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Ameliorating Effects of Curcumin on Diabetes

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Abstract

The potential health benefits of turmeric have often been overlooked, but recent research is beginning to suggest that the active ingredient found in the Turmeric, plays an important role in improving insulin resistance and metabolic disorders. Curcumin has been found to possess some remarkable medicinal properties and has wide-ranging biological activities that can help ameliorate the symptoms associated with these disorders. In this review, the positive effects of curcumin on the prevalent metabolic disorder known as diabetes would be examined. Many recent studies have shown the positive effects of this spice and the benefits to patients suffering from this disease. Curcumin has been reported extensively revealing that it improves insulin sensitivity and lowers the levels of glucose in the blood. It also possesses antioxidant properties which have been attributed to the reduction in inflammation and protection of body cells as well. The different bioactive ingredients present in curcumin, their healing characteristics and their applications in medicine as a result of this healing constituent will also be highlighted in this review.

Keywords: Antioxidant, Curcumin, Diabetes, Metabolism, Nutraceutical

INTRODUCTION

In a fast-paced world that is constantly on the lookout for ways to improve the quality of life and health, the use of nutraceuticals as an alternative to conventional medicine has been on the high rise and for justifiable reasons. The term "nutraceutical" refers to a broad category of products obtained from food sources that offer additional health advantages over and beyond the basic nutritional content found in food. Products that fall under the category of nutraceuticals include processed foods, herbal products, dietary supplements, and nutrients that have been isolated (Tesoriere, 2021). Nutraceuticals have been used for a long time, and Stephen DeFelice first used the phrase in 1989 (Caponio *et al*., 2022). Investigations have

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demonstrated the reason why nutraceuticals have attracted so much attention: the therapeutic function of nutraceuticals depends on their bioavailability, solubility, toxicity, and delivery mechanism (Caponio *et al*., 2022). Curcumin is a nutraceutical that has been termed "the golden nutraceutical" the term "golden" is attributed to it being the natural yellow pigment of turmeric. The popular name for Turmeric in English is yellow roots, and it has a variety of uses that improve health and they include fighting cancer, ulcers, inflammation, and other ailments, as well as being antifungal, antimicrobial, and protecting the kidneys and liver to name a few (Pakhare *et al*., 2020). This natural compound and its potential health benefits prove a step forward in advancing medicinal practices and procedures in today's world.

History of Curcumin

Curcumin is an important spice whose origin can be traced to Asia. The rhizomes of the plant *Curcuma longa* are where curcumin is found. *Curcuma longa* otherwise known as Turmeric belongs to the Zingiberaceae family and is one of the most useful and effective herbal medicinal plants (Pakhare *et al*., 2020). *Curcuma longa* can be cultivated in a variety of environmental situations at a temperature range of 20–35°C with yearly rain of 1500 mm. This spice has several distinct names around the world and is used extensively in cooking. For instance, in Persia, it is known as *Zardchoob* (Ahmad *et al*., 2020).

Along with its history of use, turmeric has played an essential role in treatment mechanisms particularly Ayurveda and ancient Chinese means where it had a restorative effect in numerous diseases that vary from seemingly simple ailments to complicated chronic sicknesses. In ancient Chinese therapy, turmeric is employed to promote blood flow. Turmeric grows in humid climates and is dispersed in tropic and semitropic regions, especially in India, China, and geographic regions. (Liu *et al*., 2022). When examining ancient texts, particularly those from India, turmeric is the plant that is most significant. The ancient Indian medical system Ayurveda regularly mentions both its name and its application. In actuality, Turmeric is used for a variety of things, including paint, condiments, and medication. Turmeric is referred to as "Haridara" in Sanskrit, a two-part term. In India, turmeric has been used in a variety of ways as a coloring and flavoring agent with digestive qualities. In fact, Turmeric is a necessary component of every Indian dish. Hindus hold turmeric in high regard, and interestingly, Turmeric powder is distributed as "Prasad" (a benign material) at several temples (Arli & Celik, 2020). It has been discovered that the use of turmeric encompasses a potential to soothe coarse skin, was further used as a tonic and a blood cleanser in ancient Indian medical systems, could conserve the raw freshness and its nourishing properties of food that are liable to biodegradation and rot. It is known as the "Indian saffron" because of its very distinct yellow color in Southeast Asia and is used as a resource in religious events (Pakhare *et al*., 2020). Since the dawn of time, Sri Lanka and other South Asian nations have used turmeric for culinary, medicinal, religious, and cosmetic uses. Turmeric gives curries their distinct yellow colour and flavour, and it is utilised as a colouring ingredient in dairy and other food sectors. Turmeric was utilised in the past by Hindus to heal sprains and swellings. With the use of evidence-based study, the scientific community has validated the therapeutic properties of turmeric that were employed in antiquity. The natural flavonoid, curcumin has a number of pharmacological properties, such as anti-inflammatory, antioxidant, anti-angiogenic, anticarcinogenic, and apoptogenic, antibacterial, and neuroprotective activity (Silva *et al*., 2021).

