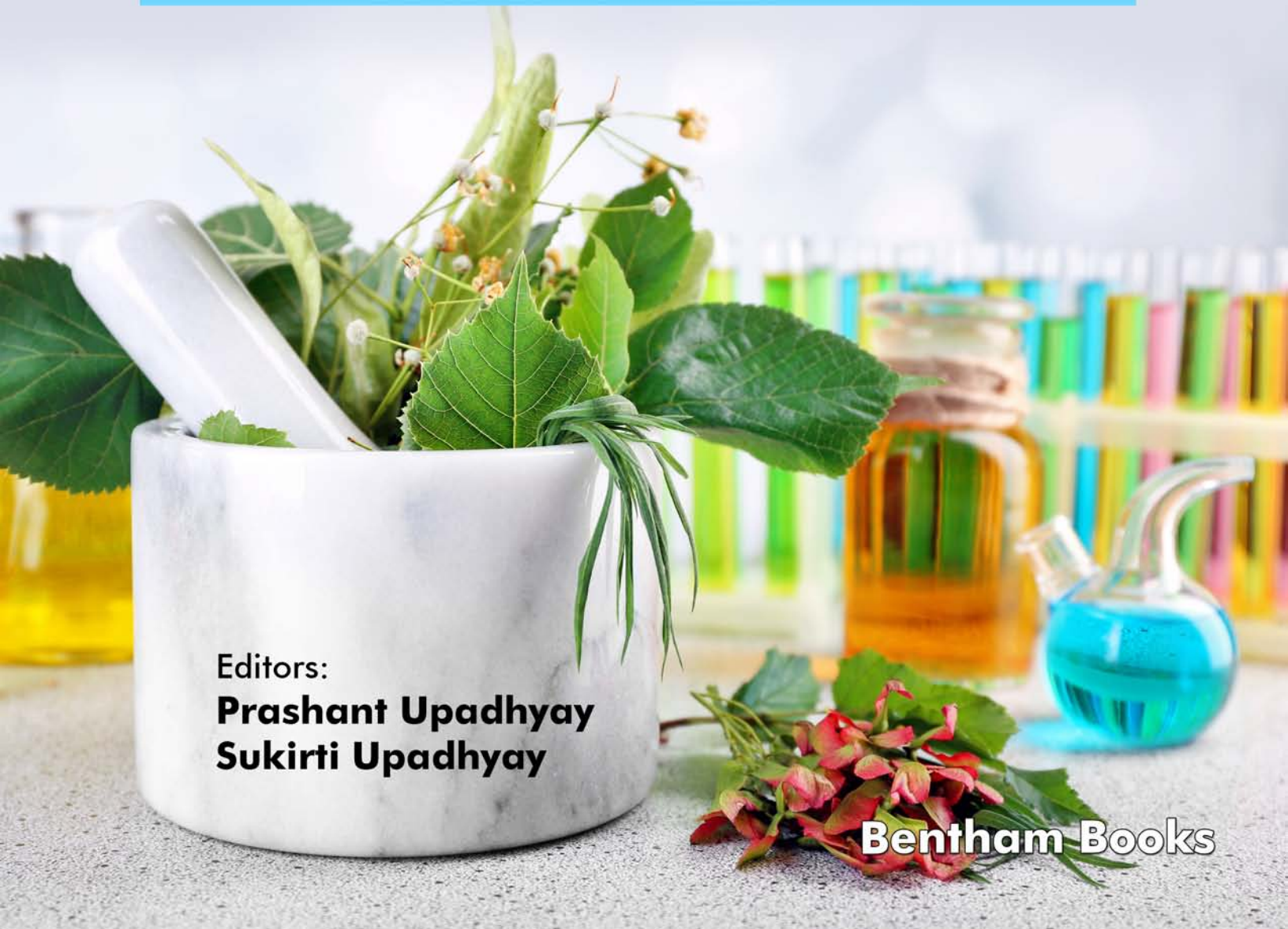
HERBAL NANOTHERAPY FOR **DIABETES**



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Herbal Nanotherapy for Diabetes

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FOREWORD

Diabetes, a complex and multifactorial disease, has become a major public health concern worldwide. The increasing prevalence of diabetes, coupled with the limitations and side effects of conventional treatments, has necessitated the exploration of innovative and complementary approaches to diabetes management.

Herbal medicine, with its rich history and diverse array of bioactive compounds, has emerged as a promising adjunctive therapy for diabetes. However, the poor bioavailability and limited solubility of herbal extracts have hindered their therapeutic efficacy.

The integration of herbal medicine with nanotechnology has revolutionized the field of drug delivery research focusing on diabetes, enabling the development of herbal nanoparticles with improved bioavailability, targeted delivery, and controlled release. Herbal nanotherapy has shown tremendous promise in enhancing the therapeutic efficacy of herbal extracts while minimizing their side effects.

This book provides a comprehensive and authoritative overview of herbal nanotherapy for diabetes, covering the principles, design, and development of herbal nanoparticles, as well as their preclinical and clinical evaluation. The contributors, renowned experts in their fields, have meticulously compiled the latest research and developments in this rapidly evolving area.

I am confident that this book will serve as a valuable resource for researchers, clinicians, and students interested in the field of herbal nanotherapy and its applications in diabetes management. It is my hope that this work will inspire further research and innovation, ultimately leading to the development of more effective and safer treatments for diabetes.

Sincerely,

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PREFACE

This book aims to provide a comprehensive overview of herbal nanotherapy for diabetes, covering the principles, design, and development of herbal nanoparticles, as well as their preclinical and clinical evaluation. Diabetes, a chronic and debilitating metabolic disorder, has become a global health concern, affecting millions of people worldwide. Despite significant advances in conventional treatments, diabetes management remains a challenging task, with many patients experiencing inadequate glycemic control, side effects, and compromised quality of life.

In recent years, herbal medicine has gained significant attention as a complementary or alternative approach to managing diabetes. The rich biodiversity of medicinal plants offers a vast array of bioactive compounds with potential antidiabetic properties. However, the poor bioavailability, limited solubility, and lack of targeting of these herbal extracts have hindered their therapeutic efficacy.

Nanotechnology has emerged as a powerful tool to overcome these limitations, enabling the development of herbal nanoparticles with improved bioavailability, targeted delivery, and controlled release. Herbal nanotherapy, a fusion of herbal medicine and nanotechnology, has shown tremendous promise in enhancing the therapeutic efficacy of herbal extracts while minimizing their side effects.

We hope that this work will serve as a valuable resource for researchers, clinicians, and students interested in the field of herbal nanotherapy and its applications in diabetes management. This book also explains the burning metabolic disorder, diabetes, and its curative aspects. The use of phytochemicals in diabetes care is well documented in this book. The nanotherapeutic approach in the efficient delivery of phytochemicals has been overviewed and the mechanism of study is also explained. So, this book paved the way for overcoming challenges and advancements of nano therapy in diabetes.

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CHAPTER 1

Introduction to Herbal Nano Therapy: Understanding the Science

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Abstract: Herbal medicines have served humanity for numerous generations all across the world. Current methods in phytochemical and phytopharmacological sciences base the clinical applicability of numerous medicinal plants on the composition of active compounds and how much of these compounds are present in samples. Numerous therapeutic compounds such as flavonoids, tannins along terpenoids exist as water-soluble substances yet they have limited potential for absorption. Multiple barriers prevent these compounds from penetrating cell membranes or taking absorption or crossing cell membrane barriers because of their large molecular size and poor absorption and inability to cross cell membranes. This causes them to have low bioavailability and reduced efficacy. Plant extracts fail to enter clinical practice due to these circumscribing factors. Researchers have extensively recommended using nanotechnology to overcome the obstacles related to herbal medicine delivery. Nanoscale technology increases the efficacy of plant extracts by reducing the amount of administration required while reducing side effects and producing therapeutic advantages. Nanocarriers maintain active components at their best concentrations during therapy while guiding them to specific destinations. Treatment methods that exist in the conservative healthcare system typically do not achieve these standards. This section evaluates both nanotechnology principles and their use in herbal drug delivery systems. The drug delivery system using herbal nanotechnology remains essential for diabetes management because polymeric and lipid nanoparticles, liposomes, dendrimers, and niosomes show superior performance than traditional oral hypoglycaemic agent treatments.

