Türk Bilimsel Derlemeler Dergisi
E-ISSN: 2146-0132 18(2): 69-87, 2025
Derleme Makalesi

FUNCTIONAL NUTRITION IN TYPE 1 DIABETES AND ITS IMPORTANCE FOR HEALTH

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(Received 4th November 2025; accepted 22nd December 2025)

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ABSTRACT. In this review, we investigated the influence of the consumption of functional foods on health in people with Type 1 diabetes (T1D). Functional foods are inclusive of different fruits, vegetables, and plant-based foods that contain phytochemicals, including lycopene, β-carotene, flavonoids, anthocyanins, sulforaphane, capsaicin, and hesperidin. The antioxidant, anti-inflammatory, and metabolic regulatory properties attributed to these bioactive compounds may help decrease oxidative stress, promote vascular health, attenuate postprandial glycemic responses, and promote metabolism in T1D. Based on the literature, functional foods are not used as an alternative to insulin therapy, but they hold supportive potential to glycemic control. Due to the wide breadth of functional foods, this review will prioritize foods typically consumed along with bioactive compounds. However, given there may be individual differences in response to functional foods, their use in a diet should be assessed as an inclusion while working with healthcare providers, including physicians and dietitians.

Keywords: *Type 1 diabetes, functional food, antioxidant, healthy living*

TİP 1 DİYABETTE FONKSİYONEL BESLENME VE SAĞLIK İÇİN ÖNEMİ

ÖZET. Bu derleme çalışmasında, fonksiyonel gıda tüketiminin Tip 1 diyabetli bireylerde sağlık üzerine etkileri ele alınmıştır. Fonksiyonel gıdalar arasında likopen, β-karoten, flavonoidler, antosiyaninler, sülforafan, kapsaisin ve hesperidin gibi fitokimyasalları içeren çeşitli meyve, sebze ve bitkisel ürünler yer almaktadır. Bu bileşenlerin antioksidan, antiinflamatuvar ve metabolik düzenleyici etkileri, T1D'de oksidatif stresin azalmasına, damar fonksiyonlarının desteklenmesine, postprandiyal glisemik yanıtın iyileştirilmesine ve genel metabolik sağlığın korunmasına katkı sağlayabilir. Literatür taramalarına göre; fonksiyonel gıdalar insülin tedavisinin yerini almamakla birlikte, tedaviye yardımcı bir unsur olarak glisemik kontrolün desteklenmesinde önemli bir potansiyel taşıdığını göstermektedir. Fonksiyonel gıdaların oldukça geniş bir yelpazeye sahip olması nedeniyle, derleme çalışmasında toplumda yaygın olarak tüketilen besinler ve bunların içerdiği biyoaktif bileşenler üzerinde durulmuştur. Bununla birlikte, bireysel metabolik yanıt farklılıkları göz önünde bulundurularak fonksiyonel gıda tüketiminin doktor-diyetisyen eşliğinde değerlendirilmesi gerekmektedir.

Anahtar Kelimeler: *Tip 1 diyabet, fonksiyonel gıda, antioksidan, sağlıklı yaşam*

INTRODUCTION

Diabetes is a long-term metabolic disorder that occurs when an individual with diabetes has a diminished secretion of insulin by the pancreas or is unable to utilize the generated insulin properly [1]. Clinical and experimental studies indicate that in Type 1 diabetes, elevated blood glucose levels and hyperlipidemia along with decreased antioxidant defense over time can result in substantial organ damage [1-5]. The incidence of type 1 diabetes (T1D) is increasing approximately 3-5% annually, and it is estimated that 8.4 million people lived with T1D worldwide in 2021. Of those, 1.5 million (18%) were under 20 years of age, 5.4 million (64%) were from 20–59 years of age, and 1.6 million (19%) were aged 60 years and older [4].

