION

The health benefits of native foods are not from individual "miracle" compounds but from the interaction of food matrices, and intended effects should be extrapolated from molecular, cellular, animal and human studies. Polyphenols, carotenoids, vitamins and antioxidant enzymes can have a direct role in maintaining redox homeostasis or through the intrinsic defence mechanisms, while flavonoids and phenolic acids may have the ability to modulate inflammatory signalling such as nuclear factor-κB, cyclooxygenases, cytokines and mitogen-activated protein kinases. Fibre, resistant starch, slowly digestible carbohydrate can help to moderate postprandial glycaemia, improve satiety and reduce dietary energy density; legume proteins and bioactive peptides may affect insulin signalling or inhibit the enzyme angiotensin-converting enzyme. A combination of unsaturated fatty acids, phytosterols, soluble fibre and antioxidant components may have a synergistic effect on improving lipid handling, endothelial function and cardiometabolic risk factors. Fermentable carbohydrates also make it to the colon where microbial fermentation to short-chain fatty acids can help maintain the integrity of the epithelium, regulate immunity, and act as a metabolic signalling; however, the microbiome response to these carbohydrates differs by person and food matrix. (18) Other phytochemicals and a variety of other micronutrients could also contribute to immune competence, protection of neurons, and regulation of cell proliferation or apoptosis, and offer mechanistic hypotheses of anticancer activity in experimental systems. As illustrated in Fig. 2, these key compound classes, molecular targets and health domains are converged, encompassing antioxidant, anti-inflammatory, metabolic, vascular, microbial and immune pathways. There is considerable variation in the strength of evidence. Assays in vitro have been used to screen for radical-scavenging capacity or enzyme inhibition, but the concentrations required are not possible to achieve when consumed, animal models provide biological plausibility, but are not likely to reflect human diets and small short-term trials may be able to uncover biomarkers, but cannot provide evidence for disease prevention. Thus, there is a need for whole food interventions, dose–response studies, validated biomarkers, metabolite measurements, and well-powered randomized trials that help answer the question of whether the mechanisms of benefit are associated with clinically meaningful outcomes. Preparation method, background diet, genetic variation, drugs and the presence of potential antinutrients or toxic components should also be considered. A balanced interpretation allows for the recognition of native plants as valuable nutrient sources in diversified food patterns, but does not make any causal claims for which no human evidence exists. (21)

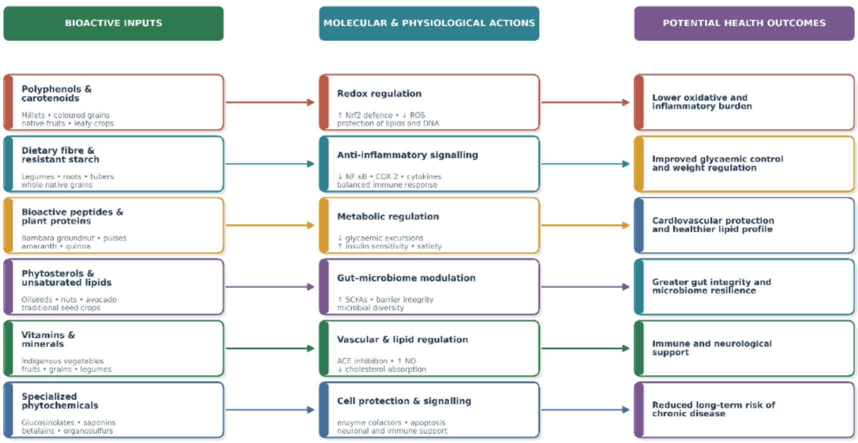

Figure 2. Bioactive compounds from native crops and their mechanisms in preventing chronic diseases.