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Keywords: Diabetes mellitus, Herbal nanocarrier system, Liposomes, Polymeric nanoparticles, Solid lipid nanoparticles.

INTRODUCTION

Medicinal plants have been leveraged for their therapeutic benefits since the beginning of human civilization; potential uses for several plant parts have been widely recognized, and they are also considered to have fewer undesirable effects relative to chemically synthesized drugs, therefore holding a crucial position in healthcare [1]. The introduction of modern scientific methods like nanotechnology in recent years has altered the delivery and potentiality of phytopharmaceuticals. Nanotechnology, the design of materials at the nanoscale level has opened new frontiers to elevate the bioavailability, stability, and target specificity of plant-based medicine [2]

A prime example of how useful this symbiosis is in the context of a chronic condition like diabetes mellitus, where an imbalance in the blood glucose levels is prevalent owing to a lack of insulin synthesis or utilize it optimally. India, often referred to as the "diabetes capital of the world" with >61 million affected individuals underscores the necessity for a better alternative [3]. Biologically active components such as flavonoids, alkaloids, phenolics, and tannins are known for their antidiabetic properties and medicinal plants have traditionally been used to help control diabetes. They work by stimulating the secretion of insulin from pancreatic cells, blocking intestinal absorption of glucose, and modulating metabolic pathways. Nonetheless, conventional plant-based therapies have limitations such as poor solubility and absorption, which limit their therapeutic activity [4].

The nanotechnology-based delivery system has been developed for the beneficial action of these bioactive compounds by providing maximum absorption and stability which in turn increases their effectiveness in maintaining glucose levels and better sensitivity towards insulin. Herbal nano therapy is a potential treatment that reduces complications of diabetes therapies and it offers a new optimized addition to conventional therapies by trapping those compounds into nanoparticles [5, 6]. Nanotechnology application in phytopharmaceuticals extends beyond diabetes to the behavior and treatment of many diseases including cancer, cardiovascular, neurodegenerative, and autoimmune diseases. However, diabetes is only one avenue, the application of nanotechnology in phytopharmaceuticals covers other diseases as well. The targeted delivery is a particularly different therapy as different strategies of nano-based drug delivery systems have been already approved by regulatory authorities like the FDA. This guarantees that the active compound of the plant extract is stable during transport in the body and

controlled release from nanocarriers at the action site, improving the treatment efficiency [7].

Herbal nanotherapy continues to face multiple obstacles that prevent it from reaching its complete potential. Achieving consistent therapeutic results is complicated by the complex nature of plant-based compounds and variable raw material quality. Active phytoconstituents found in herbal medicines may interfere with the metabolism or therapeutic effectiveness of synthetic drugs and thus create potential risks during treatment [8]. Resolving quality control and regulatory concerns about herbal medicine contamination from heavy metals and synthetic drugs is essential for ensuring these products remain safe and effective. The field of herbal nanotherapy depends on the standardization of herbal medicines through proper identification and collection practices to resolve current challenges [9].

Herbal nanotherapy unites traditional medicine practice and contemporary scientific methods to boost medicinal plant treatment capabilities. Nanotechnology enables herbal compounds to achieve better bioavailability and stability while ensuring controlled release and safeguarding them against gastrointestinal damage. Nanotechnology-based herbal therapy shows potential for treating long-term conditions such as diabetes which requires continuous management. Through Nano encapsulation techniques such as liposomes, dendrimers, and polymeric nanoparticles active plant compounds achieve increased solubility and absorption rates which enhance their pharmacological effects and minimize toxicity levels. This innovation resolves herbal medicine issues by delivering safer treatment options while establishing standardized phytopharmaceutical products that blend traditional methods with modern scientific advancements [10].

TRANSFORMING DIABETIC CARE WITH NANOTECHNOLOGY

Medicinal plants provide phytopharmaceuticals that have served global healthcare needs for centuries since healthcare providers and patients value their therapeutic advantages and reduced side effects over traditional medications. Modern drug delivery technology such as nanotechnology can greatly enhance the efficacy of phytopharmaceuticals when these are developed through scientific and methodical methods. This approach leads to improved patient adherence while simultaneously increasing bioavailability and guaranteeing precise delivery of the active compound [11].

CHAPTER 2

The Epidemic of Diabetes: Challenges and Current Treatments

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Abstract: Diabetes is a crucial health issue affecting people all over the world due to its increasing rates and huge socio-economic impact. This chapter discusses the epidemiology of diabetes by indicating that both Type-I and Type-II diabetes cases are on a sharp rise globally. The multifactorial nature of the epidemics and their susceptibility is presented in terms of genetic, behavioral, and environmental factors that have contributed to the pervasive nature of the illness. Further, in this chapter, some of the major limitations in the management of Diabetes Mellitus, such as factors related to early detection of the disease, compliance to treatment, and management of complications are presented. This is further demonstrated through the necessity of different approaches and therapies in various regions, due to differences in access to healthcare services and their outcomes. The chapter also analyzes the modern treatment strategies, which include recent advancements in drug treatment where new oral and injectable drugs have been introduced and innovations in insulin delivery devices such as continuous glucose monitoring and insulin pump systems. Also, the paper discusses in detail the role of lifestyle changes and education of the patient on diabetes control. As such, these new treatments will be grouped into ranges that include gene manipulation strategies, regenerative technologies, and healthcare information and communication technologies. These cutting-edge treatment modalities are expected to enhance disease management and treatment possibilities. The concluding section of the chapter provides an overview of potential treatments and research opportunities within

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the public health system to mitigate the burden of diabetes in the population. The significance of collaboration in addressing this intricate, demanding, and dynamic issue is also emphasized.

Keywords: Diabetes, Digital health technologies, Epidemic, Gene therapy, Hyperglycemia, Pharmacotherapy, Polyuria, Polydipsia, Polyphagia, Pancreatic beta cells, Regenerative medicine, Obesity.

INTRODUCTION

The metabolic disorder termed diabetes mellitus is characterized by long-term high blood sugar levels caused by complications with the body's ability to produce or respond to insulin. Because insulin is so important as an anabolic hormone, it can cause metabolic issues with fats, carbohydrates, and proteins [1, 2]. The insufficiency of insulin or its resistance by target tissues, primarily the liver, adipose tissue, and skeletal muscles, leads to several metabolic disorders. This could happen if there were issues with insulin receptors, the route for signaling, or effector genes or enzymes. The severity of the symptoms depends on the features of the condition and how long it has been present. Some people with diabetes, especially those with type 2 diabetes in its early stages, may not have any signs at all. Some people have serious hyperglycemia, and minors who don't have any insulin are more likely to have symptoms like frequent urination, frequent vomiting, frequent eating, weight loss, and blurred vision. Nonketotic hyperosmolar syndrome, stupor, coma, and death from ketoacidosis can happen if diabetes is not under control [3 - 5].

Diabetes impacts anyone regardless of age, gender, or geographical location. Genetic and environmental factors contribute to the etiopathogenesis of T2DM, which constitutes over 90% of all cases [6]. Broadly, diabetes mellitus can be classified into two: type I and type II, each of which has its criteria for diagnosis. Type 1 diabetes occurs when the immune system attacks the beta cells of the pancreas. Type 2 is generally de-linked from such strong genetic bases and related to obesity as well as psychological or physical inactivity. Women have a greater risk of experiencing complications during delivery and postnatal life if diagnosed with gestational diabetes during their pregnancy [4, 7].

EPIDEMIOLOGY OF DIABETES

Global and Regional Prevalence

According to the WHO, the number of people with diabetes increased from 200 million in 1990 to 830 million in 2022. The prevalence has been rising faster in low- and middle-income nations than in high-income nations. The lowest rates of

diabetes treatment coverage are found in low- and middle-income countries. In 2021, renal disease associated with diabetes claimed the lives of about 2 million people. Additionally, around 11% of cardiovascular deaths were caused by high blood glucose [8].