In Türkiye, while there is no precise and dependable data for the number of people living with T1D for the year 2025, reports, studies, and official documents regarding children and adolescents indicate that there are likely between 60,000–130,000 people at that age from T1D; however, the overall total is higher, including adults. Looking back on the past to medical health today, including nutrition and dietary approaches, it is clear that both significant changes and new approaches are being implemented in the nutritional management of people living with diabetes [6,7]. For example, in the 20th century, healthy meal planning was emphasized in the nutrition of individuals with Type 1 diabetes. These plans typically included fixed or limited amounts of carbohydrates (CHO) at each meal and snack, structured according to the patient's eating habits but generally based on strict dietary programs. However, such rigid dietary regimens were found to be intimidating or monotonous for some T1D patients, and adherence was often poor. In later years, toward the end of the 20th century, functional insulin therapy (FIT) emerged as a highly applicable and flexible alternative to traditional approaches. In this method, meal composition—particularly the amount of carbohydrates—glycemic response, and administered insulin doses were evaluated, after which an individualized insulin-to-carbohydrate ratio was established. This ratio was expressed as the number of insulin units required per 10 g of carbohydrate (e.g., 0.8 IU/10 g) or the amount of carbohydrate covered by 1 unit of insulin (e.g., 1 IU/7 g) [8]. This method not only allowed for dietary flexibility but also enhanced quality of life and led to beneficial changes in diabetes-related parameters [9]. Another recently developed approach for T1D management is the Dose Adjustment for Normal Eating (DAFNE) program [10]. However, flexible dietary approaches require a certain level of self-discipline, and sustaining long-term adherence can be difficult for people with T1D who carry a significant burden in their daily lives. Furthermore, there is no guarantee that these strategies will achieve sustainable positive outcomes, as they depend on sustained individual efforts [11]. For people with diabetes, nutritional recommendations often focus on counting carbohydrates, because correcting postprandial glycemia relies on the patient's insulin-to-carbohydrate ratio. This could shift healthy eating to a secondary goal and in fact may have a negative impact on postprandial glycemic regulation [12,13].

Hybrid closed-loop insulin pumps were recently developed and made available to persons with T1D. These devices allow for increased flexibility, while both reducing risk for hypoglycemia [14]. Nevertheless, persons wearing these pumps still must pay very close attention to their daily dietary habits. Healthy dietary patterns for T1D not only may help reduce the risk for cardiovascular disease (CVD), but healthy dietary patterns are considered a viable intervention strategy for post-prandial glycemic control [13,15,16].

The American Diabetes Association (ADA) recommendations published in 2021 emphasizes macronutrient ratios should be individualized after thoroughly evaluating person's ususal dietary habit and personal preferences (cultural background, religious beliefs, tradition, health beliefs, goals, and financial condition) along with metabolic goals [17]. The recommendations published by ADA in 2014 were, again, puts it with great brevity, that "there is no ideal percentage of carbohydrates for all persons with diabetes" [18]. This remained the case in the 2019 ADA recommendations [19]. Yet, it was written in the ADA Standards of Medical Care in Diabetes (2018 carbohydrates should contribute 45-60% of total energy intake [20].

In contrast, the International Society for Pediatric and Adolescent Diabetes (ISPAD) guidelines recommend carbohydrates to provide 40–50% of total energy intake in both the 2022 and 2018 guideline editions and 50–55% in the 2014 guidelines [21–23]. Further, the joint consensus report of the ADA and European Association for the Study of Diabetes (EASD) has noted that the low-carbohydrate and very-low-carbohydrate dietary patterns are receiving more attention and could lead to short-term reduction of HbA1c. However, it is noted that these pattern methods should be used in conjunction with healthy eating concepts [24].

FUNCTIONAL NUTRITION IN DIABETES AND ITS IMPORTANCE

Functional nutrition is a sustainable dietary system that transforms various foods into daily applicable and consumable recipes that maximize benefits for both the body and mind, without compromising freshness or intrinsic nutrient quality. This approach is considered part of modern culinary nutrition and functional medicine, and it has been receiving increasing attention as a health-supportive dietary model [25]. The primary objectives of functional nutrition therapy for individuals with diabetes are to improve their quality of life, maintain or enhance their nutritional and physiological health, reduce the risk of both acute and chronic complications associated with diabetes, and provide the therapeutic and supportive interventions they require. Functional nutrition has become particularly relevant in the context of chronic illness, such as diabetes, and the literature indicates that participation in this approach improves studies participants' comfort and well-being.