Biochemistry of Curcumin: Solubility and Class of Compound

Curcumin, known scientifically as diferuloylmethane, contains polyphenols. It is the active ingredient of turmeric whose other components are desmethoxycurcumin and

bisdemethoxycurcumin are known as curcuminoids in conjunction with curcumin (Sahoo *et al*., 2021). Known as a curcuminoid, curcumin with its IUPAC name as 1,7-bis(4-hydroxy-3-methoxyphenyl) hept-3-ene-1,6-dione is a lipophilic and hydrophobic polyphenol (Jabczyk *et al*., 2021). Curcuminoids are orange-yellow tinted compounds that are available in Turmeric and are structurally related to the major bioactive component of Turmeric: curcumin. They are soluble in polar organic solvents such as acetone, methanol, and ethanol but are not readily soluble in water, lipids, and hydrocarbons which explains it being lipophilic and as well as hydrophobic (Zhang & Kitts, 2021). Although curcumin is soluble in polar and non-polar organic solvents as well as in extremely acidic solvents like alkali or glacial acetic acid, it is practically insoluble in water at acidic and neutral pH levels. The melting point of curcumin is 183 °C. Curcumin has the chemical formula $C_{21}H_{20}O_6$, and a mass of 368.38 dalton (Arli & Celik, 2020).

Chemically speaking, curcumin is a beta diketone molecule composed of two phenyl rings that have methoxy and hydroxy groups substituting for them in the meta and ortho positions, respectively. When keto is present at an acidic or neutral pH and enol is present at an alkaline pH, they easily form keto-enol isomers. Its molecular weight is 368.39 gm/mol (Agrawal & Jaiswal, 2022). It demonstrates keto-enol tautomerism, which means that while it primarily exists in the keto form in neutral and acidic solutions, its more stable enol form predominates in solid form in alkaline solutions (Sharifi-Rad *et al*., 2020).