The research gap in type 1 diabetes is substantial, with merely 1.52 million of the 8.75 million individuals worldwide in 2022 being under the age of 20. Timely diagnosis and intervention are essential to avoid diabetic ketoacidosis and mortality, highlighting the necessity for enhanced awareness and education. Diabetes-related foot problems fluctuate worldwide due to varying definitions, diagnostic techniques, demographic variables, and data management practices. The IDF Africa Region and the South and Central America Region exhibit elevated incidences of diabetic peripheral neuropathy. Incidences of lower-limb amputations resulting from diabetes are declining in most countries; nevertheless, rigorous reviews of these consequences are few. Indigenous people, representing 6.2% of the global population, experience a disproportionately elevated incidence of diabetes, with 70% of analyzed studies indicating a prevalence exceeding 10% among their adult populations, despite their existence among more than 5,000 diverse groups globally [9].

In 2021, the prevalence of diabetes among adults aged 20 to 79 was 10.5%, increasing to 12.2% by 2045. The highest prevalence was observed in individuals aged 75 to 79. In contrast to rural areas (8.3%), urban areas (12.1%) showed a higher prevalence, while high-income countries (11.1%) outperformed low-income countries (5.5%). In middle-income nations, the predicted largest increase in the prevalence of diabetes (21.1%) will occur. Global estimates place the cost of diabetes-related healthcare at 966 billion USD in 2021; projections indicate that the amount will rise to 1,054 billion USD by 2045 [10].

Risk Factors and Demographic Trends

Diabetes mellitus (DM) is proliferating swiftly due to calorically dense meals, sedentary habits, and urbanization. Obesity is a major risk factor for diabetes mellitus, with those possessing lower educational attainment and socioeconomic status contributing to elevated obesity rates. Complications such as retinopathy are associated with the length of diabetes mellitus, and gender and racial disparities render specific groups more vulnerable. Educational attainment, urban residency, employment status, and marital conditions also influence diabetes mellitus-related outcomes. Diabetes mellitus carries significant costs, particularly when it comes to its complications. To combat diabetes mellitus and its complications, a comprehensive strategy should be implemented, including public health awareness, improved screening services, increased diabetes education for

CHAPTER 3

Exploring Herbal Remedies: Traditional Wisdom Meets Modern Science

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Abstract: This review examines how traditional medicine and recent science can coexist in the branch of herbal drugs, emphasizing the safety and effectiveness of natural therapies in modern healthcare. The long history of herbal remedies, which are ingrained in cultural customs, is experiencing a revival in tandem with the growing demand for customized and all-encompassing healthcare. Diabetes mellitus (DM) is a severe long-term metabolic condition that is linked to hyperglycemia and several side effects, such as chronic kidney disease and cardiovascular disease. A long-standing practice that has been handed down through the years, herbal medicine is gaining popularity again as its potential advantages become more widely recognized. The anti-hypoglycaemic properties of the phytochemicals found in medicinal plants (Allium sativum, Momordica charantia, Hibiscus sabdariffa L., and Zingiber officinalis) can overcome and/or prevent diabetes mellitus. The results also showed that vitamin C, D, E, or their mixture lowers blood pressure, lipid peroxidation, blood glucose, and inflammation in diabetic individuals. The health advantages of vitamins and medicinal plants as chemotherapeutic/preventive medicines for the control of diabetes, however, have not been well studied. It explores the safety profiles of herbal treatments and applies a rigorous scientific examination to them. This review aims to investigate and analyze DM and to close the information gap by examining diabetes mellitus (DM) and emphasizing the hypoglycaemic qualities of the most effective medicinal herbs and vitamins that can avoid and/or lower DM. This review contributes to the ongoing conversation in a world where combining modern science and ancient wisdom holds promise for improving healthcare. The intention is to improve global well-being by combining the best aspects of both worlds.

Keywords: Diabetes mellitus, Herbal remedies, Medicinal plants, Phyto-chemicals, Vitamins.

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INTRODUCTION

Diabetes mellitus is an endocrine condition that is not contagious, associated with hypoglycemia, and marked by abnormalities in the metabolism of carbohydrates [1, 2]. Numerous severe conditions, including microvascular (nephropathy, retinopathy, and nephropathy) and macrovascular (peripheral vascular disease and coronary heart disorders), are associated with it. Diabetes mellitus, commonly referred to as diabetes, has been linked to muscle loss and "sweet urine"-related illnesses.

The pancreas secretes the hormone insulin, which regulates blood glucose levels. The pancreas produces insulin to maintain the blood glucose level as these levels rise. Hyperglycemia in diabetic patients is brought on by either insufficient or missing insulin production. Gestational diabetes, Type 1, and Type 2 are the three types of diabetes mellitus. Diabetes mellitus reliant on insulin, also referred to as type 1 diabetes mellitus, occurs by the complete failure of the β cell in the pancreatic islets of Langerhans.

Insulin-non-dependent diabetes mellitus, sometimes referred to as type 2 diabetes mellitus, is characterized by a transient decrease of β cell mass. It is mostly caused by genetic predisposition, primarily affecting obese individuals, and is linked to elevated blood pressure and cholesterol levels. Reducing insulin resistance and boosting insulin secretion are the goals of type 2 diabetes treatment. Pregnant women with gestational diabetes have hyperglycemia as a presenting feature of their diabetes. It often appears in the 2nd or 3rd trimester of two to four percent of pregnancies [3]. Polydipsia, polyuria, polydipsia polyphagia, exhaustion, nausea, vomiting, male erectile dysfunction, delayed wound healing, and impaired eyesight are signs of diabetes mellitus [4]. The 20-79 age range makes up the majority of the 61.3 million diabetics in India, which is renowned as the diabetes capital of the world. The disease mostly distresses rural and metropolitan populations [5]. In metropolitan India, the prevalence of diabetes is steadily rising. The prevalence of diabetes is almost six times higher in urban than rural areas. In the last 20 years, reduced physical activity, weight increase, stress, dietary modifications, malnourishment, and alcohol consumption have been the primary causes of diabetes mellitus and virus infections. Because women's hormones and inflammatory systems behave differently than men's, female diabetic patients are more than their male counterparts. Less educated individuals are more likely than more educated individuals to have diabetes [6].

Herbal drugs, sometimes mentioned as phytochemical therapy or herbalism, are the utilization of plant-based components for medicinal purposes [7]. Insulin and a range of oral antidiabetic medications, including glinides, biguanides, α-gluco-

sidase inhibitors, and sulfonylureas, are currently the available treatments for diabetes. Products in developing nations are pricey and not very widely accessible [8]. The COVID-19 pandemic has spread over the world in a way that has never been seen before, and as a result, demand for herbal medication has increased beyond prepandemic levels in every corner of the world. People's awareness of the benefits of utilizing herbal medicines instead of allopathic ones and the adverse effects of allopathic pharmaceuticals has increased the demand for herbal medical goods. Another factor driving the market is the growing population and the rise in the prevalence of chronic illnesses [9].

In the last several decades, there has been considerable advancement in the prevention and control of diabetes mellitus. However, serious antagonistic effects from anti-diabetic drugs might include hypoglycemic coma and issues with the kidneys and liver [10]. The World Health Organization (WHO) recommends herbs in products to treat diabetes mellitus. Four billion or more people living in emerging economies have used herbal plants to treat metabolic diseases, including diabetes mellitus. Consequently, vitamins, vital substances with anti-hypoglycemic qualities, and medicinal plants remain crucial for the treatment of diabetes. Studies have demonstrated that the usage of vitamins, vital components, and medicinal herbs can effectively lower blood sugar levels in the form of research, including clinical and pre-clinical. For instance, research found that insulin receptor regulation is mediated by zinc and raises its activity. A research study conducted on adult albino rats revealed that garlic guards against diabetic retinopathy [11]. Many phytochemicals with medicinal herbs' anti-diabetic qualities were discovered, identified, and divided into main groups based on variations in their chemical structures. The main categories of phytonutrients include phytosterols, inhibiting protease, tannins, terpenes, phenols and phenolics, compounds, aromatic acids, carotenoids, flavonoids, glycosides, and organic acids. The anti-diabetic effects of therapeutic plants and minerals, such as having the ability to act similarly to insulin and to be antihyperglycemic, anti-lipidemic, and hypoglycemic, have been demonstrated by recent research in pharmacology [12, 13].