Functional nutrition standards primarily emphasize the importance of sustaining normoglycemia, optimal blood pressure, healthy body weight, and appropriate lipid profiles in order to achieve normal growth and development, prevent, delay, or slow the onset of complications, and promote an enhanced quality of life.

Functional foods are defined as food products that provide health benefits in addition to basic nutrition, such as reducing the risk of some diseases or aiding in the prevention of various diseases/health conditions [26,27]. The definition of functional foods would not include drugs, capsules, pills, or supplements, but it would include; for example, fruits, vegetables, grains, drinks, and fortified or enriched foods. The key idea of functional foods is foods that contain added; vitamins, minerals, fatty acids, antioxidants, etc. Pribiotics, prebiotics, omega-3 fatty acids, vitamins, and minerals, beta-glucans, beta-carotene and bioactive compounds are some of the usual additives used in functional foods [28,29]. It is very important to point out that the general public confuses "functional foods" with "dietary supplements". The difference is that functional foods are foods that are standard items found in the food supply and can be used as part of a normal diet while dietary supplements come in non-standard forms, such as capsules, powders, drinks, etc. [26,27]. In individuals with diabetes, functional nutrition focuses on carbohydrates, proteins, fats, as well as dietary minerals, fiber-rich foods, and foods high in bioactive compounds [30].

Studies have shown that nutrition therapy improves glycemic control [31], can lower HbA1c levels by approximately 1.0-1.9% [32-34], and, with other aspects of diabetes care, can also elicit additional improvements in clinical and metabolic response [33-37] and lower hospitalization rates [38].

There is no single optimal percentage of calories from carbohydrates, fat, or protein for individuals with type 1 diabetes. However, individual differences should not be overlooked when considering food composition, particularly because high amounts of fat and/or protein can impact glycemic control. This may require some adjustments to insulin dose and/or timing of insulin delivery. Beyond being able to achieve a balanced and controlled intake of macronutrients, the source, naturalness, and overall quality of calories and macronutrients is equally important [18,39,40].

Carbohydrates

Carbohydrates (CHO) generally include carbohydrates derived from “starches and sugars” as well as those derived from “fiber” [41]. The Dietary Reference Intakes (DRIs) specify a Recommended Dietary Allowance (RDA) of at least 130 g/day of available carbohydrates for adult men and women aged 18 years and older, in order to meet the glucose needs of the brain [42]. The DRIs also recommend that a minimum of 45% of total energy intake should come from carbohydrates to limit saturated fat consumption and reduce the risk of chronic diseases [42].

Carbohydrates obtained from low–glycemic index (GI) and high-fiber foods may contribute up to 60% of total energy intake and can improve glycemic and lipid parameters in adults with diabetes [43]. The GI describes the effect of carbohydrate-containing foods on postprandial glucose response, whereas glycemic load (GL) combines the GI value with the amount of carbohydrates in a serving to estimate the overall glycemic impact of the food [15,16].

Evidence regarding the effects of GI and GL in individuals with diabetes is heterogeneous. Some studies have reported that reducing the glycemic load of the diet may lower HbA1c by approximately 0.2–0.5% [44,45]. However, studies lasting longer than 12 weeks indicate that GI or GL have no significant effects on HbA1c independent of weight loss, and findings related to fasting glucose and insulin levels remain inconsistent [20]. Nonetheless, replacing high-GI carbohydrates with low-GI alternatives has been associated with clinically meaningful improvements in glycemic control over periods ranging from 2 weeks to 6 months in individuals with both type 1 and type 2 diabetes [46].

In addition, concerns have been raised regarding the effectiveness of glucagon in the treatment of hypoglycemia among individuals following a low-carbohydrate diet. One study demonstrated that, in individuals with type 1 diabetes using continuous subcutaneous insulin infusion (CSII), the glycemic response to a glucagon bolus was reduced after one week on a low-carbohydrate diet [47,48].

