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Diabetes & its Complications

A Current and Futuristic View on Nutrition for the Maintenance of Diabetic Health

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Introduction

The role of diet in the management of diabetes mellitus has been extensively studied over the past decades, with increasing emphasis on the individualization of dietary recommendations and the understanding of cultural and behavioral barriers to dietary adherence. Below, the main points addressed in a representative selection of the literature on the topic are highlighted. Reports ranging from Frank Q. Nuttall, a researcher well known in the field of diabetes and nutrition, to the American Diabetes Association emphasized dietary flexibility and the role of macronutrients in the progression of the disease. One of the main conclusions was that there is no 'ideal' proportion of carbohydrates, proteins, and fats for all individuals with diabetes, and that distribution should be personalized based on metabolic, cultural, and individual preference factors. Nutritional therapy is a central component in the management of both type 1 and type 2 diabetes mellitus. This review explores the evolution of dietary recommendations, practical adherence to nutritional guidance, dietary patterns observed in diabetic populations, and the impacts of specific diets, such as low-carb, Mediterranean, and DASH. The role of micronutrients and the dietary management differences between the two main types of diabetes are also discussed. The authors of this review present suggestions for the exclusion and inclusion of certain food groups, considering that diet is one of the central pillars of glycemic control. Finally, in the basis of future perspective it is proposed by the autor's the inclusion of a differentiated new alimentary group, named, Rindering Food, this will represent a New Paradigm for Functional Nutrition and Planetary Health.

Reports of Difficulties in Dietary Recommendations for Glycemic Control in Diabetic Patients

Reports from the Nutrition Subcommittee of Diabetic Medicine

The 2003 report by the Nutrition Subcommittee of Diabetic Medicine highlighted the practical difficulties in implementing dietary recommendations. Although patients are generally advised to increase their intake of fruits, vegetables, and fiber, actual adherence is often limited by factors such as cost, access, and nutritional literacy. Similarly, the study by Nthangeni et al. identified significant barriers to adherence among Black patients with type 2 diabetes in rural areas of South Africa. Cultural factors, lack of information, and economic challenges were determinants of poor compliance with dietary guidelines.

Reports on Dietary Patterns and Nutritional Behavior

Studies such as those by Albarran et al. and Saaty & Aljadani compared the eating behaviors of diabetic patients with those of healthy individuals. Findings suggest that despite receiving more guidance, diabetic patients still face challenges in daily dietary practices, such as excessive carbohydrate intake or irregular eating patterns. The Spanish study from the Diabetes Nutrition and Complications Trial also revealed that incomplete dietary reporting is common among diabetic patients, which hinders follow-up and nutritional goal adjustments.

Current Recommendations and New Approaches

The review by Gray & Threlkeld offered an updated perspective on low-carbohydrate diets in the management of type 2 diabetes, suggesting they may benefit glycemic control and reduce medication use, although sustainability in the long term remains controversial. Moreover, recent literature has incorporated psychological and social aspects into the nutritional approach, recognizing that the

success of dietary treatment is closely linked to emotional support, continuous food education, and multidisciplinary follow-up.

Type 1 vs. Type 2 Diabetes: Dietary Implications

In type 1 diabetes, the emphasis is on synchronizing food intake with insulin administration to prevent both hypoglycemia and hyperglycemia. Precise carbohydrate counting and knowledge of the glycemic index are key strategies.

In contrast, type 2 diabetes is often associated with obesity and insulin resistance. The dietary approach focuses on weight loss, improving insulin sensitivity, and preventing cardiovascular complications. Caloric moderation of carbohydrates, increased fiber intake, and the selection of complex carbohydrates are essential components of dietary management in these cases.

Current Diets and Clinical Evidence

Low-Carb Diet

Reducing carbohydrate intake (typically below 130 g/day) has shown benefits in glycemic control and lowering glycated hemoglobin (HbA1c) levels in patients with type 2 diabetes. However, its long-term sustainability and renal safety remain debated, as persistently high blood glucose levels can damage kidney blood vessels, impairing proper blood filtration. Author's note: many diabetic individuals are not aware of how to group foods, and thus need clarification on the carbohydrate content across different food categories.