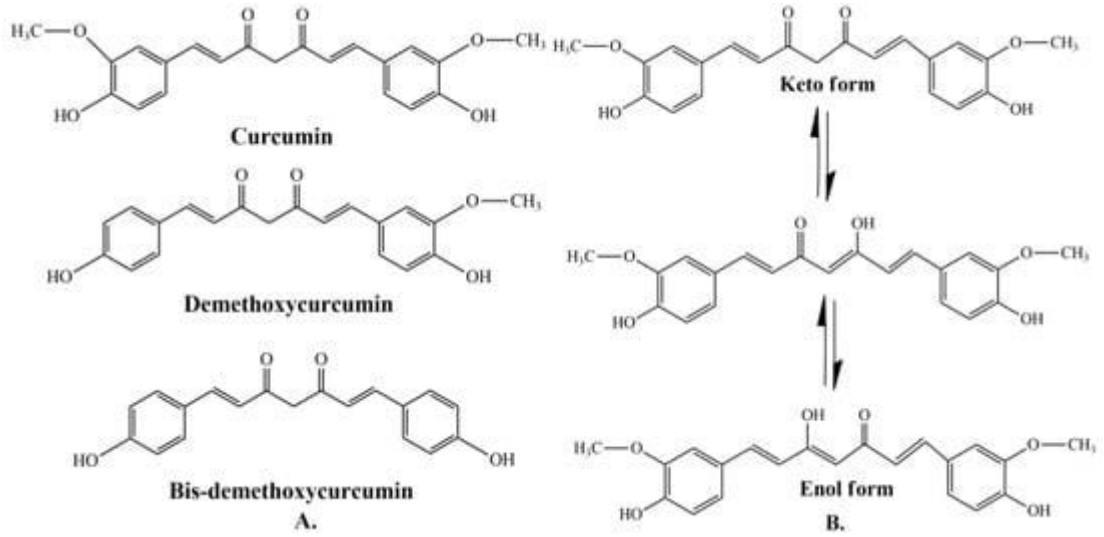

Figure 1: The chemical structure of curcuminoids found in turmeric (Liu *et al*., 2022;Racz *et al*., 2022)

Bioactive Ingredients in Curcumin and their Importance

Bioactive ingredients are those that contain compounds with biological activities. This refers to compounds that can exert a directly related nutritional effect on the human body. They are components in diet asides from those required for day-to-day functions which control changes in an individual's state of health and well-being. Studies which range from *in vitro* to *in vivo* experiments showed that curcumin, the major component of turmeric has biological activities, contains vitamins or vitamin precursors that produce ascorbic acid, beta-carotene, polyphenols, fatty acids, and essential oils mainly terpenoids (Ugo *et al*., 2022). These nutrients indicate the effective and important nature of curcumin. With beta-carotene being a precursor to vitamin A, it shows curcumin's role in human growth and development as vitamin A, a retinoid is necessary for several functions in the human body like aiding with cell differentiation, vision, sight, and immune function as vitamin A aids in sustaining the

epithelium. It also shows curcumin's antioxidant role as ascorbic acid helps in stabilizing free radicals which can cause damage and leads to oxidative stress if not properly managed.

Table 1: Role of curcumin in selected bioactivity linked to diseases

Health disorder	Reported bioactivity
Oxidative stress	Antioxidant
Inflammation and inflammatory diseases	Anti-inflammatory , Immunomodulatory
Allergy	Anti-allergic
Cardiovascular diseases	Hypolipidemic, Atheroprotective, Cardioprotective
Diabetes	Hypoglycemic, Antiglycation, Antidiabetic
Cancer	Antitumor, Pro-apoptic, Antimetastic, Anticancer
Neurodegenerative diseases	Neuroprotective
Depression	Antidepressant
Liver diseases	Hepatoprotective

(Zhang & Kitts, 2021)

Recommended Daily Intake of Curcumin

This herb's excellent safety record is maybe its most intriguing feature. There is no evidence of any toxicity linked to *C. longa* or its chemical components in either animal studies or human studies, and this is true even at larger doses. Using healthy volunteers, dosage escalation research was conducted to determine the maximum tolerated dose and safety of a single dose of standardized curcumin powder. The results showed that doses of 500 to 12,000 mg of curcumin were extremely well tolerated. However, in life, the general rule that applies is that consumption of any substance in excess is not a wise idea as it could lead to complications as nephrotoxicity, diarrhoea, elevated liver function tests, and an increased risk of bleeding have all been linked to high dosages of curcumin (Silva *et al*., 2021) This indicates that while this is a "wonder-working herb" of some sort, its use should also be in moderation. It has been speculated that the weak water solubility and rapid gastrointestinal digestion of curcumin, which lower its bioavailability, may contribute to the substance's low toxicity (Ugo *et al*., 2022).

