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Role Of Nutraceuticals

A REVIEW ON THE ROLE OF NUTRACEUTICAL IN MANAGING DIABETES

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ABSTRACT

Hyperglycemia, which results from insufficient insulin production, is a hallmark of diabetes, a chronic illness. Diabetes outcomes have been demonstrated to be improved by nutraceuticals, which are non-specific biological medicines derived from organic materials. These plant-based medications preserve normal cholesterol and blood sugar levels. Due to synthetic medications' inability to satisfy the therapeutic demands for a variety of pathological disorders, the usage of natural products, herbal remedies, and nutraceuticals has increased internationally. Nutraceuticals are well-known for their powerful ability to prevent, treat, and promote health. In recent years, there has been a growth in the use of naturals, nutritionals, and nutraceuticals in worldwide treatments. The therapeutic requirements for diabetes are not sufficiently met by conventional synthetic medications; herbal medications provide superior care with fewer adverse effects. Botanicals, vitamins, minerals, antioxidants, amino acids, and fatty acids are examples of nutraceuticals that support health, stop cancerous processes, and manage symptoms. They provide a variety of therapeutic advantages and have been demonstrated to modulate a number of biochemical and clinical endpoints while focusing on the pathophysiology of diabetes mellitus, metabolic syndrome, and consequences. In traditional medicine, hypoglycemic medications are frequently used to prevent diabetes.

Keywords:- Nutraceuticals, Diabetes Mellitus, Insulin, Phytoconstituents.

INTRODUCTION

The prevalence of metabolic diseases, malignancies, cardiovascular ailments, and mental illnesses has grown due to the industrial age, fast-paced lifestyle, long workdays, mental obstacles, and detachment from natural resources. Insulin resistance, impaired insulin signaling, abnormal sugar and lipid metabolism, subclinical inflammatory processes, and high oxidative load levels are the hallmarks of diabetes mellitus (DM), a serious health issue. Globally, 537 million people are impacted, and by 2040, that number is expected to rise to 640 million. In addition to microvascular problems including diabetes, nephropathy, and retinopathy, symptoms include elevated blood pressure, blood sugar, and cholesterol levels. Because of its efficacy, affordability, and absence of adverse effects, people are becoming more and more interested in dietary supplements, nutritional therapy, phytotherapy, and nutraceuticals. It is essential to do research on traditional medicinal herbs made from common plants in order to preserve health and fighting DM. Obesity, sedentary lifestyles, and urbanization have all contributed to the

worldwide health catastrophe of diabetes mellitus, a chronic metabolic disease marked by persistent hyperglycemia. Type 2 diabetes, which makes up the majority of cases, is mainly caused by insulin resistance and increasing beta-cell malfunction. Type 1 diabetes is an autoimmune illness in which the pancreas is unable to generate insulin. Through processes like boosting antioxidant defenses, controlling glucose metabolism, improving insulin sensitivity, and modifying inflammatory pathways, nutraceuticals—which include functional foods, carotenoids, dietary fibers, fatty acids, phytochemicals, herbs, probiotics, and supplements—have demonstrated encouraging anti-diabetic qualities. There is a lot of scholarly interest in their ability to lessen diabetes and its related problems.

NUTRACEUTICAL

The word "nutraceutical" was first used in 1989 by Stephen De Felice, the founder of the Foundation for Innovation in Medicine, to refer to food or dietary ingredients that have health or medical advantages, such as preventing or treating disease. According to De Felice, food ought to be seen as medicine with an emphasis on prevention. For a variety of reasons, European medical regulation defines nutraceuticals as medications. Diabetes can cause serious side effects that impair quality of life and raise the chance of death, including cardiovascular disorders, neuropathy, nephropathy, and retinopathy. Insulin therapy, oral hypoglycemic medications, and lifestyle changes are examples of traditional therapies. These therapies do, however, have drawbacks and negative consequences. Alternative treatments with improved safety records and perhaps synergistic benefits are gaining popularity. Bioactive substances called nutraceuticals, which come from plants, animals, and microbes, have become popular because of their possible use as treatments for long-term conditions like diabetes. Beyond their fundamental nutritional importance, these bioactive substances have pharmacological qualities that improve human health. A class of food known as nutraceuticals can be used to treat, cure, or lessen a number of medical ailments. These include of diets, dietary supplements, separated nutrients, processed foods, genetically modified meals, and herbal goods. Anti-arthritis, colds and coughs, digestion, cancer prevention, osteoporosis, high blood pressure, cholesterol control, pain management, depression, diabetes, heart issues, Parkinson's and Alzheimer's diseases, and chronic illnesses like these are just a few of the many uses for nutraceuticals.