Mediterranean Diet

Rich in olive oil, vegetables, fruits, legumes, whole grains, fish, and nuts, the Mediterranean diet has been shown to reduce cardiovascular risk and improve glycemic control. It is considered one of the most balanced diets with high long-term acceptance. Author's note: while this diet appears more realistic, leafy greens were not included. Dietary fiber plays a fundamental role in managing diabetes by helping control blood glucose levels and improving overall health. Fibers delay sugar absorption, increase satiety, and promote better intestinal function.

DASH Diet

Originally proposed for blood pressure control, the DASH diet (Dietary Approaches to Stop Hypertension) is rich in fruits, vegetables, low-fat dairy, whole grains, and low in sodium. Its antihypertensive and anti-inflammatory effects are particularly beneficial for diabetic patients at elevated cardiovascular risk. Author's note: this diet also seems realistic but again lacks the inclusion of leafy vegetables. Dietary fibers are crucial for diabetes management as they help regulate blood glucose levels, enhance satiety, and support healthy digestion.

Role of Micronutrients and Nutritional Education

Role of Micronutrients

- Deficiencies in certain micronutrients can negatively affect carbohydrate metabolism. Notable examples include:
- Magnesium: essential for insulin action; low levels are associated with insulin resistance.
- Zinc and Chromium: involved in glucose metabolism; may be deficient in some type 2 diabetes patients.
- Vitamin D: low levels have been correlated with increased insulin resistance and risk of complications.

Nonetheless, systematic supplementation is not recommended in the absence of proven deficiencies, as per ADA guidelines.

Nutritional Behavior and Education

Studies such as (4) demonstrate that dietary behavior in diabetic patients is strongly shaped by emotional states, access to reliable information, and the presence of structured educational support. While the inclusion of a multidisciplinary team—comprising nutritionists, psychologists, and diabetes educators—is essential for successful treatment outcomes, this approach alone is insufficient.

Author's note: Standard explanations often lack creativity and fail to address the root problem—patients are rarely taught how to organize food groups or understand the glycemic implications of their daily choices. Nutritionist-prescribed menus are frequently impractical, leading to confusion and requiring nearly daily visits to supermar. Authors'note: a multidisciplinary team is not enough without education on food groups and their content in simple and complex sugars.

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Listing of Food Groups with Usage Suggestions

Cereals

Used in baked goods—pose a risk due to high levels of complex sugars (starch). Commercial sandwich breads sold in Brazil contain large amounts of sugar.

Legumes

Beans, chickpeas, peas—also pose a risk due to high complex carbohydrate (starch) content.

Genuinely Protein-Based Foods

Meat, milk, and eggs do not pose a risk since they are mainly composed of proteins. However, they should not be consumed alongside calcium-rich foods, as calcium inhibits the absorption of heme iron.

Vegetables

Completely safe (e.g., chayote, eggplant, carrot), as long as the intake of foods rich in simple and complex sugars is controlled. May contain some simple sugars (glucose, sucrose, and fructose).

Leafy Greens

Completely safe. Dark green varieties offer therapeutic benefits for

diabetics. These can be cooked and pureed to fully replace beans.

Fruits
Should be consumed with caution due to high levels of simple sugars.

Oilseeds
Nuts, hazelnuts, almonds—permitted. Do not contain starch but are rich in proteins and healthy fats, support glycemic control, and are fiber-rich. Author's note: a mix of these seeds can be added to plant-based creams; people with meat-rich diets may avoid allergenic animal milk.

Processed Foods
Should be completely excluded. They are high in sugar, salt, fats, and additives, which can contribute to weight gain, insulin resistance, and complications with glycemic regulation.

Tubers
Yam and sweet potato are rich in complex carbohydrates but recommended due to their low glycemic index. Sweet potato stands out for its antioxidant properties due to high levels of beta-carotene, flavonoids, and anthocyanins, which reduce the risk of chronic diseases including diabetes [1]. Yam roots contain medicinal molecules like dioscorin and diogestin. Dioscorin is a storage protein representing 80% of yam proteins, with a molecular weight of 32 kDa, potentially containing therapeutic peptide sequences.