Bioavailability and Biocompatibility of Curcumin

Despite curcumin being a powerful herb and spice, its role as a therapeutic agent is constrained by boundaries because it has low bioavailability. Bioavailability can be explained simply as the degree to which a substance or medicine is fully absorbed by its designated biological target. The fundamental issue with curcumin is that it is unstable under poor absorption, is quickly metabolized and is rapidly eliminated as it is not retained for extended periods in the human body due to the inclusion of a functional methylene group and a p-diketone fragment. These issues contribute to the obstacles in the intake of curcumin alone as they affect the bioavailability of curcumin (Arli & Celik, 2020). Asides these, other reasons account for curcumin's limited bioavailability: low water solubility which means that its efficacy can be limited when taken orally, poor absorption, and significant metabolic conversion. Although curcumin's polarity and slow rate of dissolution contribute to its limited solubility in water, its lipophilic nature plays a critical role in its malabsorption (Ugo *et al*., 2022).

Although curcumin availability may vary across different people because of the microbiota present in the human gut, various methods of improving the biological and pharmacological activity of curcumin have emerged, one of them being nanoencapsulation (Jabczyk *et al*., 2021). Other methods which have surfaced boost the stability and solubility of curcumin, including the addition of human serum albumin or other proteins, integration into oil-in-water emulsions, or the use of solid dispersion innovation technology. It is crucial to increase

curcumin stability against degradation in order to increase bioavailability during intestinal absorption (Racz *et al*., 2022)

Methods of Enhancing the Bioavailability of Curcumin

1. **Nanoencapsulation**- In order to preserve the coated component (food or taste molecules/ingredients), nanoencapsulation is a technique that involves encasing a bioactive substance in its liquid, solid, or gaseous form inside of a matrix or inert substance (Pateiro *et al*., 2021). Conjugates, cyclodextrins, solid dispersions, micelles, nanospheres, nanogels, and nanodisks are the curcumin nanoformulations that are most advantageous. Liposomes, polymers, magnetic nanoparticles, solid lipid nanoparticles (SLNs), solid dispersions, micelles, and solid dispersions are also among them. Due to the increase in solubility and oral bioavailability, conjugating curcumin with molecules and hydrophilic polymers is effective. Curcumin's biological action is enhanced by many different nanoformulations such as nanogels and, nanodisks. These techniques could be useful for limiting medication release and circulation (Jabczyk *et al*., 2021). According to studies, oral administration of curcumin as nanoparticles increases its usage 5–6 times more than oral administration of the standardized extract because the nanoparticles dissolve more easily in the gastrointestinal tract due to their greater water solubility. Additionally, nanoparticles may be designed to release gradually, and they are non-toxic, biodegradable, and do not trigger allergic reactions in people (Ugo *et al*., 2022).

2. **Addition of curcumin to proteins**- It has been suggested that complexation with proteins is a promising method for improving curcumin's negative pharmacokinetic and antioxidant properties, as well as its bioavailability and solubility in aqueous solutions. The field of biomedical nanoparticles has made extensive use of protein-based carriers. A self-assembly process occurs when the hydrophobic curcumin is combined with an amphiphilic protein in an aqueous environment. The hydrophobic core of the protein is confined in this instance, and the hydrophilic surface generates a micelle structure. Numerous studies have shown how complexing with milk proteins such as casein, whey protein isolate (WPI), and bovine serum albumin or with plant-derived proteins like sunflower protein isolate, mung bean protein, and soy protein can alter the properties of curcumin. The ability of proteins obtained from plant sources to bind water-insoluble curcumin to hydrophobic regions and enhance curcumin's water solubility and stability through complexation has been demonstrated in all of the experiments. By making curcumin more stable against degradation, its bio availability during intestinal absorption would improve. In this regard, it is known that whey proteins can result in cold-set hydrogels. This process, known as cold-set gelation, entails two steps that happen in succession: i) heating a protein solution to create soluble aggregates; and (ii) cooling the resulting solution before adding salt to induce cold gelation (by adding $CaCl_2$ and NaCl) or acid to generate cold gelatins (adding glucono-D-lactone). The cold-set whey protein hydrogels may be prone to enzymatic breakdown because of their low mechanical resistance. Obtaining gels based on proteins and polysaccharides that have the ability to remain intact in some regions of the superior gastrointestinal tract, then breakdown and deliver the active ingredient in the colon, would be a solution for prevention. These characteristics suggest that whey protein isolate glycation with glucose may boost the bioavailability of curcumin.