Proteins

Protein is a fundamental structural and functional component of all cells in the body. Consumption of protein from both vegetarian sources and low-fat animal sources, preferably in balanced proportions, is recommended [49]. The 2004 nutrition guidelines of the Diabetes and Nutrition Study Group of the European Association for the Study of Diabetes (EASD) recommend that protein intake for individuals with type 1 and type 2 diabetes should constitute 10–20% of total energy intake. According to the ADA (2004 and 2019), there is no evidence suggesting that protein intake (15–20% of total daily energy) should be altered in individuals with normal renal function. Furthermore, in 2019, the ADA emphasized that higher protein intake should be considered in patients undergoing dialysis due to the high risk of malnutrition in this population [19,50].

According to the DRIs, the Recommended Dietary Allowance (RDA) for protein in adult men and women over 18 years of age is 0.8 g per kilogram of body weight per day [42]. Daily protein consumption equivalent to approximately 15–20% of total energy—usually ranging from 1 to 1.5 g/kg/day—does not require modification in individuals with diabetes [51]. However, in energy-restricted diets, maintaining or, when necessary, increasing protein intake is recommended.

Animal-based protein sources (fish, dairy products, egg whites, poultry, and meat) are considered higher quality because they provide all essential amino acids; however, they also tend to contain higher levels of salt and saturated fat. Consequently, it is suggested to remove skin and visible fat before consumption. Conversely, vegetarian protein sources (those containing soy, beans, and lentils) contain less saturated fat and contain more fiber and complex carbohydrates. Therefore, it is recommended to have protein derived from both vegetarian and low-fat animal sources in roughly equal proportions [52].

Fats

Dietary composition influences glycemic control, but the specific roles of different nutrients, particularly fat intake, remain a matter of debate. While clinical manifestations of cardiovascular disease usually appear in adulthood, vascular damage can begin at an early age in individuals with type 1 diabetes [53]. The Indian Council of Medical Research (ICMR) recommends a fat intake of up to 30% of total daily energy intake. A study by Mackey et al. (2018) [54] showed that a high-fat diet providing more energy than daily requirements has adverse effects on the metabolic control of diabetes. Currently, most people who strive to reduce their fat intake do not consume enough essential fatty acids (EFAs), which are not produced by the body. In fact, these fats are essential for health. Omega-3 [(n-3)] long-chain polyunsaturated fatty acids (PUFAs), including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are fats with a wide range of health benefits [54,55].

The Diabetes Control and Complications Trial (DCCT) showed that higher HbA1c concentrations were associated with higher intakes of saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs), and total fats [55]. even ıf fats such as epa and dha and pufas are benefıcıal for health, theır consumptıon ratıos are ımportant. Therefore, avoiding excessive or low-quality fat consumption is considered beneficial in preventing complications associated with type 1 diabetes.

Grains and dietary fibers

Dietary fiber consists of non-starch polysaccharides, lignin, and associated plant components, and it cannot be digested by human enzymes. Dietary fibers include those naturally present in commonly consumed foods as well as “novel” fibers synthesized from or extracted as agricultural by-products [56]. According to the Dietary Reference Intakes (DRIs), the Adequate Intake (AI) for total fiber is 25 g/day for women and 38 g/day for men aged 19–50 years; for adults aged ≥51 years, the recommended intake is 21 g/day for women and 30 g/day for men [42]. Although these recommendations do not distinguish fibers based on solubility or viscosity, it has been reported that the most favorable metabolic responses are associated with viscous soluble fibers derived from a variety of plant sources—for example, β-glucan in oats and barley, mucilage in psyllium, glucomannan in konjac mannan, and pectin in legumes, eggplant, okra, and temperate-climate fruits such as apples, citrus fruits, and strawberries.

Viscous soluble fibers slow gastric emptying, thereby delaying glucose absorption in the small intestine, and through this mechanism contribute to improved postprandial glycemic control [57,58]. The high fiber content of rye products reduces the rate of carbohydrate digestion and absorption, while the colonic fermentation of their soluble fibers increases metabolite levels. Studies have shown that biologically active compounds found in rye—such as phenolic acids, tannins, benzoic acid, and phenylalanine derivatives—may exert effects on insulin secretion similar to those of antidiabetic medications [59,60].