Leafy Greens – Superior Functional Fibers
Leafy vegetables (spinach, kale, arugula, etc.) contain digestively tolerable soluble and insoluble fibers, and are a low FODMAP content, and high levels of bioactive compounds (glucosinolates, flavonoids, carotenoids) acting to reduce the body's anti-inflammatory response by restoring the balance of the gut microbiota. When consumed in processed forms (blended, cooked, pureed), their fibers become more accessible to fermentation by beneficial bacteria like Faecalibacterium prausnitzii, Akkermansia muciniphila, and bifidobacteria.

Critical Consideration of the Role of Legumes in Relation to Protein and Complex Carbohydrate Content
Legumes (beans, lentils, chickpeas, peas, soybeans, among others) are traditionally valued as 'dual' foods because they provide significant amounts of complex carbohydrates (mainly starch) and a modest amount of protein when cooked. However, their protein quality is inferior to that of meat due to low levels of the essential amino acid methionine.

Comparison of Legume Proteins with Meat Proteins:

- Legumes contain an average of 20–25g of carbohydrates per 100g cooked, most of which is starch.
- They provide approximately 7–9g of protein per 100g cooked, with low levels of sulfur-containing amino acids (such as methionine) and lower digestibility compared to animal proteins.
- By contrast, 100g of lean meat (chicken or beef) provides 25–30g of high biological value protein, with negligible carbohydrates.

Implications for Patients Who Consume Animal-Based Foods
Considering that genuinely protein-based foods include meat, milk, and eggs, as lean meats, eggs, dairy, legumes are not essential protein sources. In such diets, legumes primarily serve as sources of complex carbohydrates with high fiber content but are inferior in quantity as comparing to cruciferous vegetables, such as • Broccoli, Cauliflower, Cabbage (green and red), Kale (including collard greens), Brussels sprouts as well leafy-vegetables.

Moreover, excessive legume intake can:

- Increase total carbohydrate intake, which may be undesirable in low-glycemic dietary strategies.
- Compromise glycemic control in patients sensitive to starch.

When Are Legumes Particularly Recommended
Legumes are especially beneficial in:

- Vegetarian or vegan diets, where legumes (rich in lysine and low in methionine) are a primary protein source and must be complemented with cereals (rich in methionine and low in lysine).
- Diets with low meat consumption due to cultural, ethical, or economic reasons.
- Diets targeting microbiome modulation benefit from the inclusion of legumes, which are rich in fermentable fibers and prebiotics that support the growth of beneficial gut bacteria.

Critical Considerations: The Role of Legumes, Tubers, and Leafy Vegetables in Diabetic Diets

Are Legumes Really Necessary in Diets with Meat?
Although often recommended as alternative protein sources, legumes have a nutritional composition that warrants reevaluation in certain contexts:

- They are rich in resistant starch and fermentable oligosaccharides (such as raffinose and stachyose), which are part of the FODMAP group—compounds often linked to gas, bloating, and intestinal discomfort.
- Their real ability to positively modulate the gut microbiota is questionable, especially in individuals with dysbiosis, irritable bowel syndrome (IBS), or intestinal sensitivity.
- From a protein standpoint, legumes provide modest and incomplete amounts of protein (6–9g per 100g cooked), with lower digestibility compared to animal-based proteins.

Thus, in diabetic patients who regularly consume meat or dairy, legumes are not an essential food group. Their nutritional value may be overestimated, particularly when the dietary goal is glycemic control and digestive stability.

Leafy Greens: The True Source of Functional Fiber

Leafy vegetables (spinach, kale, lettuce, Swiss chard, arugula, watercress, etc.) are superior sources of:

- Soluble and insoluble fiber, highly digestible and low in FODMAPs.
- Antioxidant and anti-inflammatory compounds, including flavonoids, carotenoids, and glucosinolates.
- Micronutrients that support a healthy microbiota, such as magnesium, potassium, and folic acid.

When consumed in processed forms (e.g., blended soups, green juices with retained fiber, concentrated broths, or finely chopped sautés), these vegetables provide fibers that are more bioavailable for colonic fermentation. This promotes the selective nourishment of beneficial bacterial strains like Faecalibacterium prausnitzii, Akkermansia muciniphila, and even Bifidobacterium.