Figure 1: Concept of Nutraceuticals.

HEALTH BENEFIT OF NUTRACEUTICALS

These natural supplements may improve our health, nutrition, and overall well-being since they have few or no negative side effects, can increase health advantages, and are natural dietary supplements. In order to promote general health, nutraceuticals target certain bodily systems, such as the eyes, and provide vital nutrients, such as multivitamins.

CLASSIFICATION OF NUTRACEUTICALS

A broad category of bioactive substances originating from natural sources such as plants, animals, and microbes, nutraceuticals are categorized according to their content, source, and physiological effects.

- **FUNCTIONAL FOOD**

Probiotic-fortified dairy products, whole grains enriched with vitamins and minerals, and fruit juices fortified with antioxidants or plant extracts are examples of functional foods—conventional foods that have been fortified, enriched, or enhanced with extra nutrients or bioactive compounds to provide health benefits beyond their basic nutritional value.

- **CAROTENOID**

Naturally occurring pigments called carotenoids, which are present in microbes, plants, and algae, have antioxidant qualities and can alter cellular functions. Potential therapeutic advantages for cardiovascular protection, cancer prevention, and eye health include beta-carotene, lutein, lycopene, and astaxanthin.

- **DIETARY FIBERS**

Dietary fibers are indigestible carbohydrates that may be found in plant-based foods such as fruits, vegetables, whole grains, and legumes. A healthy gut flora, lower cholesterol, and better glycemic management have all been associated with consuming these fibers.

- **FATTY ACIDS**

required lipids, fatty acids—including omega-3 fatty acids like EPA and DHA—are required for many bodily functions. These fatty acids, which are present in flaxseeds and fish, have been researched for their possible advantages in controlling glucose metabolism, lowering inflammation, and enhancing cardiovascular health.

- **PHYTOCHEMICALS**

Flavonoids, phenolic acids, isoflavones, and terpenes are examples of phytochemicals, which are bioactive substances that plants make as secondary metabolites. These molecules give plants their color, flavor, and scent, and their anti-inflammatory, chemopreventive, and antioxidant qualities have been well investigated.

- **HERBS**

Antioxidant-rich plants, such as ginger and garlic extract, have been shown to reduce cholesterol and encourage the healing of wounds and ulcers without causing any negative side effects.

- **PROBIOTICS**

Probiotics are living microorganisms, mostly bacteria and yeasts, that are present in fermented foods such as kefir, yogurt, and certain vegetables. When taken in sufficient quantities, they can aid digestion, boost immunity, and alter the gut microbiota, among other advantages.

ANTI-DIABETICS CLAIMS OF HERBS

By changing the metabolism of fat and carbohydrates, diabetes mellitus, a condition that is becoming more and more prevalent worldwide, has an impact on both physical and mental health. Traditional herbal therapies are employed as a safe substitute for modern medications like insulin because of their restricted uses and high risk of drug resistance. Rich in vital plant-based nutrients, ayurvedic herbs may serve as "potentiators" for these medications, bolstering efforts to preserve the quality of life for diabetics. Better therapies are becoming more and more necessary as we get more knowledge about this ailment. Diabetes mellitus is a metabolic disorder that is becoming more and more prevalent worldwide. It affects both physical and mental health and the metabolism of fats and carbohydrates. Due to their restricted usage and significant danger of drug tolerance, traditional herbal remedies are utilized as a safe substitute for synthetic pharmaceuticals in the treatment of insulin-dependent diabetic mellitus (IDDM) and non-insulin-dependent diabetes mellitus (NIDDM). Rich in vital phytonutrients, Ayurvedic herbs can boost the quality of life for diabetics by acting as "potentiators" for these medications. The function of herbal nutraceuticals, nutritionals, and naturals in metabolic illnesses like diabetes has been the subject of several research by CSIR, ICMR, DBT, and academics.