3. **Innovation in solid dispersion technology** -This has proved one of the most widely used and effective techniques in the medical profession for increasing the solubility and dissolution rates and, consequently, the bio availability of molecules with limited

solubility. It is predicated on the notion that the hydrophobic molecule is disseminated in a solid, inert carrier that has the ability to dissolve in water. There are three categories which solid dispersion occurs, which is based on the carrier that was utilized. One of them is the third-generation solid dispersion process, in which active molecules are dispersed in a surfactant or a blend of amorphous polymers and surfactants. The use of a water-soluble polymer and surfactant combination greatly improved the bioavailability of a low water-soluble medication. Polyethylene glycols (PEG) have been used in various research studies as carriers for third-generation solid dispersions. The curcumin molecules connect to the polyethylene glycols chains either covalently or noncovalently during the PEGylation process and this enhances curcumin hydrophilicity, increases its solubility better than raw curcumin and allows it remain chemically stable in emulsion (Racz *et al*., 2022).

4. **Co-ingestion with Lipids**- By enclosing curcumin in mixed micelles produced by lipid hydrolysis in the GIT, curcumin co-ingestion with lipids can help improve curcumin solubility and bio accessibility. In addition to preventing curcumin from being destroyed, co-ingestion with lipids enhances its absorption into the GIT epithelial lining. The length of the fatty acid chains and the level of saturation influence how soluble nutraceuticals are in mixed micelles. It has been discovered that utilizing medium-chain triglycerides (MCT) and long-chain triglycerides (LCT) improves the solubility and bio accessibility of curcumin. Curcumin's bioavailability is increased when combined with piperine (an alkaloid found in black pepper), liposomal, and phospholipid substances (Ugo *et al*., 2022)

Diabetes: Types, Cause, Onset, and Symptoms

Diabetes is a very prevalent disorder that is rampant and becoming an epidemic in various parts of the world. This is largely an issue due to the fact it is a disorder with no scientific cure yet. The French word "jiyabatis" (meaning a pitcher with a hole or a pitcher with a leak, causing water to spray out) is where the word "diabetes" first appeared. The term "diobos" refers to a fountain with a meaning akin to that of the fountain, from which the word "diabetes" is derived. The Greek words for "diabetes" translates to "to go through a syphon" in English and "mellitus" means honey. Diabetes then, is group of disorders which include chronic hyperglycemia, polyuria, polydipsia, polyphagia, emaciation, and weakness brought on by disturbances in the metabolism of carbohydrates, fats, and proteins that are linked to an absolute or relative deficiency in insulin secretion and/or action (Silva *et al*., 2021).

In 2021, it was estimated that 27 million people aged 20 to 79 had diabetes, according to data from the International Diabetes Federation (IDF) Atlas. It is predicted that this figure would probably rise to 653 million by 2030. These statistics indicate that diabetes is a common condition that is seen as a major problem worldwide (Mahmoudi *et al*., 2022).

Diabetes is brought on by a number of unique pathologic mechanisms. These range from abnormalities that cause insulin resistance to the autoimmune death of the pancreatic beta cells. As insulin fails to effectively operate on its target tissues, diabetes results in abnormalities in the metabolism of glucose, lipids and proteins. Insulin shortage is brought on by inadequate insulin synthesis and/or diminished tissue responses along the intricate hormone activity pathways at one or more sites. These relations of diabetes lead to the broad classification of diabetes into three types (Mahmoudi *et al*., 2022). Type 1 diabetes mellitus, type 2 diabetes mellitus, and gestational diabetes mellitus are the different types of the disease. The primary characteristic of type 1 diabetes mellitus is the precise and selective death of pancreatic beta cells whose role is insulin secretion. In type 1 diabetes, the immune system