Replacing Cereals with Low-Glycemic Tubers May Be Advantageous

In people with diabetes, controlling postprandial glycemia is critical. Foods with a low or moderate glycemic index (GI), such as sweet potato and yam, are preferable as they promote a slower glucose release into the bloodstream. In contrast, foods like white rice, white bread, and white potatoes have a higher GI and can trigger sharper glucose spikes.

Therefore, when substituting cereals with tubers, priority should be given to:

- Whole-grain cereals (brown rice, oats, quinoa);
- Low-GI tubers like yam and sweet potato;
- Combining meals with fiber, protein, or healthy fats to modulate glucose absorption.

As energy sources, yam and sweet potato stand out not only for their low glycemic index but also for their medicinal properties. Yam contains the compound diosgenin, which offers health benefits ranging from digestive support and immune function to appetite regulation and cardiovascular health, and even potential cancer treatment [2].

Sweet potato leaves are traditionally used to treat oral infections, inflammation, and type 2 diabetes. Varieties include white, yellow, orange, and purple-fleshed types. Yellow and orange types are high in phenolic acids (e.g., hydroxycinnamic acids) and carotenoids (e.g., β-carotene). Purple-fleshed varieties contain high levels of acylated anthocyanins. These bioactive compounds—flavonoids, phenolic acids, carotenoids, and anthocyanins—exhibit antioxidant, anti-inflammatory, anticancer [3], immunostimulant [4], antidiabetic [5], and hepatoprotective activities.

A Futuristic Perspective: Rindering a Food as a New Paradigm for Functional Nutrition and Planetary Health

In a world facing increasing challenges related to chronic diseases, environmental degradation, and food insecurity, the search for novel, sustainable and health-promoting food sources becomes imperative. Within this context, the introduction of non-vertebrate animal-based foods, such as the larvae of T. molitor (mealworm), represents a ground breaking alternative, for cultural paradigm. Author's propose a designation of such foods as "rendering food"—a futuristic nutritional category that integrates nutritional excellence, metabolic safety, and ecological responsibility, specially to occidental part of the world that are not used to handle to Beyond its Asiatic traditional form of consumption, larvae in the occidental countries, must be served with a sensorial aspect bringing similarity to high cost caviar, as an example. The association of creatively spices associated with technological innovation industrial appreciate to the Brazilian taste. They may be used as a dietary supplement for the elderly, that may be effectively achieved through its incorporation into baked products such as biscuits and bread, utilizing thermally dehydrated larval flour as a functional ingredient. These products should be carefully formulated to meet the nutritional and sensory needs of older adults, potentially empowering them with greater autonomy and reducing dependence on institutionalized care models that often prioritize commercial interests over genuine well-being.

Unlike conventional sources of calcium and protein—especially full-fat dairy products and red meats—Tenebrio molitor offers a composition uniquely suited for modern dietary needs. Diets rich in calcium from dairy may elevate the risk of cardiovascular diseases in both diabetic and non-diabetic individuals due to their typically high content of saturated fats and cholesterol, which contribute to increased LDL cholesterol and the development of atherosclerosis.

In contrast, the larvae of Tenebrio molitor provide a naturally optimized nutritional profile, composed of approximately 60% high-quality protein and 40% beneficial lipids, without the harmful saturated fat load associated with traditional animal products. Moreover, they are notably rich in essential minerals, including:

- Calcium: 80–100 mg/100g (dry basis) – important for bonhealth, nerve conduction, muscle contraction, and blood clotting.
- Iron: 29–35 mg/100g (dry basis) – a crucial micronutrient for oxygen transport and enzymatic activity.

Although iron is indispensable, excessive intake—especially from heme sources like red meat—has been implicated in reduced insulin sensitivity and disruption of glucose homeostasis, posing additional risks for individuals with diabetes. Therefore, the moderation of red meat consumption is advisable not only for diabetic patients but also for the general population.

What distinguishes T. molitor larvae is the absence of these metabolic liabilities, coupled with promising functional benefits. Emerging studies reveal that proteins from these insects can release bioactive peptides with antidiabetic properties, including mechanisms that potentially enhance insulin sensitivity and regulate glycemic response [10,11].

Furthermore, the environmental impact of insect farming is significantly lower compared to conventional livestock, reinforcing its alignment with global sustainability goals.

