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Editorial

Functional foods and their role in diabetes

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Diabetes mellitus (DM) has emerged as one of the most pressing global health challenges of the 21st century. This chronic metabolic disorder is increasingly prevalent, particularly in low- and middle-income countries, with India among the most affected. As per recent estimates, approximately 588.7 million individuals worldwide live with diabetes, and this number is projected to rise to 852.5 million by 2050. The International Diabetes Federation (IDF) reports that nearly 11.1% of adults aged 20 to 79 are affected by the condition.[1] Factors such as rapid urbanization, aging populations, sedentary lifestyles, smoking, and poor dietary habits have contributed to escalating rates of obesity and diabetes across both developed and developing nations.[2]

Functional foods refer to natural or processed food products that contain biologically active substances—whether currently identified or not—that, when consumed in appropriate, safe, and practical amounts, offer proven health advantages.[3] Such foods may originate from either plant or animal sources and can also include processed foods enriched with beneficial compounds. These additions may include prebiotics, probiotics, symbiotic, polyunsaturated fatty acids (PUFAs), essential fatty acids (EFAs), vitamins, minerals, amino acids, and proteins. Moreover, many functional foods are rich in phytochemicals such as flavonoids, polyphenols, phenolic acids, phytosterols, and both nutrient and non-nutrient antioxidants.[4] Depending on their active components, functional foods may support various physiological functions. They may help combat oxidative stress, lower inflammation, enhance insulin sensitivity, reduce glucose absorption, support insulin secretion, and improve lipid metabolism.[5,6] These include whole grains, legumes, spices, vegetables, fruits, fermented foods, and food-derived bioactive compounds that can positively influence metabolic pathways. Their integration into daily diets—particularly in culturally appropriate ways—offers a sustainable, low-cost, and accessible means of supporting diabetes prevention and control.

Whole grains, such as brown rice, oats, millet, barley, and quinoa, are rich sources of fibre, antioxidants, vitamins, minerals, and bioactive phytochemicals like carotenoids and phenolic compounds. These constituents have been shown to play a pivotal role in modulating postprandial glycaemic responses and enhancing insulin action.[7] Studies suggest that a higher intake of whole grains is associated with a significantly reduced risk of developing type 2 diabetes mellitus (T2DM).[8] Oats, in particular, contain β-glucan, a soluble fibre that lowers fasting blood glucose and glycosylated haemoglobin (HbA1c) levels in individuals with T2DM. Regular consumption of oats improves insulin sensitivity and reduces markers of inflammation.[9] In India, traditional grains like pearl millet and finger millet also hold promise. These grains are high in dietary fibre and resistant starch, which modulate glucose absorption, reduce glycaemic load, and support gut health. Encouraging their use in daily diets—especially as a replacement for refined grains—can have a meaningful impact on glycaemic control at the population level.[10]

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Legumes—including lentils, chickpeas, kidney beans, black beans, and soybeans—are low-glycaemic foods packed with plant-based protein, fibre, and polyphenols. These bioactive compounds offer anti-diabetic, hypolipidemic, and anti-inflammatory benefits. Studies show that legumes reduce fasting blood glucose, improve insulin secretion, and lower cardiovascular risk. Peptides derived from legumes, such as aglycin and vglycin, are known to exert insulin-mimetic effects, regulate key signalling pathways like PI3K/Akt, and support β-cell preservation.[11] For example, chickpeas have demonstrated the ability to lower postprandial glucose and suppress appetite, aiding in weight and glucose regulation.[12] Similarly, black bean peel extract has been found to alleviate oxidative stress and modulate lipid metabolism via hepatic gene regulation.[13] Incorporating legumes into traditional Indian meals, such as dals and curries, aligns with both cultural preferences and nutritional goals, making them an ideal functional component in diabetes dietary planning.