Barley and barley-based products are rich in β-glucan, antioxidants, and bioactive compounds, and have demonstrated improvements in glucose tolerance and insulin resistance in prediabetic individuals, as well as hypolipidemic, antioxidant, and anti-inflammatory effects [61]. In diabetic animal models, barley has been shown to improve certain features of fatty liver disease, reduce hepatic lipid content, enhance fatty acid oxidation, and increase adiponectin levels [62,63].

Whole wheat and its derivatives have also been reported to exert multiple beneficial effects on carbohydrate and insulin metabolism. Wheat bran and whole-grain wheat products serve as abundant sources of dietary fiber, phenolic acids, α-tocopherols, carotenoids, and various antioxidant and magnesium (an essential cofactor for enzymes regulating glucose metabolism and insulin release), potassium [64]. The beneficial effects of whole wheat grains are thought to be largely attributable to the bran and germ fractions. In particular, wheat bran—owing to its fiber, lignans, phenolic acids, and alkylresorcinols—not only supports gastrointestinal health and weight management but also has promote better postprandial glucose regulation, HbA1c levels, lipid markers, and additional cardiovascular risk factors in people with diabetes [65].

Research has shown that alkylresorcinol in wheat bran inhibits the activation and aggregation of platelets, lowers de novo triglyceride synthesis, and lowers the risk of cardiovascular disease risk factors [66]. Wheat germ is a remarkable source of indigestible oligosaccharides, phytosterols, benzoquinones, and flavonoids, all of which have significant antioxidant and anti-inflammatory effects and play a role in modulating aspects of the immune system [67]. Avemar, a fermented wheat germ extract, has shown potential for cardiovascular disease management as well as improving metabolic abnormalities including hyperglycemia, lipid peroxidation, and abdominal adiposity [68].

Rice bran is a byproduct of brown rice processing that contains 31% total fiber (mostly insoluble) and is an excellent source of β-glucan, pectin, tocopherols, oryzanol, ferulic acid, lutein, xanthin, vitamin K, thiamine, niacin, pantothenic acid, α-lipoic acid, coenzyme Q10, and many other nutraceutical compounds. In patients with diabetes, rice bran consumption has been shown to reduce levels of glycated hemoglobin, low-density lipoprotein cholesterol (LDL-C), and total cholesterol (TC) while increasing levels of high-density lipoprotein cholesterol (HDL-C) [69,70].

In summary, swapping out refined grains for whole grains and grain-based products when planning meals improves glycemic control and reduces diabetes-related metabolic anomalies, and may help prevent chronic conditions such as cardiovascular disease and atherosclerosis.

Legumes

Legumes such as peas, beans, lentils, and peanuts contain significant levels of dietary protein, resistant non-digestible carbohydrates (including dietary fiber, resistant starches and oligosaccharides), functional fatty acids (such as α-linolenic acid, linoleic acid, etc.), isoflavones (e.g. genistein, daidzein, and glycitein), phenolic acid, phytic acid, saponins, and a number of other bioactive compounds. In addition, legumes contain several polyphenols such as cyanidin, pelargonidin, malvidin and delphinidin [71,72]. Their low glycemic index and high content of fiber and phytochemicals make legumes functional foods particularly suitable for individuals with diabetes [73,74].

As an example, lentils—among the most commonly consumed legumes—contain high levels of dietary fiber, slowly digestible starch, resistant starch, tannins, β-glucan, and various functional antioxidant constituents, along with an extensive range of phenolic acids such as gallic acid, proanthocyanidins, prodelphinidins, catechins, procyanidins, epicatechin, quercetin, kaempferol, sinapic acid, and apigenin [75]. Studies have shown that the bioactive proteins in lentils reduce plasma LDL-C levels and the activity of adipose tissue lipoprotein lipase. Furthermore, lentil polyphenols have been demonstrated to prevent angiotensin II–induced hypertension, vascular remodeling, and pathological changes such as vascular fibrosis [76,77].