Moreover, nothing is total defined as related to a solidetaded studies of proteomic in of this organism, that is determinates by as well its numbers of proteins content in the larvea and their chemical and advanced protein characterization,

Author's note: Key Advantages of molitor as Rindering Food: High-quality protein and lipid content, suitable for human metabolic needs.

Rich in calcium and iron, without associated cardiovascular risks;
Free from carbohydrate content, ideal for glycemic control;
Demonstrated antidiabetic peptide activity;

Authors's note: Minimal ecological footprint, suporting sustainable food systems.
In sum, the incorporation of T. molitor into human diets as a new class of rendering food marks a transformative step toward healthier populations and a healthier planet. It offers not only a nutritional revolution but also a cultural shift in how we perceive animal-derived foods, no longer limited to vertebrate sources.

This vision embraces the principles of functional nutrition, metabolic safety, and planetary health, encapsulating the promise of a future where food innovation harmonizes with human physiology and ecological preservation.

Table 1: Iron content in meats and Tenebrio molitor larvae (mg/100g dry basis).

Food	Iron (mg/100g, dry basis)	Comparison with Tenebrio	Reference(s)
Beef liver	40–80 mg	Higher	USDA [9]; Biesalski [10]
Tenebrio molitor larvae	29–35 mg	— Reference —	Bukkens [11]; FAO [12]; Latunde-Dada et al. [13]
Lean beef	20–25 mg	Lower	USDA [9]; Lombardi-Boccia et al. [14]
Lean pork	15–20 mg	Lower	USDA [9]
Fish (tuna, sardine)	10–25 mg	Variable; generally lower	USDA [9]; Lombardi-Boccia et al. [14]
Chicken meat	10–13 mg	Much lower	USDA [9]

Table 2: Global Consumption of Larvae as Alternative Food.

Region / Country	Common Species	Forms of Use / Product
Thailand	Beetle larva, silkworm	Fried, roasted, snacks
China	Beetle larvae, silkworm	Fried, protein flours
South Korea	Fermented larvae (limited)	Condiments, fermented
Vietnam / Laos / Cambodia	Various edible larvae	Fried, cooked
Dem. Rep. of Congo	Moth larvae (Imbrasia belina)	Fried, dried
Cameroon / Zimbabwe	Mopane worms	Dried, grilled
South Africa	Mopane worms	Dried, sold in supermarkets
Mexico	Maguey worms (Aegiale hesperiaris)	Fried, in tacos and traditional dishes
Peru / Ecuador / Colombia	Chontacuro (Rhynchophorus palmarum)	Roasted, grilled, Amazonian traditional
Netherlands / Belgium	Tenebrio molitor (beetle larva)	Protein flour, bars, pasta
France / Switzerland / Denmark	Tenebrio molitor	Snacks, flours, breads
USA / Canada	Tenebrio molitor	Bars, baking flour
Australia	Witchetty grub (moth larva)	Roasted or grilled (aboriginal tradition)

Conclusion

Both type 1 and type 2 diabetes require strict monitoring of the glycemic index of complex carbohydrates. In this work, the authors propose a novel strategy for self-management of caloric and glycemic intake. The futuristic approach involves incorporating Tenebrio molitor larvae into a new food group, emphasizing their lack of carbohydrates—an important factor for individuals with diabetes—while offering high levels of organic macronutrients such as proteins and lipids, which are essential for human maintenance.

In terms of mineral content, Tenebrio molitor larvae surpass beef liver, particularly in calcium levels. Calcium is vital for bone health, nerve transmission, muscle function, and blood clotting. This innovative protein source is gaining regulatory and commercial approval in Europe and North America and has a long-standing cultural acceptance in Asia, Africa, and Latin America. International bodies such as the FAO endorse insects as sustainable alternatives to conventional animal protein sources [12,13,14].

As a technological innovation, the authors suggest developing a functional ice cream made with a low-glycemic fruit and sweet potato base, as source of bioactive compounds. The incorporation of Tenebrio larval flour would enrich the product with high-quality

protein, enhancing both nutritional value and functional properties. This addition is expected to contribute to desirable texture and flavor, potentially achieving favorable sensory acceptance.

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