1. ALOE VERA

The plant aloe vera, which contains anthraquinones, polysaccharides, and lectins, has anti-diabetic qualities. Hypoglycemia may result after consuming leaf pulp meat gel. Additionally, it possesses anti-inflammatory, antioxidant, hypoglycemic, immune system-regulating, and anti-hyperlipidemic qualities. By improving glycemic management, it may help reduce blood sugar levels. By controlling the enzymes that break down carbohydrates and inducing the release of insulin from pancreatic beta cells, the pancreas maintains glucose homeostasis. Numerous ancient literature mention A. vera, a plant used in traditional medicine to treat skin conditions. Because of its calming, hydrating, and restorative qualities, it is also utilized in the alternative medical and cosmetics sectors. Aloe gel is used in yogurts, drinks, and desserts, and its juice and gel protect against sunburn. At some dosages, nevertheless, its hazardous effects can be rather severe. Aloe latex has strong laxative qualities and is used orally to treat diseases including multiple sclerosis and glaucoma. There isn't any solid proof that A. vera works for psoriasis, genital herpes, or burns or wounds. Phlebitis brought on by intravenous infusion can be treated or avoided by topical treatment.

2. GARLIC (ALLIUM SATIVUM)

The sulfur components of garlic, a spicy onion belonging to the Liliaceae family, provide several health advantages. Its sulfur components give it anti-inflammatory, anti-obesity, and antioxidant qualities. Garlic is an anti-diabetic drug since it also boosts insulin sensitivity and secretion. By overregulating the enzymes involved in glycolysis and glycogenesis, it also improves the absorption of glucose. An indigenous herb from Western Asia and the Mediterranean, garlic is a perennial plant of the Alliaceae family. It has been grown for millennia in nations including Korea, China, India, the United States, Spain, Argentina, and Egypt. It is used as a condiment and culinary flavoring in a variety of dishes and seasonings, such as pickles, kimchi, mayonnaise, salad dressing, and spaghetti. In order to defend itself against fungus and insects, garlic has a complex defensive mechanism that includes an enzyme that releases allicin when it is damaged.

3. TURMERIC (*CURCUMA LONGA*)

Because of its curcuminoids, which include curcumin, desmethoxycurcumin, demethoxycurcumin, and bisdemethoxycurcumin, turmeric, also known as *Curcuma longa*, has several medicinal uses. Anti-inflammatory, antioxidant, anti-cancer, anti-apoptotic, anti-obesity, and anti-atherosclerotic qualities are all possessed by these substances. Numerous medical conditions, such as diabetes, arthritis, joint pain, anorexia, coughing, gastrointestinal problems, and heart disease, can be treated with turmeric. With over 120 species, the genus *Curcuma* has a long history of use in medicine. The most well-known and extensively planted plant, *Curcuma longa* L., is found in warm areas all over the world. Its brief flowering time and the herbarium preparation required because of the inflorescence, rhizomes, and tubers' ostentatiousness make taxonomic identification difficult. The most often utilized plant portion is the rhizome, which contains a variety of substances such as volatile oil molecules and bioactive non-volatile curcuminoids.

4. GINGER (*ZINGIBER OFFICINALE*)

Gingerone, gogaol, and gingerol, which are found in *Zingiber officinale*, a plant in the Zingiberaceae family, control insulin signaling pathways. It preserves beta cells, controls insulin release, and improves glucose absorption. Additionally, it controls insulin sensitivity and prevents the production of α -amylase and α -glucosidase. *Zingiber officinale* guards against the negative consequences of diabetes, such as retinopathy, neuropathy, liver damage, and kidney damage. Gingerols, zingiberene, and shogaols are among the bioactive chemicals that provide ginger its nutraceutical benefit. Gingerols, which are volatile phenolic chemicals, give fresh ginger rhizome its strong flavor. Traditional medicine and cooking both employ ginger, a spice belonging to the Zingiberaceae family. Asthma, stroke, diabetes, constipation, and neurological illnesses have all been investigated in relation to its antiviral and antioxidant qualities. Primarily planted in tropical and subtropical climates, ginger is an underground rhizome that may reach a height of 75 cm. The top exporting countries are China, the Netherlands, Thailand, Peru, and India. The top importers are the United States, Japan, the Netherlands, Pakistan, and Germany.