But with rising demand, an increase in adulterated methods, such as adding synthetic substances and replacing natural materials has been observed. As a result, systems for standardization and quality control have become crucial. Furthermore, certain negative effects can also result from a plant's inherent toxicity; they are not always caused by contamination, adulteration, or misidentification of plant species. A comprehensive toxicological evaluation is therefore required to allay any potential safety concern. In addition, exogenous

CHAPTER 4

Nanotechnology as a Medicine: A Brief Overview

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Abstract: Nanotechnology presents an entirely new era in the area of applied medical science, from diagnosis to treatment or prevention of various diseases. This chapter reviews the principle of nanotechnology and the wide range of its applications within the medical science boundaries. Targeted drug delivery, improved image-formation techniques, and advanced diagnostic tools constitute the most diversified applications in nanomedicines, which include the use of nanoparticles, nanorobots, and nanosensors. One of the applications of nanotechnology in medicine has marked a paradigm shift toward extremely personalized medicine where highly particular treatment plans can become possible. This chapter will therefore describe the type of nanomaterials deployed for medical applications, the functional mechanism of these materials, and potential benefits and risks from their use. The discussion also considers the recent breakthroughs in this area of study and those that are under research with promising prospects for transforming health care through nanotechnology. Only by comprehending the intersection of nanotechnology and medicine will researchers and medical professionals recognize the potential benefits of these breakthroughs for patients with complex issues.

Keywords: Diagnostic tools, Future healthcare, Nanomedicine, Nanoparticles, Targeted drug delivery.

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INTRODUCTION

Nanotechnology in Medicine

Innovation in nanomaterials has increased manifold in the last decade for industrial as well as commercial applications. It is being realized more and more that nanoscale-engineered materials with at least one dimension smaller than 100 nm display properties far different from their corresponding bulk forms. Everything can be done in terms of conductivity, strength, surface area-to-volume ratio, and optical properties. Nanoparticles are a new horizon in medicine: nanomedicine will soon allow for the discovery of new drugs and the manipulation of present drugs so that their efficacy is enhanced, their distribution is tailored, and their side effects are decreased [1].

The terms “nanoparticle” and “nanomaterial” refer to a vast class of really tiny structures. The molecular structure of the nanoparticles determines physical properties of the nanoparticle. They can be formulated into virtually any shape and any dimension. Nanoscale architectures or drug delivery applications are not a new technology. Liposomes and dendrimers were synthesized over 33 years ago, and many nanomedicines prepared using this technique are now approved for use in humans [2]. These are a great landmark in nanomedicine in the 21st century, hence holding the possibility of developing complex structures that will selectively target specific tissues and integrate controlled release mechanisms with the ability to escape speedy clearance. Artificial nanomaterials are of size less than 100 nm, and it is somewhat subjective [3]. For nanomedicine, the size of the nanoparticle in terms of particle size is within 1 μm. Nanomedicine is an increasingly important emerging technology that applies nanotechnology for disease screening and diagnosis as well as treatment, leading to a revolution in personal and public health in recent times. While clinical medicine protects the health of individual patients, public health promotes, protects, and maintains the health of populations or groups [1]. It is therefore especially important that one examines research in nanomedicine in the context of public health to maximize advantages and minimize possible risks as widely as possible [4]. Nanotechnology, which works with materials that range in size from 1 to 100 nanometers, has greatly advanced medicine due to its unique properties, particularly in the development of drug formulations based on nanoparticles that improve efficacy and decrease side effects. It also encourages improvements in medical technology and minimally invasive surgery, which result in improved quality of life, reduced infection risks, and faster recovery times. Despite these benefits, there is still a lack of comprehensive understanding regarding the behavior of engineered nanoparticles in biological systems. Due to the lack of data on long-term exposure to synthetic nanomaterials and the unfinished

regulatory guidelines, especially those issued by the FDA, there are still concerns regarding potential health and environmental risks. Further research is required to adequately assess and handle the safety implications of nanotechnology [5]. For nanotechnology to progress effectively, particularly in nanomedicine, stakeholders must communicate transparently regarding its potential risks and benefits. There are also big problems with rules and institutions that need to be fixed. Regulatory bodies, government agencies, insurers, and researchers will all have to work hard to make nanomedicine a part of everyday medical practice. To solve tough problems and come up with new ideas in the field, it is important to get people to work together. Researchers should make efforts for clinical and community-based studies that focus on collecting data and performing epidemiological evaluations of nano-enabled drugs, while also pushing for more funding [6, 7]. Nanomedicine experts and public health professionals need to work together to make sure that these two areas work well together and make people's health better. This article aims to inform diverse audiences, including laypersons, scientists, policymakers, and scholars, about the fundamental public health principles that should be incorporated into the research, development, and application of nanotechnology (Fig. **1**) [8].

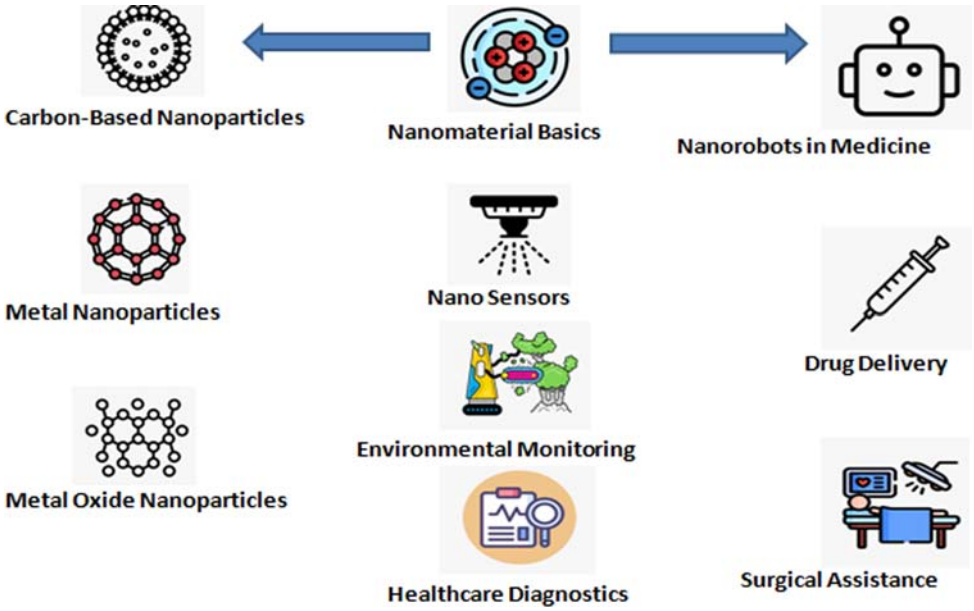

Fig. (1). Nanoparticles used as Nanomedicines [7, 8].

Historical Success

The use of nanoparticles and structures dates back to four hundred years AD . The Lycurgus Cup happens to be one of the best examples of ancient glasswork found

CHAPTER 5

Herbal Nano Therapy: Mechanism of Action

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Abstract: The life-threatening ability of certain diseases including cancer, diabetes, asthma, stroke, heart disease, and others received more attention in modern medicinal advancement. To enhance the solubility, bioavailability, controlled release, and dose reduction of medications, greater attention is given to creating innovative formulations for drug delivery. However, resistance toward conventional synthetic drugs with their toxicity and side effects has sparked demand for herbal medicine. Therefore, herbal medicines are more prone to integrate into nanocarriers as compared to synthetic medicines because of their fewer adverse effects and better therapeutic efficacy. Herbal nano therapy includes nanocarriers containing herbal drug extract, phytoconstituents, and bioactive or biomarker constituents. The phytoconstituent-loaded nanocarrier proposed novel formulations with controlled and targeted drug delivery of herbal components and instantaneously increased their therapeutic efficacy. Herbal nanomedicine is safe concerning diagnostic and therapeutic aspects. The synthesis of herbal nanomedicine, its mechanism, and characterization by various analytical techniques have significant advances in the future impact of nanotechnology on smart herbal medicine.

Keywords: Ayush, Ayurveda, Bhasma, Characterization, Coacervation method, Ethosomes, Functionalized nanocarriers, Green synthesis, Herbal nanomedicines, Herbal therapy, High-pressure homogenization, Metallic nanoparticles.