Important Minerals in Type 1 Diabetes

Sodium (Na^+)

Individuals with Type 1 diabetes should be cautious about sodium intake and avoid foods high in salt. According to ICMR (2022) and ADA (2019) recommendations, daily sodium intake in adults should be limited to 2300 mg (equivalent to 6.0 g of salt). For children aged 1–3 years, the recommended limit is 1000 mg (2.5 g salt); for those aged 4–8 years, 1200 mg (3 g salt); and for children and adolescents aged 9 years and older, 1500 mg (3.8 g salt) [19,52]. Additionally, studies examining urinary sodium excretion in individuals with T1D have shown that very low sodium intake is associated with increased mortality, indicating the need for caution when universally reducing sodium intake to 1500 mg in non-hypertensive diabetic populations [78]. Vitamin and mineral supplements are ineffective unless a deficiency exists, and individuals with diabetes are encouraged to achieve their RDAs through healthy food choices and macronutrient balance.

Magnesium (Mg)

Research indicates that levels of magnesium are frequently low in those with T1D [79]. It appears that magnesium enhances insulin sensitivity and alleviates oxidative stress in T1D. Foods that have a dense amount of magnesium include almonds, cashews, peanuts, spinach, chard, whole grains (oats, brown rice), avocados, and legumes.

Zinc (Zn)

Zinc deficiency has been observed in individuals with T1D. Zinc warrants close monitoring due to its important role in carbohydrate metabolism and insulin activity [80]. Foods recommended to reduce zinc deficiency include meat, eggs, cheese, pumpkin seeds, sesame seeds, beans, lentils, and whole grains.

Chromium (Cr)

Chromium appears to improve insulin action and chromium levels may drop when progression of the metabolic dysregulation worsens in diabetes. While chromium supplementation can be considered when chromium status cannot effectively be identified, caution should be used due to the pro-oxidative properties of copper ions makes it necessary to have reliable measurements of minerals to avoid complications with supplementation [81]. Foods with a lot of chromium include broccoli, grape juice, whole grains, and red meat.

Potassium (K)

In the last 10 years, epidemiological studies have suggested that low potassium intake or low serum potassium are linked with higher insulin resistance and increased risk for developing diabetes, although this needs to be confirmed in larger trials. Outside of reducing sodium intake, increasing potassium intake has the potential to lower blood pressure and perhaps glucose metabolism in people with T1D [82]. Foods especially high in potassium include bananas, avocados, sweet potatoes, spinach, and yogurt.

Calcium (Ca) and Vitamin D

Vitamin D is a fat-soluble steroid and a precursor to human steroid hormones. The Endocrine Practice Guidelines Committee recommends daily vitamin D_3 intake of 400–1000 IU for infants, 600–1000 IU for children and adolescents aged 1–18 years, and 1500–2000 IU for adults [83]. Studies in individuals with T1D have shown significantly lower serum 25 (OH)D levels compared to healthy controls [84]. Another study conducted in Australian children and adolescents also found significantly lower vitamin D levels in those with T1D compared with healthy peers [85]. Calcium and vitamin D are essential for bone health, and due to the increased risk with advancing age, monitoring their intake is important [86]. Calcium can be obtained from a range of dietary sources such as dairy products, almonds, leafy green vegetables, and sardines. Sources of vitamin D include exposure to sunlight, consumption of fatty fish and egg yolks, as well as foods and cereals that have been fortified with this nutrient. Bone health also benefits from regular physical activity, especially for individuals with Type 1 diabetes.

Fruits and Vegetables

Fruits and vegetables provide significant levels of both water-soluble and insoluble fiber, important vitamins, and a variety of phytochemical components, which all have a role in promoting general health and reducing the risk of chronic disease [87]. Eating patterns that prioritize fruits and vegetables are important strategies for managing Type 1 Diabetes and metabolic syndrome and for reducing risk of complications. Numerous studies show that consistent consumption of fruits and vegetables in individuals with diabetes may promote glycemic control indices, reduce HbA1c and triglyceride levels, enhance antioxidant defenses, diminish oxidative stress and inflammatory biomarkers, lower the rate of diabetic retinopathy, and lessen the burden of carotid atherosclerosis [88,89].