5. FENUGREEK (*METHI*)

An annual legume belonging to the Fabaceae family, fenugreek has several therapeutic uses, including as anti-inflammatory, anti-cancer, anti-diabetic, and anti-hyperlipidemic effects. 4-hydroxyleucine, galactomannan, and saponin all influence its hypoglycemic action. The annual legume fenugreek is well-known for its anti-diabetic qualities. Its active ingredients, which include galactomannan, saponins, and 4-hydroxyleucine, improve insulin sensitivity, glucose absorption, and enzyme activity in the metabolism of glucose.

6. *OCIMUM SANCTUM* (TULSI)

In Ayurvedic medicine, tulsi, often called holy basil, is a revered plant with healing qualities. Its bioactive components, including as carvacrol, ursolic acid, and eugenol, have been demonstrated to have anti-diabetic benefits by improving glucose absorption, increasing insulin secretion, and displaying anti-inflammatory and antioxidant qualities, which may lessen problems associated with diabetes. Recent scientific studies have demonstrated that tulsi, a well-known herb in Ayurveda, successfully addresses physical, physiological, metabolic, and psychological stress through a special combination of pharmacological effects.

7. CINNAMOMM ZEYLANICUM (CINNAMON)

The inner bark of the *Cinnamomum zeylanicum* tree is used to make cinnamon, a spice and traditional medicine that has anti-diabetic effects. It has active ingredients such as eugenol, cinnamonyl acetate, and cinnamonaldehyde that decrease glucose absorption, increase insulin sensitivity, and block enzymes involved in glucose metabolism. The green tree cinnamon is utilized for its antioxidant, anti-fungal, and anti-inflammatory qualities. Diabetes, heart disease, elevated cholesterol, and hypertension can all be successfully treated with it. Higher levels of GLUT-4 and PPARs, stimulation of cellular glucose absorption, and activation and control of enzymes involved in carbohydrate metabolism are all thought to contribute to cinnamon's hypoglycemic action.

8. OTHER PROMISING HERBS

The possible anti-diabetic properties of other plants, such as *Panax ginseng*, *Gymnema sylvestre*, *Aloe vera*, *Curcuma longa*, and *Pterocarpus marsupium*, have been investigated. Gymnemic acids, aloemodin, curcuminoids, ginsenosides, and pterostilbene are among the bioactive substances found in these plants that enhance insulin sensitivity, control glucose metabolism, and have anti-inflammatory and antioxidant properties.

Table: 1 Different plant with anti-diabetic activity.^[51]

Plant	Family	Plant part
<i>Artocarpus integrifolia</i> Linn	Moraceae	Root barks
<i>Abelmoschus esculentus</i> Linn	Malvaceae	Fruits
<i>Acacia arabica</i>	Leguminosae	Seeds
<i>Acacia modesta</i> Wall	Fabaceae	Leaves
<i>Adhatoda zeylanica</i> Nees	Acanthaceae	Leaves and fruits
<i>Camellia sinensis</i>	Theaceae	Leaves
<i>Casearia esculenta</i>	Flacourtiaceae	Roots
<i>Cassia auriculata</i> Linn	Leguminosae	Flowers
<i>Catharanthus roseus</i>	Apocyanaceae	Aerial parts
<i>Chamaemelum nobile</i>	Asteraceae	Leaves
<i>Aegle marmelos</i>	Rutaceae	Root bark, fruits and leaves
<i>Allium cepa</i>	Liliaceae	Bulbs
<i>Aloe vera</i> Linn	Liliaceae	Leaves
<i>Alpinia calcarata</i> Rasc	Zingiberaceae	Rhizomes
<i>Alpinia galanga</i> Willd	Zingiberaceae	Rhizomes
<i>Alternanthera sessilis</i> Linn	Amaranthaceae	Whole plant
<i>Amaranthus esculents</i>	Amaranthaceae	Whole plant, oil
<i>Ampelodesma mauritanica</i> Durand	Poaceae	Roots
<i>Andrographis paniculata</i> Nees	Acanthaceae	Roots
<i>Annona squamosa</i>	Annonaceae	Leaves
<i>Artemisia pallens</i>	Compositae	Aerial parts
<i>Biophytum sensitivum</i> Linn	Oxalidaceae	Leaves
<i>Boerhaavia diffusa</i> Linn	Nyctagenaceae	Aerial parts
<i>Bridelia Retusa</i> Spreng	Euphorbiaceae	Stem barks
<i>Caesalpinia bonducella</i> Roxb	Caesalpiniaceae	Seeds
<i>Tinospora cordifolia</i>	Menispermaceae	Roots
<i>Trigonella foenum-graecum</i>	Leguminosae	Seeds
<i>Triumfetta rhomboidea</i>	Liliaceae	Whole plant
<i>Viscum album</i>	Llorenthaceae	Whole plant
<i>Withania somnifera</i>	Solanaceae	Roots
<i>Psidium guajava</i>	Myrtaceae	Whole plant
<i>Pterocarpus marsupium</i> Roxb	Fabaceae	Wood and barks