INTRODUCTION

Nanomaterials are referred to as any constituent having nanometric scale magnitudes. Their exclusive physicochemical characteristics together with size, surface area, surface charge, narrow size distribution, and quantum effects showed their widespread applications in various fields [1]. Their potential applications in health care offer an innovative approach to treating or diagnosing various diseases. These include metallic nanoparticles, tissue implants, nano scaffolds, biosensors, nanofibers, nanorobotics, and ligand-attached drug delivery [2].

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Therefore, widespread innovation in nanomaterials influences the formulation of drug delivery known as nanoformulations or nanocarriers. They showed high drug entrapment, prolonged drug delivery, less side effects, and toxicity. The nanoformulations/nanocarriers that possess their therapeutic properties are called nanomedicine. They controlled the drug release rate and drug release manner at the site of action. They have also shown to increase the effectiveness, reduce toxic effects or side effects, enhance stability, and improve the pharmacokinetics of the entrapped drug. These formulations are prepared by using various natural as well as synthetic biodegradable and non-biodegradable polymers such as polylactic acid, collagen, PLGA, cellulose, chitosan, gelatine lactoferrin, *etc* [3].

Herbs are a vital component of medicinal plants with an ancient therapeutic history. Herbal medicines with Indian ayurvedic medicines, Chinese medicines, Japanese, and Arabian Aroma therapy are significantly applied for the treatment of various diseases. The World Health Organization (WHO) recognizes the unique efficacy of herbal medicines with minimal toxicity. Therefore, the WHO initiated a program to promote the therapeutic efficacy, safety, and potential of herbal medicines by using nanoformulation [4]. The nanoformulation is comprised of herbal phytoconstituents, which are used to treat various diseases and are known as herbal nanotherapy. Herbal nanotherapy includes nano-sized and nano-delivery medicines containing herbal extract, phytoconstituents, bioactive components, or biomarkers. Its nano-sizing properties can improve the solubility, stability, and therapeutic effectiveness of phytoconstituents. Nano therapy overcoming the off-target drug delivery, therefore helps to reduce the toxicity and side effects associated with herbal medicines [5].

In Ayurveda, the concept of nano therapy is old, where metallic nanoparticles are used in the form of Bhasma. The synthetic process used in the preparation of Bhasma is known as “Bhasmikarana”. This technique is used with slight modifications in current herbal nanoformulation. In this process, metal ions of silver (Rajata), mercury (Parada), zinc (Yasada), iron (Loha), tin (Vanga), lead (Sisaka), copper (Tamra) or gold (Swarna), and herbal medicine are converted into nanoparticles with higher oxidative state as represented in Table **1**. The superior properties of these Bhasma/ metallic nanoparticles improved absorption, stability, and biocompatibility and proved their therapeutic efficacy in different disease conditions [6, 7].

Table 1. Application of metallic nanoparticles loaded with different herbal extracts.

Metallic Nanoparticles	Plant Extract	Size	Application	References
Silver nanoparticles	Ethanolic extract of Alove vera extracts	60-150nm	Antibacterial and wound healing	[8]

(Table 1) cont.....

Metallic Nanoparticles	Plant Extract	Size	Application	References
Silver nanoparticles	Genistein	130-150nm	Enhance apoptosis	[9]
Gold nanoparticles	*Beta-sitosterol*	60-85nm	Antioxidant activity	[3]
Iron oxide magnetic nanoparticles	*Argemore mexicanal*	10-30nm	Diuretic and purgative	[10]
zinc oxide nanoparticles	-	10-185nm	Antidiabetic activity	[11]
Zinc oxide and titanium dioxide nanoparticles	*Psidium guajava*extract	25-110nm	Antioxidant and antibacterial properties.	[11]
Gold Nanoparticles	Genistein	80-110nm	Treatment of prostate cancer.	[12]
Iron nanoparticles	Aqueous extract of *Saccharum arundinaceum*	20-80nm	Cytotoxic effect and antitumor activity.	[13]

Need for Herbal Nanotherapy

As discussed above, the ancient Indian medical discipline of Ayurveda has long recognized the medicinal benefits of herbal remedies. They are more recognized due to their better therapeutic efficacy and fewer adverse effects than synthetic conventional ones as represented in Table **2**. However, there are several difficulties in developing herbal medications, such as standardizing bioassays, conducting clinical research, assessing pharmacology, lack of scientific validation, processing issues, and toxicological characteristics. Other major challenges include figuring out absorption sites, evaluating the safety of harmful herbal constituents, and negotiating regulatory systems that refuse to invest in herbal formulation. Therefore, there is a need to isolate bioactive phytoconstituents from herbal medicine, which are responsible for the therapeutic activity [14].

Table 2. Applications of different phytoconstituents as compared to synthetic drugs in different disease conditions.

Sr. No.	Disease State	Drugs	Drawbacks	Phytoconstituents Used	Mechanisms	References
1.	Anticancer	5-fluorouracil, methotrexate, doxorubicin	Low bioavailability, high cytotoxicity, and short half-life.	*Curcumin, camptothecin.*	It significantly regulates the rate of apoptosis in different types of cancer by inactivation of the PI3K/Akt pathway.	[21]

CHAPTER 6

Formulation and Delivery of Herbal Nanocarriers

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Abstract: Diabetes mellitus, a widespread metabolic disorder, requires innovative treatment strategies to address the limitations of conventional therapies, such as poor bioavailability and side effects. Herbal medicines are promising alternatives due to their natural origin and therapeutic potential. However, their clinical application is hindered by challenges in stability and bioavailability. This chapter explores the use of nanocarrier systems to enhance the delivery and efficacy of herbal compounds in diabetes management and explores the innovative approach of using nanocarrier systems for the delivery of herbal compounds in the treatment of diabetes. Also, the chapter delves into various nanocarrier systems, like liposomes, polymeric nanoparticles, and nanoemulsions, outlining their formulation techniques, encapsulation efficiency, and drug-loading capacities.

Keywords: Diabetes mellitus, Herbal nanocarrier, Nanotechnology, Plant-based nanoformulations, Phytochemicals.

INTRODUCTION

Overview of Diabetes Mellitus

India, the world's "Diabetes metropolis", has an impact on practically every type of community, whether it is rural or urban [1]. Diabetes mellitus has been ranked as one of the greatest pandemics facing the global community, and abnormal, persistent hyperglycemia, due to defective or inadequate insulin production, is what causes this condition. The prevalence has been growing with more than 460

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million individuals being affected by it. In the upcoming decades, the number of cases will rise hundreds of times [2, 3].

The WHO projects that diabetes mellitus (DM) will rank seventh among the leading causes of mortality in 2030 [4]. According to estimates from the International Diabetes Federation (IDF), 536.6 million people worldwide will have diabetes by 2021. By 2045, we anticipate a 46% increase to 783.2 million. Microvascular disorders (stroke, peripheral artery disease, and cardiovascular disease) and macrovascular disorders (neuropathy, nephropathy, and retinopathy) are the two main long-term effects of the condition. There are more microvascular problems. Prioritizing early detection and modifying diabetes care in light of the disease's high prevalence, serious health effects, and growing expense of treatment is imperative [1, 5]. This trend, mainly induced by rising obesity rates, urbanization, and sedentary lifestyles, affects the progress of type 2 diabetes with a special impact on younger populations. About 90% of all diagnosed cases occur [6].

Insulin therapy, oral medications, and lifestyle alterations are the cornerstones of conventional diabetes management. It has been noted that lifestyle changes, including regular physical activity, dietary control, and weight loss, tend to be more effective in managing type 2 diabetes compared to type 1 diabetes [7]. Insulin therapy has been recommended for patients who are unable to reach their glycemic objectives with lifestyle changes and oral hypoglycemic medications [8]. Recently, several innovative approaches have been implemented to manage diabetes, including nanotechnology-based insulin delivery systems designed to enhance patient compliance, accuracy, and efficiency in insulin administration [9].

Current Treatment Strategies and their Limitations

Diabetes can be effectively managed with dietary changes. Consuming complex carbohydrates, proteins, fiber, polyunsaturated fatty acids (PUFA), and low-glycemic foods can all help to keep blood sugar levels within normal ranges. By reducing fatty acids, moderate exercise also lowers blood glucose by enabling the glucose transfer into the muscle in an insulin-independent manner [10]. Diabetes management remains a multifaceted challenge, with current strategies often falling short of delivering long-term control or addressing all aspects of the disease. Behavioral and environmental factors, such as modern sedentary lifestyles and access to unhealthy food choices, create barriers that prevent many individuals from achieving sustained lifestyle changes [11, 12]. Even among those who can adhere, the benefits may be insufficient in more advanced stages of diabetes. Current therapies for type 2 diabetes are shown in Fig. (**1**).