Because different fruits and vegetables provide a wide array of micronutrients and bioactive compounds, consumption of a variety of these foods is particularly recommended. It should be noted that the colors of fruits and vegetables reflect their dominant pigment-based phytochemicals, and considering this color diversity provides access to a broader spectrum of nutraceuticals [90,91]. Tomatoes and tomato products are among the primary sources rich in lycopene, β-carotene, flavonoids, and various other bioactive compounds. These components have been reported to reduce blood pressure and dyslipidemia, thereby lowering cardiovascular risk factors and enhancing the body's antioxidant defense capacity [92–94]. Similarly, other lycopene- and carotenoid-containing foods such as watermelon and grapefruit have been shown to beneficially influence lipid and lipoprotein metabolism, blood pressure regulation, and vascular function [95,96].

Fruits that are high in anthocyanins, including red apples, cherries of various kinds, berries, grapes, red cabbage, and pomegranate, have been shown to decrease carbohydrate digestion and absorption, lower post-meal glycemic response, and thereby lower levels of glycated hemoglobin, indicating possible glucose-lowering effects [97–99]. They also provide high anthocyanin content for protection against oxidative stress–mediated cellular damage [97,98].

In addition, functional foods like artichoke (silymarin), orange (hesperidin, tangeretin), onion and garlic (diallyl disulfide), carrot (β-carotene), tea (catechins), red pepper (capsaicin), dark green leafy vegetables (lutein, zeaxanthin), pomegranate (ellagic acid), apple (phloretin), broccoli (sulforaphane), cabbage (indoles), and cauliflower (isothiocyanates) have also been shown to have beneficial effects on blood glucose regulation and antioxidant status in healthy and Type 1 diabetes subjects [97–101].

Nevertheless, it must not be overlooked that the fruits have fructose. While the fruits offer fructose providing additional fiber, vitamins, minerals, and antioxidants, the amount of fruit should still be controlled to meet optimal health.

Nuts

Current scientific evidence suggests that nuts have protective effects on cardiovascular risk factors. Almonds, pistachios, walnuts, and hazelnuts are the most commonly consumed types of nuts, and they are substantial sources of quality proteins, bioactive peptides, healthy fatty acids (monounsaturated and polyunsaturated), dietary fiber, phytosterols, polyphenols, tocopherols, and other antioxidant vitamins [102]. The antioxidant capacity of nuts is largely attributed to their abundant α- and γ-tocopherol levels, phenolic compounds, melatonin, oleic acid and selenium. The anti-inflammatory properties of nuts are due to the presence of ellagic acid, α-linolenic acid, and magnesium.

Moreover, regular nut consumption could aid in weight control, especially in individuals with diabetes. The anti-obesity effects reported in the literature are associated with enhanced thermogenic activity, satisfaction with food, reduced dietary fat absorption, and increased fat loss in the stool. The bioactive constituents in nuts also impact appetite-regulating neurotransmission and adipose tissue metabolism by reducing adipocyte proliferation and differentiation, inhibiting lipogenesis, and stimulating fatty acid β-oxidation [103–105].

Spices

Cinnamon, turmeric, and ginger have anti-inflammatory effects and potentially affect blood glucose regulation, insulin resistance, and immune response. Because their effects may be different for everyone, these widely consumed spices should be used with caution [106,107].

CONCLUSION

A food has to be part of a regular dietary intake but also provide benefits that are evidence-based for it to be defined as "functional." Guidelines on nutrition for individuals with Type 1 diabetes can support dietary compliance and assist healthcare providers—particularly with prescriber and dietitians— in making treatment decisions. As a result of their bioactive components, functional foods can offer a broad range of benefits, but it should be made clear, that they should not replace insulin or other medical treatments. The functional foods highlighted in this review indicate a potential benefit of incorporating these foods into the dietary practices of individuals with Type 1 diabetes.

It can be hypothesized that when used in conjunction with pharmacological management, functional foods may be linked to improved metabolic management high likelihood of improved metabolic control. The impact of functional foods may also differ based on an individual's metabolic responses, allergies, or gluten sensitivity. As a result, these foods should be included in dietary recommendations in partnership with the individual's healthcare provider so that their personal health needs and other medical conditions are taken into consideration.

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