ANTI-DIABETIC CLAIMS OF DIFFERENT MICRO-NUTRIENTS

Essential vitamins, minerals, and other nutrients that our systems need in trace amounts for certain functions are known as micro-nutrients. They facilitate the conversion of sugars and carbs into energy and a healthy metabolism. Alpha lipoic acid (ALA), coenzyme Q10, carnitine, inositol, vitamins B12, C, D, E, and H, and vanadium are a few well-known dietary supplements that have been demonstrated to have an impact on diabetes.

1. ALPHA -LIPOIC ACID (ALA):

ALA is an antioxidant and a rare disulfide molecule that is essential to mitochondrial enzyme complexes. It avoids diabetic cardiomyopathy, relieves diabetic neuropathy, and enhances insulin-mediated glucose clearance. Along with vitamin E and 13 omega-3 fatty acids, ALA improves lipid metabolism and insulin sensitivity. ALA helps with erectile dysfunction and diabetic metabolic problems by having a beneficial effect on BMI, HbA1C, and cholesterol levels when given parenterally in 15 doses over 7 days. Additionally, diabetic distal sensory- motor neuropathy can be effectively treated with ALA.

2. CALCIUM:

By lowering parathyroid hormone secretion, which can decrease adipocytes' insulin sensitivity by raising intracellular free calcium, calcium and vitamin D supplements might improve insulin sensitivity and perhaps prevent diabetes. According to a research, women who consume a lot of calcium, especially those in the top quintile, had a 30% lower risk of developing diabetes over a six-year period. No further research has, however, pursued this route. The effects of regular vitamin D consumption and sun exposure on the risk of diabetes have not been investigated in any prospective trials. However, by inhibiting the release of parathyroid hormone, a healthy calcium/vitamin D balance may assist maintain insulin sensitivity and avoid diabetes mellitus, according to theoretical justifications.

3. MAGNESIUM:

Numerous functions, including neuronal transmission, DNA and RNA synthesis, and glucose control, depend on magnesium. A magnesium deficiency can result in decreased insulin-mediated glucose absorption; diabetics excrete more magnesium and have lower blood magnesium levels.

4. VANADIUM:

According to a research, vanadium, a chemical that resembles insulin, may help people with type 1 and type 2 diabetes. Additionally, it lowers hemoglobin A1c, fasting blood sugar, and cholesterol levels. Although daily dosages of 45–150 mg are usually safe and well-tolerated, they may raise fasting blood sugar levels. Mild people, however, could feel queasy during the first week or after taking larger doses.

5. CHROMIUM:

In individuals with type 2 diabetes, chromium supplementation may improve glucose tolerance and insulin sensitivity, according to a meta-analysis of randomized controlled studies. Despite the fact that chromium supplements shown a relatively significant increase in glycaemic control, the American Diabetes Association believes that there is equivocal data about their advantages for diabetes.

6. ZINC:

Zinc is essential for the synthesis, storage, and release of insulin; it also maintains the structural integrity of the hexameric form and improves metabolism in those with impairments.

MECHANISM ON ANTI-DIABETICS

Through a variety of physiological pathways and processes related to insulin action and glucose homeostasis, nutraceuticals exert anti-diabetic effects.

- **INSULIN**

A prevalent problem in type 2 diabetes is insulin resistance, which results from dysregulated glucose metabolism brought on by an impaired cellular response to insulin. Cinnamon, fenugreek, and bitter melon are examples of nutraceuticals that can improve insulin sensitivity and peripheral tissues' ability to absorb and use glucose. These bioactive substances promote the development of insulin receptors, which in turn promotes the insulin signaling cascade and the effective absorption of glucose by skeletal muscles and adipose tissues. Certain nutraceuticals, such as vanadium and alpha-lipoic acid, also have insulin-mimetic qualities, which directly promote the absorption and use of glucose.