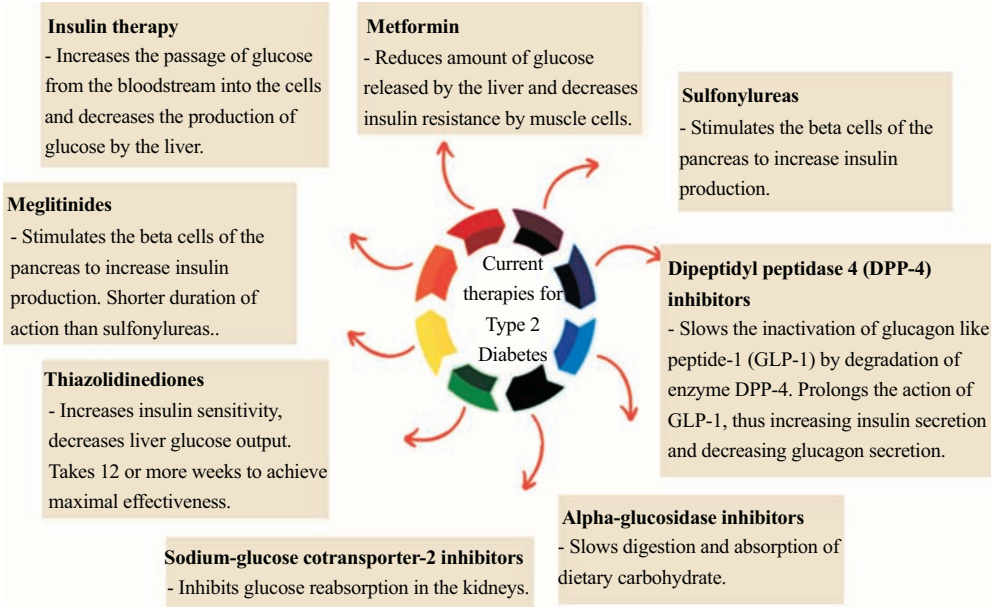

Fig. (1). Current therapies for type 2 diabetes [13].

Recent advancements in diabetes management reflect a paradigm shift in treatment and monitoring. By giving continuous glucose monitoring (CGM), real-time glucose data systems have greatly improved glycemic management by reducing both hyperglycemic and hypoglycemic episodes and enabling precise insulin changes [14]. Innovations in the delivery of insulin, such as insulin pumps and closed-loop systems, have also advanced the standard of care by automating insulin delivery in response to CGM data, thereby enhancing overall glucose management [15]. Another trend is the drive for personalized medicine to tailor treatment and then improve patient outcomes with diabetes using genetic and environmental data [16]. Public health interventions will need to focus on both early detection and prevention and comprehensive management in an attempt to minimize that burden. These are activities that include awareness worldwide, group involvement programs, and policy initiatives to promote healthy lifestyles and access to care [17].

Pharmacological therapies remain the cornerstone of Type 2 diabetes management, with metformin perhaps being the most prominent example. Metformin is an insulin-sensitizing drug that reduces hepatic glucose production while enhancing peripheral glucose uptake. However, based on current studies, gastrointestinal adverse effects occur in up to 25% of patients, making it such that about 5% of them stop its use [18]. Metformin efficiently decreases blood glucose

CHAPTER 7

Clinical Evidence: Efficacy and Safety of Herbal Nano Therapy

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Abstract: Herbal nanotherapy is an emerging and innovative therapeutic approach that synergistically combines the principles of modern nanotechnology with the time-tested efficacy of traditional herbal medicine to significantly enhance treatment outcomes. This chapter offers an in-depth exploration of the scientific advancements and clinical evidence supporting the development and application of herbal nanotherapies. It discusses the latest progress in nanoformulation techniques that improve the physicochemical stability, enhance bioavailability, and enable precise, targeted delivery of bioactive herbal compounds, thus overcoming many of the limitations associated with conventional herbal treatments. Drawing on a wide range of recent clinical trials, case studies, and experimental research, the chapter illustrates the successful implementation of herbal nanoformulations in the treatment of complex diseases such as cancer, cardiovascular disorders, and metabolic syndromes. It further examines the comparative therapeutic benefits and improved safety profiles of nanoformulated herbal drugs in contrast to their traditional counterparts. In addition, critical attention is given to long-term safety concerns, potential adverse effects, and the evolving regulatory landscape that governs the clinical use and approval of herbal nanotherapies. By presenting a holistic synthesis of cutting-edge scientific findings and technological innovations, the chapter aims to equip researchers, clinicians, and policy-makers with a comprehensive understanding of the transformative potential, current challenges, and future directions of herbal nanotherapy in modern healthcare systems.

Keywords: Clinical trials, Efficacy, Herbal nano therapy, Nanoformulation, Safety.

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INTRODUCTION

The herbal nano treatment is a promising advancement at the nexus of natural medicinal medications and nanotechnology. By turning natural compounds into nanoparticles, this technique seeks to enhance drug transport, stability, and bioavailability while addressing persistently difficult issues with conventional herbal treatments [1]. Nanoparticles exhibit unique physicochemical properties; such as an increased surface area-to-volume ratio and enhanced permeability, which significantly improve the absorption, bioavailability, and targeted delivery of therapeutic agents. These attributes enable nanoparticles to cross biological barriers more efficiently, ensuring that active compounds are delivered directly to the intended site of action with greater precision, thereby maximizing therapeutic efficacy while minimizing systemic side effects [2].

For instance, curcumin, a substance that comes from turmeric, has anti-inflammatory as well as anti-cancer properties, yet in its natural state, it has poor bioavailability. Curcumin-loaded nanoparticles, which improve their absorption and therapeutic benefits, have been produced using nanotechnology [3, 4]. Similarly, other herbal bioactive compounds such as quercetin, resveratrol, and silymarin have been successfully nano-formulated to address key challenges associated with their low water solubility, limited stability, and low bioavailability. Through nanocarrier systems, these phytochemicals demonstrate improved solubility profiles, enhanced pharmacokinetic properties, and greater therapeutic potential by enabling sustained release and site-specific delivery, ultimately overcoming the limitations of their conventional formulations [5]. Herbal nanomedicine may not only improve healing effectiveness but also allow for controlled release of active ingredients, which lowers dosage frequency and minimizes side effects [6]. This approach is particularly advantageous for the treatment of chronic diseases, where sustained and long-term clinical management is essential. By enabling controlled and targeted delivery, nanoformulated herbal compounds help maintain therapeutic drug levels over extended periods, reduce dosing frequency, and minimize adverse effects, thereby improving patient compliance and treatment outcomes. The integration of herbal medication with nanotechnology is, therefore, visible as a progressive step toward extra powerful and safer treatments, bridging the distance between conventional know-how and present-day scientific advances [1].

IMPORTANCE OF ASSESSING EFFICACY AND SAFETY

While the benefits of herbal nano therapy are substantial, it is crucial to rigorously evaluate its efficacy and safety through well-designed scientific studies and clinical trials. Comprehensive testing ensures that these advanced formulations

not only deliver therapeutic advantages but also meet established safety standards, minimizing potential risks and building confidence among healthcare providers, patients, and regulatory authorities. Nanoparticles can regulate the pharmacokinetics and pharmacodynamics of herbal compounds. Therefore, efficacy assessments must make certain that nano-formulations offer the desired healing outcomes and that these outcomes are constant and dependable across extraordinary patient populations [7].

The safety assessment of various therapeutic options is equally important, especially when introducing nanoparticles into the body. Unlike traditional herbal remedies, nanoparticle-based formulations may pose potential risks such as toxicity, immunogenicity, and unforeseen long-term health effects. Therefore, a thorough evaluation of these risks is essential to ensure that the benefits of herbal nanotherapies are not overshadowed by adverse outcomes and to establish a clear understanding of their biocompatibility, metabolism, and overall safety profile [8, 9]. Certain nanoparticles, for instance, have been observed to accumulate in vital organs such as the liver and spleen, raising significant concerns about their potential toxicity. Additionally, the interactions of nanoparticles with biological systems at both molecular and cellular levels may lead to unforeseen effects, including altered cellular functions, immune responses, or oxidative stress. These complexities underscore the need for comprehensive safety evaluations, including in vitro and in vivo studies, to thoroughly assess their biocompatibility, biodistribution, metabolism, and potential long-term impacts before clinical application [10].