4. FUNCTIONAL FOOD DEVELOPMENT, PROCESSING, AND COMMERCIALIZATION

The first steps in developing successful functional foods are the selection of the crop that has nutritional potential and is both agronomically suitable and readily available, culturally acceptable, safe, and appealing to local producers. A participatory sourcing and traceable contracts process can help safeguard genetic diversity and traditional knowledge and discourage extractive commercialization. Cleaning, dehulling, milling, soaking, cooking, roasting, germination and fermentation are technologies that, after harvesting, can be considered for improving digestibility and palatability of cereals and reducing the levels of antinutrients, which are still practical in the field of cereal processing. New technologies such as extrusion, high-pressure processing, pulsed electric fields, ultrasound-assisted extraction, freeze drying, and microencapsulation can provide convenient ingredients or protect sensitive ingredients by increasing energy use and cost and may not be applicable on a large scale. (24) Bioavailability is a key design criterion; it is the fraction of the raw crop that reaches the biological target, and is influenced by particle size, food structure, interactions with fats or minerals, gastrointestinal transformation and microbial metabolism. Formulation should therefore be accompanied by compositional analysis, followed by simulated digestion and stability testing, followed, if appropriate, by pharmacokinetics/human bioavailability testing. Representative product concepts, processing routes, functional attributes and commercialization considerations are presented in Table 2. Sensory acceptance is also a key determinant for repeat purchase: colour, flavour, texture, familiarity, ease of preparation, price and credible communication are more important than laboratory antioxidant measurements. Allergens, microbial hazards, mycotoxins, pesticide residues, heavy metals, natural toxins, antinutrients, adulteration and batch variability, and appropriate serving levels are all related to safety and quality systems. (27) Regulatory positioning ought to differentiate between ordinary foods, novel foods, supplements and foods with nutrition or health claims, and evidence commensurate with the claim, while labelling is not misleading consumers. For commercial expansion, there is a need for the creation of seed systems, the training of farmers, aggregation, seed storage, processing facilities, standards, intellectual property and benefit-sharing agreements, and market development which does not lead to the elimination of local food systems and the replacement of diversified local food crops with a single popular export crop. A responsible innovation model thus connects technical possibilities with life-cycle considerations, cost, gender considerations, livelihood and conservation incentives. In alignment, these components can transform unexploited crops into regionally scaled functional foods, while retaining the ecological and cultural diversity that gave rise to them. (28)

Table 2. Functional food products developed from underexplored native crops, processing methods, health benefits, and commercialization status.

Crop/ingredient	Functional-food concept	Processing approach	Targeted attribute	Commercialization consideration
Finger millet	High-fibre breakfast cereal	Malting and extrusion	Mineral-rich, lower glycaemic cereal	Control tannins; optimize crispness and flavour
Bambara groundnut	Protein beverage or snack	Soaking, fermentation, wet milling	Plant protein, fibre, satiety	Improve solubility; manage beany flavour
Amaranth	Popped cereal and composite flour	Popping, milling, sourdough fermentation	Protein quality, minerals, gluten-free positioning	Validate gluten controls and shelf stability
Baobab pulp	Synbiotic drink or fruit powder	Low-temperature drying, encapsulation	Vitamin C, polyphenols, prebiotic fibre	Moisture control and regulatory claim substantiation
Breadfruit	Gluten-free flour products	Drying, milling, baking/extrusion	Resistant starch and local staple diversification	Seasonal supply, browning, texture standardization

Crop/ingredient	Functional-food concept	Processing approach	Targeted attribute	Commercialization consideration
Moringa leaf	Fortified soup, pasta, or snack	Blanching, drying, micronization	Micronutrients and antioxidant compounds	Dose optimization for colour, bitterness, and safety