attacks pancreatic islet cells; hence, it is referred to as an autoimmune condition. The fact that there is a lack of insulin is a distinguishing factor of type 1 diabetes mellitus whether the cause is autoimmune or idiopathic. Insulin resistance and insulin hypersecretion in the Islet of Langerhans beta-cells of the pancreas are two features of Type 2 diabetes mellitus along with hyperglycemia. Regarding insulin resistance and beta -cell dysfunction, the severity of type 2 diabetes mellitus differs. The main contributor to the onset of type 2 diabetes mellitus is the resistance to insulin by the cells which need to utilize insulin for glucose uptake. In most cases, insulin resistance results from a dysfunction in the insulin signalling pathways, which causes the target tissues to respond to circulating insulin either insufficiently or not at all. Insulin resistance, ageing, obesity, and inflammation are all related to diabetes mellitus. An increase in glucose intolerance that manifests while pregnant is known as gestational diabetes mellitus (GDM). The diagnosis of gestational diabetes mellitus (GDM) is made by examining pregnant women for clinical risk factors and at-risk individuals for decreased glucose tolerance, which is typically mild and subclinical.

There are a number of various methods in which diabetes mellitus is diagnosed. If one or more of the following conditions are present: fasting blood sugar level at 7.0 mmol/L which is equivalent to 126 mg/dl, two-hour oral glucose tolerance test (OGTT) at a level of 11.1 mmol/L which is equivalent to 200 mg/dl, or the haemoglobin A1C or HbA1c test which measures the glycosylated hemoglobin in the blood spanning over the previous 3 months which is the average blood span of a red blood cell. In the presence of hyperglycemia symptoms, random plasma glucose is 11.1mmol/L (200mg/dl). If one or more of these conditions are present, the appropriate diagnosis is diabetes (Utura & Fikrie, 2022).

Regarding an elevation in blood sugar levels, many intrinsic factors could be the cause. Numerous endogenous factors raise blood glucose levels. Glucagon, adrenaline, and cortisol are three distinct hormones that elevate blood sugar levels. By promoting gluconeogenesis and glycogenolysis, these hormones raise blood glucose levels. For extrinsic factors, carbohydrate obtained from the diet is the primary external factor that leads to an increase in blood glucose levels.

When it comes to a decrease in blood glucose levels, a loss of carbohydrate in diet or a reduction of carbohydrate obtained from diet would lead to a reduction in blood sugar levels. Physiologically, the blood glucose also drops when physical activity or exercise is increased. Blood sugar levels are also dropped when cells utilize glucose for energy (Westman, 2021).
Various studies have determined various factors that increase the risk of diabetes. Poor eating and dietary practices, tobacco use, physical inactivity, overweight and obesity, excessive alcohol use, advanced age and hypercholesterolemia are the most prevalent (Utura & Fikrie, 2022).

The role of curcumin in diabetes management: therapeutic and preventive methods
Numerous studies have been conducted which shows curcumin's efficacy against the metabolic disorder, diabetes. As it stands, there is no cure for diabetes, but curcumin has been found to possess remarkable therapeutic properties that can reduce the symptoms associated with the disease. Various researches have shown that the yellow-colored polyphenol curcumin, which is present in *C. longa*, has the bioactivities necessary to treat disease and the problems of diabetes. Curcumin's hypoglycemic activity is its most valuable medicinal effect. Insulin resistance, in which insulin has little to no biological impact on tissues or cells, is a primary aetiology of diabetes mellitus (DM). Insulin resistance, which occurs when cells are unable to use insulin that is present, is the main problem with type 2 diabetes mellitus. Greater

and more severe complications, including hyperlipidemia, hyperuricemia, and cardiovascular disease, might result from this disorder (Silva *et al*., 2021). Preclinical research using animal models and clinical trial results of type 2 diabetes mellitus demonstrated that curcumin significantly lowers fasting plasma glucose and glycated haemoglobin (HbA1c) levels. Curcumin also effectively lowers triglycerides and low-density lipoprotein cholesterol (LDL-C) when treating metabolic syndrome, there are also improvements in insulin resistance and fasting blood sugar levels, as well as a decrease in alanine aminotransferase levels and body weight. The activities of glucose transporters on the cell membranes of cells in the intestinal lining and carbohydrate-digesting enzymes in the gastro-intestinal tract can also be inhibited by curcumin treatments, suggesting that curcumin inhibits both carbohydrate digestion and glucose absorption, which lowers the blood glucose fluctuation range after food intake (Fu *et al*., 2021).