Regulatory agencies worldwide are increasingly prioritizing the establishment of comprehensive guidelines to ensure the safe and effective integration of nanotechnology into healthcare. These efforts underscore the importance of extensive preclinical and clinical evaluations to assess the safety, efficacy, pharmacokinetics, and long-term effects of nanoparticle-based therapies. By enforcing stringent regulatory frameworks, authorities aim to protect public health while simultaneously encouraging innovation in the field of nanomedicine [11]. However, if safety concerns and regulatory barriers are not adequately addressed, they could significantly impede the widespread adoption of herbal nanotherapy. Therefore, rigorous scientific evaluation and strict adherence to regulatory standards are essential. Such measures are vital for achieving regulatory approval, building public and clinical trust, and ensuring the responsible incorporation of these advanced therapies into mainstream healthcare systems [1].

CHAPTER 8

Integrating Herbal Nano Solutions into Diabetes Care Plans

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Abstract: Diabetes mellitus, a chronic metabolic condition, poses numerous challenges to global healthcare systems. Traditional pharmaceutical medications function effectively, yet they generate problems together with adverse effects primarily affecting patients who suffer from ongoing conditions. In 2014, World Health Organization data shows that diabetes affects 8.5 percent of adults who are 18 years old and above. The worldwide mortality rate from diabetes reached 1.5 million deaths in 2019, and 48% of these deaths occurred among individuals under seventy years old. Blood glucose levels that were too high were responsible for 20% of cardiovascular disease deaths, whereas the total kidney disease deaths due to diabetes amounted to 460,000. Between 2000 and 2019, the death rates because of diabetes showed a 3% increase in every standard measure. The review investigates three natural herbs, Gymnema Sylvestre, bitter melon (*Momordica charantia*), and turmeric (*Curcuma longa*), for diabetes treatment while evaluating the nanoscale formulation potential of these remedies. Research in nanotechnology enables healthcare providers to enhance herbal solutions at the nano level to achieve better bioavailability with targeted delivery systems and sustained release mechanisms as essential elements for optimizing diabetes care treatment. The chapter analyzes how herbal products integrated with nanoformulations work as part of diabetes care plans through discussions of improved therapeutic results regarding drug absorption rates while addressing stability and toxicity levels. The discussion ends with guidance on implementing herbal nano solutions within complete diabetes care plans and approaches combining personalized treatment with multidisciplinary teamwork for optimal patient results.

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Keywords: Bioavailability, Diabetes management, Herbal nanomedicine, Nanoformulations, Personalized medicine.

INTRODUCTION

The metabolic disorder known as chronic hyperglycemia arises from improper insulin function, reduced insulin production, or either condition. The crucial hormone insulin controls how the body processes proteins, fats, and carbohydrates. Insulin resistance causes diabetes-related metabolic disorders, primarily affecting liver and muscle tissue and fat storage tissue. The symptoms' extent depends on the specific diabetes type and how long the diabetes duration has been present. People with high blood sugar often develop vision troubles and weight reduction in addition to experiencing frequent thirst and increased hunger together with dysuria. Children and other individuals without sufficient insulin levels experience these symptoms [1, 2]. Some persons with diabetes, particularly those with type 2 diabetes who are still in the early stages of the disease, may not exhibit any symptoms. If untreated, uncontrolled diabetes can lead to several complications, such as coma, confusion, and, in severe cases, death from untreated nonketotic hyperosmolar syndrome or ketoacidosis [1].

A World Health Organization (WHO) survey from 2014 found that 8.5% of persons over the age of 18 have diabetes. Diabetes killed 1.5 million people in 2019; 48% of them were under the age of 70. Furthermore, high blood glucose was linked to 20% of cardiovascular disease deaths, while diabetes was responsible for 460,000 renal disease deaths. Between 2000 and 2019, the standard death rates for diabetes increased by 3%. Diabetes is connected with a 13% increase in mortality in low- and middle-income countries. However, between 2000 and 2019, the likelihood of dying between the ages of 30 and 70 from any of the four primary noncommunicable diseases cancer, chronic respiratory diseases, diabetes, and cardiovascular diseases decreased by 22% worldwide [1, 3].

The present search parameters were determined by screening all reputable and accessible research and review publications within the diabetic literature. The authors examined more than five hundred scientific publications from several databases, including PubMed and Google Scholar (See Fig. **1**).

Pathophysiology

Insulin, a hormone generated by the pancreas that facilitates glucose absorption and utilization as power, is the primary cause of both Type 1 and Type 2 diabetes. The destruction of beta cells inside the pancreas causes poor insulin production, leading to hyperglycemia in Type 1 diabetes patients since cells cannot absorb

glucose from the bloodstream. Insulin resistance is the main factor causing Type 2 diabetes, leading to impaired cell reaction to insulin. The pancreas releases more insulin, as aresult of which, blood sugar increases, but this process becomes insufficient over time. Uncontrolled persistent high blood sugar leads to eye damage (retinopathy), nerve damage (neuropathy), and kidney damage (nephropathy) alongside heart disease complications [4].

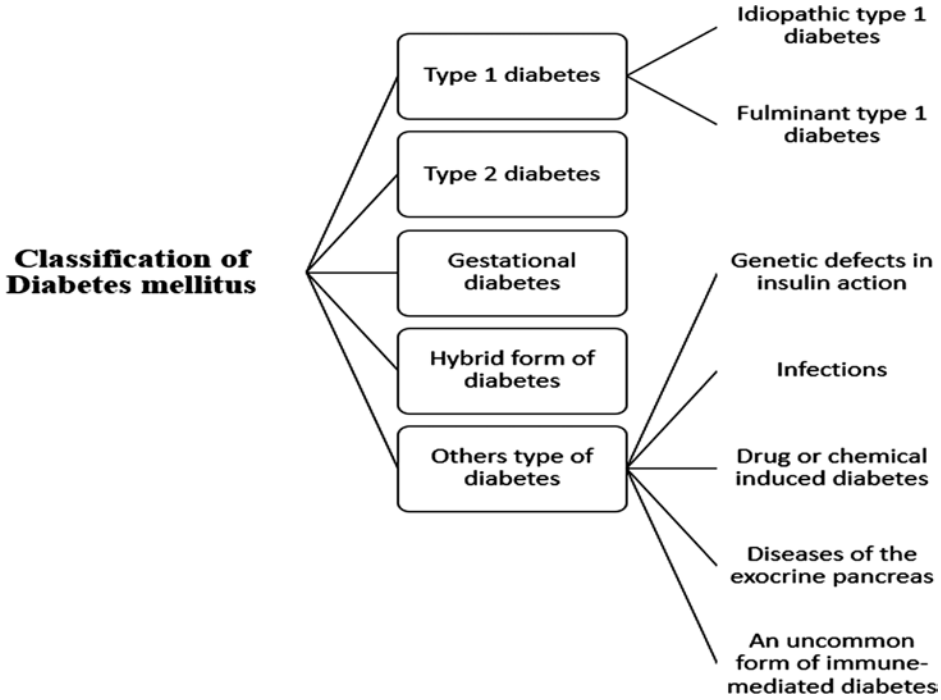

Fig. (1). The most recent classification of diabetes mellitus (DM) encompasses the various forms and subtypes of the disease, such as type 1 diabetes, type 2 diabetes, gestational diabetes, hybrid forms of diabetes (mostly Type 2 Diabetes with ketosis risk), and other special types of diabetes.