5. CHALLENGES, FUTURE PERSPECTIVES, AND CONCLUSION

The germplasm records are fragmentary, the nomenclature is inconsistent, seed availability is low, there are variable yields and limited mechanization, poor post-harvest systems, and inadequate compositional and toxicological data. While climate resilience is often claimed for native crops, performance needs to be measured for each location, each management system and each climate scenario; it is not sufficient to base climate resilience on the traditional persistence of the crop. (30) Diversity will live long when it is useful for those who have it, and conservation strategies should include gene banks, on-farm cultivation, community networks of seeds, culinary use and inter-generational transmission of indigenous knowledge. Future studies should aim to create harmonized food composition data, validate cultivars, use omics tools, compare processing techniques, assess bio accessibility and perform well-designed human trials with standardized foods and clinically relevant endpoints. Shared processing facilities, inclusive finance, public procurement, claims transparency, farmer–researcher–industry partnerships and fair access-and-benefit-sharing mechanisms should be supported by innovation policies. Consumer research is also required to understand the impact of taste, convenience, place of origin, sustainable labels, and culturally meaningful stories on the adoption of indigenous foods without a nostalgic exoticism. In conclusion, underexplored native crops offer a viable pathway to provide a credible platform for diversifying diets, enhancing climate resilience, adding rural value and creating functional foods, provided that there is strong evidence and appropriate governance. Innovation based on biodiversity must be focused on the quality, safety, economic sustainability, environmental boundaries and community ownership of whole foods and not on the isolation of a single commercializable component of a complex biocultural resource. Strategic investments in conservation, agriculture, food science, nutrition, clinical research, regulation and enterprise can make crop health innovations, and ensure that the knowledge and ecosystems that allow crops to thrive in the future. (35)

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REFERENCES

[1] Food and Agriculture Organization of the United Nations. The state of the world's biodiversity for food and agriculture. Rome: FAO; 2019.

[2] Khoury CK, Bjorkman AD, Dempewolf H, Ramirez-Villegas J, Guarino L, Jarvis A, et al. Increasing homogeneity in global food supplies and the implications for food security. Proc Natl Acad Sci U S A. 2014;111(11):4001-6.

[3] Granato D, Barba FJ, Bursać Kovačević D, Lorenzo JM, Cruz AG, Putnik P. Functional foods: product development, technological trends, efficacy testing, and safety. Annu Rev Food Sci Technol. 2020;11:93-118.

[4] Grosso G. Nutrition and aging: is there a link to cognitive health? Int J Food Sci Nutr. 2021;72(3):265-79.

[5] Knez M, Ranić M, Gurinović M. Underutilized plants increase biodiversity, improve food and nutrition security, reduce malnutrition and enhance human health and well-being: let's put them back on the plate! Nutr Rev. 2024;82(9):1111-24.

[6] Hunter D, Borelli T, Beltrame DMO, Oliveira CNS, Coradin L, Wasike VW, et al. The potential of neglected and underutilized species for improving diets and nutrition. Planta. 2019;250(3):709-29.

[7] Convention on Biological Diversity. Nagoya Protocol on access to genetic resources and the fair and equitable sharing of benefits arising from their utilization. Montreal: Secretariat of the Convention on Biological Diversity; 2011.

[8] Tadele Z. Orphan crops: their importance and the urgency of improvement. Planta. 2019;250(3):677-94.

[9] Mabhaudhi T, Chimonyo VGP, Hlahla S, Massawe F, Mayes S, Nhamo L, et al. Prospects of orphan crops in climate change. Planta. 2019;250(3):695-708.