Garlic (*Allium sativum L.*), a widely used culinary spice, offers multiple health benefits owing to its rich content of bioactive compounds such as allicin, alliin, various organosulfur compounds (e.g., diallyl sulfide, trisulfide), saponins, and phenolics. Both raw and processed forms of garlic have been shown to help lower blood glucose levels and positively influence lipid profiles by reducing total cholesterol and Low Density Lipoprotein (LDL) cholesterol, while potentially improving High Density Lipoprotein (HDL) cholesterol levels.[14] Several plant-based foods also exhibit hypoglycemic properties. Curry leaves (*Murraya koenigii*) are rich in polyphenols, alkaloids, and flavonoids like *mahanine* and *girinimbine*, contributing to their antidiabetic potential.[15] Drumstick leaves (*Moringa oleifera*) contain potent antioxidants such as beta-carotene, chlorogenic acid, and epigallocatechin gallate, along with flavonoids and saponins that support glucose regulation.[16] Bael leaves (*Aegle marmelos*) offer additional benefits due to their alkaloids, terpenoids, and coumarins.[17] Mulberry leaf extract has shown promise in helping manage post-meal blood glucose in T2DM individuals.[18] Nuts like almonds, pistachios, walnuts, and hazelnuts are considered functional foods due to their dense nutrient profile. They are rich in high-quality proteins, unsaturated fatty acids, fibre, phytosterols, polyphenols, and antioxidant vitamins such as tocopherols. Their cardioprotective and anti-inflammatory effects are largely attributed to compounds like α- and γ-tocopherol, ellagic acid, oleic acid, α-linolenic acid, and magnesium.[19]

Indian kitchens are abundant in spices and condiments that not only add flavour but also deliver potent health benefits. Turmeric (Haldi), cinnamon (Dalchini), fenugreek (Methi), ginger (Adrak), Indian gooseberry (Amla), and bitter gourd (Karela) are examples of everyday culinary ingredients with scientifically validated anti-diabetic properties. Turmeric contains curcumin, which reduces inflammation, regulates blood sugar, and improves insulin sensitivity. Cinnamon has been shown to lower fasting glucose and improve lipid profiles by enhancing insulin receptor function and promoting GLUT4 expression. Fenugreek seeds are rich in soluble fiber and 4-hydroxyisoleucine, which support insulin secretion and glycaemic control. Bitter gourd, a staple in Indian cuisine, contains polypeptide-p and charantin, compounds that mimic insulin action. These ingredients also exhibit antioxidant and anti-inflammatory effects, helping to mitigate complications such as neuropathy and nephropathy.[20,21] Encouraging the use of these traditional spices within a structured dietary plan can enhance adherence and health outcomes.

Food Protein Derivatives (FPDs, including peptides and hydrolysates derived from food proteins) are gaining attention for their therapeutic potential. These bioactive compounds exhibit anti-diabetic properties by inhibiting carbohydrate-digesting enzymes such as α-glucosidase and DPP-IV, enhancing glucose uptake, and improving insulin signalling. Legume-derived peptides, in particular, are being studied for their ability to modulate glucose homeostasis.[22,23]

Artificial intelligence (AI) is revolutionizing nutritional science by enabling precision medicine approaches in diabetes care. AI can analyse genetic, metabolic, and microbiome data to tailor personalized dietary interventions. In the context of functional foods, AI is being used to identify novel bioactive peptides, predict their metabolic effects, and simulate their interaction with human enzymes and receptors.[24,25] Furthermore, AI-driven digital health platforms can aid in dietary tracking, glycaemic monitoring, and behaviour modification, reinforcing long-term adherence to functional food-based diets.

Integrating functional foods into diabetes care requires a multi-pronged approach:

1. Cultural Relevance: Encourage use of locally available and culturally accepted foods such as millets, pulses, and spices.
2. Clinical Evidence: Promote more randomized controlled trials to validate efficacy, safety, and mechanisms of functional food components.
3. Dietary Counselling: Nutritionists should guide individuals on how to incorporate fibre-rich, antioxidant-loaded, and low-glycaemic foods into balanced meal plans.
4. Policy Support: Governments and food industries must collaborate to promote labelling, subsidies, and education programs that make healthy foods more accessible.
5. Technology Integration: Utilize AI and digital tools to personalize and monitor dietary interventions.

The global burden of diabetes is rising, especially in economically transitioning nations like India. While pharmacological therapies remain essential, they are not without risks and limitations. Functional foods and their derivatives represent a promising adjunct strategy for preventing and managing diabetes. A combined effort involving healthcare providers, nutritionists, researchers, and policymakers is necessary to integrate these approaches into mainstream diabetes care. As we look toward a future of personalized and preventive medicine, functional foods may serve not only as nourishment but also as tools for healing.

1. Conflict of Interest

None.

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