Types of diabetes therapy presently include dietary adjustments, oral medicines, and insulin administrations, with selected cases requiring bariatric surgery. The advancement of diabetes management techniques has not eliminated ongoing issues with ideal blood sugar control, together with a reduction of long-term complications alongside the management of medication side effects [5]. These challenges show the need for more personalized and sustainable treatments. Recently, there has been growing interest in using herbal medicine to manage diabetes [6]. Various herbs like *Gymnema Sylvestre*, bitter melon (*Momordica charantia*), and turmeric (*Curcuma longa*) have been studied for their ability to lower blood sugar levels and improve insulin sensitivity [7, 8]. More extensive research is required to evaluate the safety, effectiveness, and mechanism of action

CHAPTER 9

Future Perspectives: Advancements and Challenges in Herbal Nano Therapy

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Abstract: Herbal nanotechnology is a groundbreaking amalgamation of herbal medicine and nanotechnology. This approach has advantages over conventional herbal formulations, such as improved solubility, enhanced bioavailability, and site-specific targeting. Nanocarriers like nanoparticles, nanocapsules, and nanosheets, allow precise delivery of herbal components, which reduce side effects and increase therapeutic efficacy. This chapter highlights the innovation in nanocarrier formulations, integration of therapeutic and diagnostic functionalities, harnessing of artificial intelligence (AI) and machine learning (ML) in the optimization of herbal nanoformulations, and future perspectives of herbal nanocarrier-based therapy. Upcoming advancements are anticipated to emphasize on the design of multifunctional nanocarriers with diagnostic capability, such as biosensing and bioimaging, and deliver therapeutic molecules, laying the foundation for personalized medication. Harnessing AL and ML in formulation and optimization accelerates the development and improves clinical significance in the innovation and formulation of novel herbal-based therapy. Nevertheless, the application of herbal nanocarrier therapy faces limitations, from innovation to clinical trials. Major challenge encompasses potential toxicity, long-term biocompatibility, and environmental impacts of nanomaterials. Developing thorough regulatory guidelines will guarantee the safety, efficacy, and ethical implementation of herbal nanotherapy.

Keywords: Diagnostic techniques, Herbal nanotherapy, Nanocapsule, Nanosheets.

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INTRODUCTION

The therapeutic properties of plants have been extensively recorded in various ancient medicinal systems, including Chinese Medicine, Ayurveda, Siddha, and the Unani System of Medicine. Currently, plant sources or other natural origins are about one-third of the leading sources of medications [1]. However, the majority of pharmaceutical companies are disregarding this field due to multiple limitations, including a lack of understanding of the applications of herbal remedies for modern diseases such as cancer, viral infections, multidrug-resistant microbial infections, diabetes, obesity, and cardiovascular disorders. By introducing novel drug delivery systems (NDDSs) for herbal compounds, we can minimize the frequency of dosing, thereby enhancing patient compliance. Additionally, these systems enhance therapeutic efficacy by lowering toxicity and enhancing bioavailability along with other advantages [2].

Incorporating herbal extracts in innovative formulation systems offers significant merits, like addressing challenges related to large dosage sizes and improving absorption, which are significant challenges, hence attracting the interest of prominent pharmaceutical companies.

Nanotechnology focuses on developing devices and dosage forms that fall within the range of 1 to 100 nanometres. In medicine, nanotechnology is used for treating, diagnosing, monitoring, and regulating biological systems. These nanocarriers are composed of biocompatible ingredients like lipids, polysaccharides, and synthetic biodegradable polymers [3].

The effectiveness of herbal medications relies on the synergistic action of multiple active components, each playing a significant and interconnected role in enhancing therapeutic outcomes. However, many herbal-derived medications are insoluble, resulting in reduced bioavailability and amplified systemic clearance. Such behaviors often necessitate frequent administration, which makes them less suitable for therapeutic applications. The exploration of phytoformulations reveals that the creation of nanotechnology-based dosage forms, including proliposomes, solid lipid nanoparticles, polymeric nanoparticles such as nanospheres and nanocapsules, and nanoemulsions, offers significant advantages for herbal medications, as shown in Fig. (**1**). These advantages encompass improved solubility, bioavailability, and biocompatibility; augmented pharmacological efficacy; superior stability; targeted administration to tissue macrophages; sustained release; and protection against physical and chemical degradation. Nano-sized drug delivery methods for herbal treatments possess considerable promise to enhance efficacy and tackle problems in phyto therapeutics. The integration of nanocarriers as an innovative drug delivery system in conventional

medicine is essential for the treatment of chronic conditions such as asthma, cancer, and diabetes.

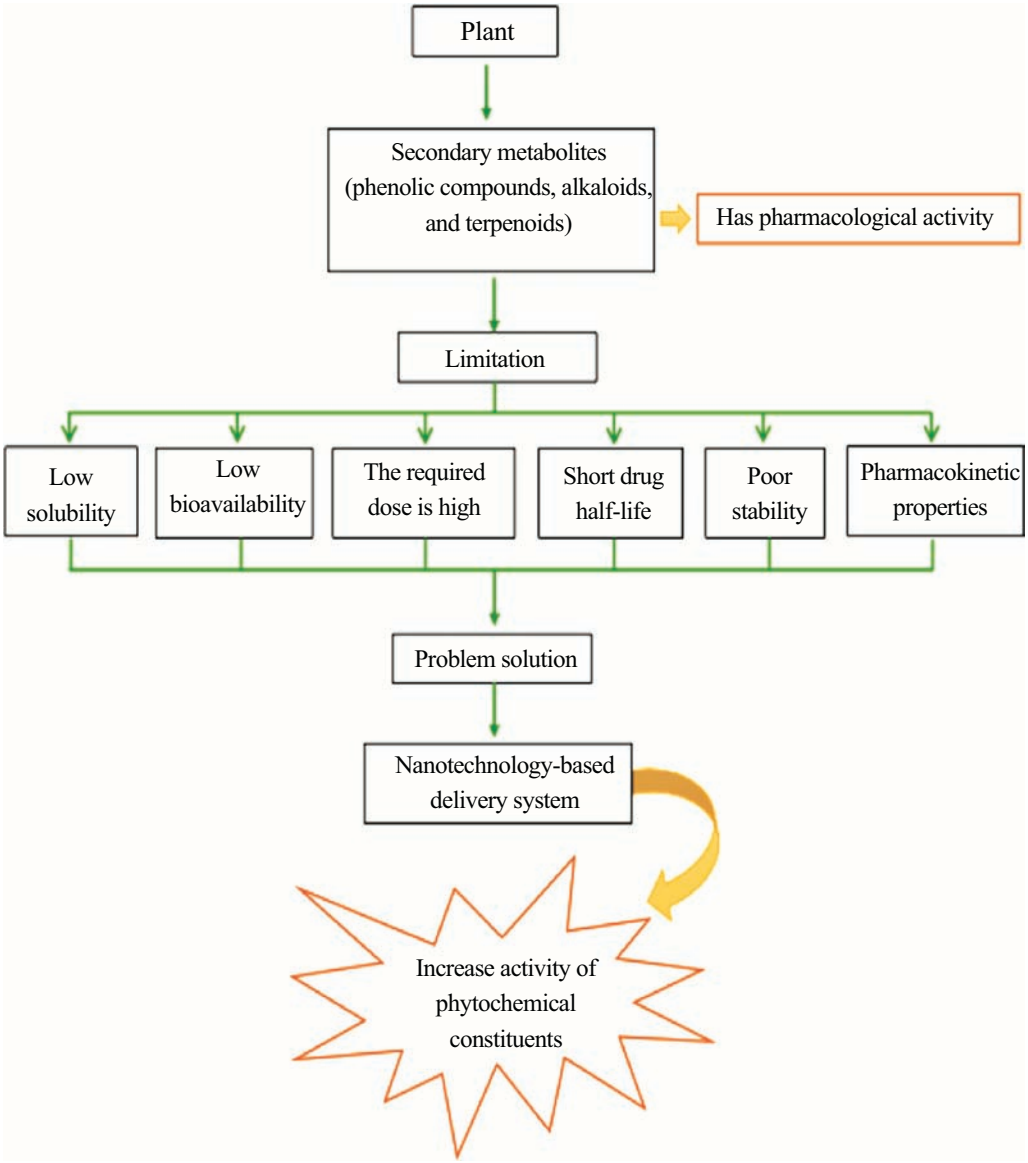

Fig. (1). Schematic representation of herbal nanotechnology.

IMPORTANCE OF NANO CARRIERS IN NATURAL TREATMENTS

Herbal medicine components often face degradation in the stomach's acidic environment or undergo metabolism in the liver, hindering their ability to enter

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