[10] Popoola JO, Aworunse OS, Ojuederie OB, Adewale BD, Ajani OC, Oyatomi OA, et al. Nutritional, functional, and bioactive properties of African underutilized legumes. Front Plant Sci. 2023;14:1113894.
[11] Mungofa N, Malongane F, Tabit FT. Prospective role of indigenous leafy vegetables as functional foods. Food Res Int. 2022;157:111346.
[12] Stadlmayr B, Charrondiere UR, Eisenwagen S, Jamnadass R, Kehlenbeck K. Nutrient composition of selected indigenous fruits from sub-Saharan Africa. J Sci Food Agric. 2013;93(11):2627-36.
[13] Samtiya M, Aluko RE, Dhewa T. Plant food anti-nutritional factors and their reduction strategies: an overview. Food Prod Process Nutr. 2020;2:6.
[14] Food and Agriculture Organization of the United Nations. Guidelines on assessing biodiverse foods in dietary intake surveys. Rome: FAO; 2017.
[15] Cory H, Passarelli S, Szeto J, Tamez M, Mattei J. The role of polyphenols in human health and food systems: a mini-review. Front Nutr. 2018;5:87.
[16] Liu RH. Health-promoting components of fruits and vegetables in the diet. Adv Nutr. 2013;4(3):384S-92S.
[17] Trautwein EA, McKay S. The role of specific components of a plant-based diet in management of dyslipidemia and cardiovascular risk. Nutrients. 2020;12(9):2671.
[18] Makki K, Deehan EC, Walter J, Bäckhed F. The impact of dietary fiber on gut microbiota in host health and disease. Cell Host Microbe. 2018;23(6):705-15.
[19] Grosso G, Godos J, Lamuela-Raventos R, Ray S, Micek A, Pajak A, et al. A comprehensive meta-analysis on dietary flavonoid and lignan intake and cancer risk. Mol Nutr Food Res. 2017;61(9):1600930.
[20] Williamson G, Holst B. Dietary reference intake concepts for bioactives: case study of flavan-3-ols. Adv Nutr. 2008;9(4):544-52.
[21] Santini A, Cammarata SM, Capone G, Ianaro A, Tenore GC, Pani L, et al. Nutraceuticals: opening the debate for a regulatory framework. Br J Clin Pharmacol. 2018;84(4):659-72.
[22] Padulosi S, Thompson J, Rudebjer P. Fighting poverty, hunger and malnutrition with neglected and underutilized species: needs, challenges and the way forward. Rome: Bioversity International; 2013.
[23] Hotz C, Gibson RS. Traditional food-processing and preparation practices to enhance the bioavailability of micronutrients in plant-based diets. J Nutr. 2007;137(4):1097-100.
[24] Barba FJ, Terefe NS, Buckow R, Knorr D, Orlien V. New opportunities and perspectives of high pressure treatment to improve health and safety attributes of foods. Food Res Int. 2015;77:725-42.
[25] Carbonell-Capella JM, Buniowska M, Barba FJ, Esteve MJ, Frígola A. Analytical methods for determining bioavailability and bioaccessibility of bioactive compounds from fruits and vegetables. Compr Rev Food Sci Food Saf. 2014;13(2):155-71.
[26] Tuorila H, Hartmann C. Consumer responses to novel and unfamiliar foods. Curr Opin Food Sci. 2020;33:1-8.
[27] Food and Agriculture Organization of the United Nations, World Health Organization. General principles of food hygiene CXC 1-1969. Rome: FAO; 2022.
[28] Mabhaudhi T, Chimonyo VGP, Hlahla S, Chibarabada TP, Modi AT. Developing a roadmap for improving neglected and underutilized crops: a case study of South Africa. Front Plant Sci. 2017;8:2143.
[29] Mudau FN, Chimonyo VGP, Modi AT, Mabhaudhi T. Neglected and underutilised crops: a systematic review of their conservation and utilization in South Africa. Sustainability. 2022;14(3):1720.
[30] Ndlovu M, Scheelbeek P, Ngidi M, Mabhaudhi T. Underutilized crops for diverse, resilient and healthy agri-food systems: a systematic review. Front Sustain Food Syst. 2024;8:1498402.
[31] Ebert AW. Potential of underutilized traditional vegetables and legume crops to contribute to food and nutritional security, income and more sustainable production systems. Sustainability. 2014;6(1):319-35.
[32] Ali A, Choudhary MI, Raza A, Khan IA. Nutrition security, constraints and agro-diversification through underutilized crops. Front Nutr. 2023;10:1144439.
[33] High Level Panel of Experts on Food Security and Nutrition. Nutrition and food systems. Rome: Committee on World Food Security; 2017.
[34] Burlingame B, Dernini S, editors. Sustainable diets and biodiversity: directions and solutions for policy, research and action. Rome: FAO; 2012.

[35] Purba NH, Petrus H, Setyaningsih W. Exploring the potentials of neglected and underutilized crops for food and nutrition security. NPJ Sci Food. 2025;9:129.