- **REGULATION IN GLUCOSE METABOLITE**

Through the modification of enzymes and pathways involved in glucose metabolism, nutraceuticals can have anti-diabetic effects. For instance, alpha-glucosidase and alpha-amylase enzymes can be inhibited by phytochemicals found in bitter melon and cinnamon, which lowers postprandial blood glucose levels and intestinal absorption of glucose. Gymnema sylvestre and fenugreek are two nutraceuticals that increase the activity of glucokinase and hexokinase, which are essential for the storage and use of glucose. By blocking enzymes that are involved in gluconeogenesis and glycogenolysis, such as glucose-6-phosphatase and fructose-1,6-bisphosphatase, some nutraceuticals can also alter the synthesis of glucose in the liver.

- **ANTIOXIDENT AND ANTI - INFLAMMATORY ACTIVITY**

Vitamins C, E, and D as well as phytochemicals like quercetin, resveratrol, and curcumin are examples of nutraceuticals with antioxidant and anti-inflammatory qualities that can help slow the onset and progression of diabetes and its related problems. These substances improve insulin sensitivity, reduce diabetes sequelae including neuropathy, nephropathy, and retinopathy, neutralize reactive oxygen species, shield cells from oxidative damage, and maintain pancreatic beta-cell activity. Inhibiting pro-inflammatory cytokines, which lead to insulin resistance and beta-cell malfunction, is another way that nutraceuticals alter inflammatory pathways.

CLINICAL STUDY

- **HERBAL FOR NUTRACEUTICALS**

Numerous herbal nutraceuticals have been found in clinical research to be useful in managing diabetes. In individuals with type 2 diabetes, the bitter fruit *Momordica charantia* has been demonstrated to have hypoglycemic benefits, lowering HbA1c and fasting blood glucose levels. A cinnamon supplement called *Cinnamomum zeylanicum* has been demonstrated to increase insulin sensitivity, decrease fasting blood glucose, and minimize the risk of complications from diabetes. Another tulsi, *Ocimum sanctum*, has also been shown to enhance antioxidant status, lipid profiles, and glycemic management.

- **MICRONURIENTS IN NUTRACEUTICALS**

Vitamins, minerals, and bioactive compounds are examples of micronutrient nutraceuticals that have been researched for their possible advantages in the treatment of diabetes. Vitamin D supplementation has been shown in clinical studies to enhance insulin sensitivity and glycemic management in people with type 2 diabetes and prediabetes. Additionally, zinc supplementation may lessen problems associated with diabetes and improve glycemic management, particularly in individuals who are zinc deficient. Coenzyme Q10, inositol, and alpha-lipoic acid have also been investigated for enhancing glycemic management and insulin sensitivity.

SAFETY IN TOXICITY CONSIDER

- **HERBAL FOR NUTRACEUTICALS**

When taken in the authorized dosages, herbal nutraceuticals are typically safe; but, some, like *Momordica charantia*, which can induce hypoglycemia, headaches, and stomach pain, may interact with pharmaceuticals or have possible adverse effects, particularly when used in larger amounts or over an extended period of time.

- **MICRONURIENTS IN NUTRACEUTICALS**

While most people can manage taking micronutrient nutraceuticals like vitamins and minerals in the recommended daily allowances, taking too much of some micronutrients, including zinc or vitamin D, might have negative consequences.

CONCLUSION

Insulin resistance or reduced production is connected to diabetes, which affects a large percentage of people worldwide. Both insulin-dependent and non-insulin-dependent diabetic patients have been treated with plants. Significant pharmacological and therapeutic benefits have been demonstrated by nutraceuticals, which are nutrient-dense dietary supplements. Increased insulin synthesis, improved glucose absorption in muscle and adipose tissue, decreased stomach glucose absorption, and decreased hepatocyte glucose are the ways in which hypoglycemic herbs work. More people are looking for natural anti-diabetic medications. With advantages including insulin sensitization, glucose metabolism control, anti-inflammatory and antioxidant properties, and gut microbiota manipulation, nutraceuticals are interesting therapeutic alternatives for the management of diabetes. However, issues including standardization, bioavailability, clinical trial design, and regulatory factors require more investigation. Combining nutraceuticals with traditional treatments may result in more thorough and individualized diabetic care. As knowledge of nutraceuticals' therapeutic potential advances, their use in enhancing or supplementing current therapies may help diabetics achieve better health results.

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