Also, many other pathways for curcumins' antidiabetic action have been proposed. Several instances include- the ability to demonstrate strong inhibitory activity against human pancreatic amylase (HPA), activation of pancreatic sites to lower blood sugar levels, and the ability to directly stimulate pancreatic beta-cell function. A 9-month intervention was conducted in a cohort of people with pre-diabetes receiving 1500 mg/day of curcumin. Following that, the number of people developing diabetes mellitus markedly reduced. On the other hand, people with confirmed type 2 diabetes mellitus have benefitted from the administration of curcuminoids. Additionally, curcumin facilitates its hypoglycemic and insulin-sensitizing effects by decreasing plasma glucose and inflammation-induced hyperglycemia, decreasing hepatic gluconeogenesis and promoting glucose uptake by up-regulating the expression of glucose transporter type 4 (GLUT4), type 2 (GLUT2), and genes for type 3 (GLUT3), and activating AMP kinase, enhancing the activity of cells in the pancreas and lowering insulin resistance, strengthening the effects of ligands in the pancreas, and inducing insulin release from pancreatic tissues. Furthermore, curcumin increases overall nuclear factor erythroid 2-related factor 2 (Nrf2) mediators, which suppress insulin resistance in liver cells caused by reactive oxygen species (ROS). In addition, studies using several animal diabetic models have shown that curcumin has positive benefits on DM by improving insulin sensitivity and reducing blood glucose levels (Silva *et al*., 2021).

Complications and Dangers of Mismanaged Diabetes

A decline in insulin production or function is the underlying cause of diabetes. The kidneys, heart, eyes, nerves, heart, and blood arteries are just a few of the organs that diabetes is linked to long-term damage, dysfunction, and failure of. Long-term microvascular and macrovascular complications from diabetes can lead to cerebrovascular disease, peripheral arterial disease, nephropathy, retinopathy, and other conditions like these: neuropathy, cerebrovascular disease, atherosclerotic cardiovascular disease, and peripheral arterial disease.

Diabetes that is untreated or inadequately managed can also cause renal failure, blindness, and amputation of the lower extremities (Utura & Fikrie, 2022). The probability of microvascular and macrovascular problems rises even after a diagnosis of DM, depending on how long it took from hyperglycemia to the diagnosis. Therefore, it is critical that diabetes mellitus be identified and treated in individuals with high blood sugar levels otherwise known as hyperglycemia as soon as an opportunity presents itself. It is also important to observe the time period until the patient was diagnosed or until the patient began to receive treatment and to check the prevalence of these complications at these times. These challenges

and complications in diabetes management emphasizes the need for better strategies in the management of this disorder as it is one that is yet to have an effective cure (Jeong & Kang, 2022).

Challenges and Limitations faced in Managing Diabetes with Curcumin

While curcumin is a wonder working component of *Curcuma Longa* that has shown promising and effective methods of reducing the progressiveness of diabetes, it is not an absolute cure for this highly rampant disorder. Since curcumin is a phenolic molecule, its main limitations include its solubility in water being limited, poor stability, and poor biodegradability when consumed by living things. These limitations necessitate a need for the bioavailability of curcumin to be enhanced in order to make it an effective therapeutic agent.

CONCLUSION

The benefits of curcumin are not limited and the possibilities it offers in modern medicine look promising. Curcumin is actively involved in reducing insulin resistance, glycosylated hemoglobin and fasting insulin, according to recent studies on phytochemicals, which results in optimal diabetes management. Previous studies have demonstrated that the safe phytochemical curcumin can reduce oxidative stress, inflammation, and insulin resistance caused by obesity. Future research is required to examine the structure activity connection of curcumin in order to create novel curcumin compounds that are more potent than natural curcumin due to curcumin's poor bioavailability.

However, with all the researches that have been done so far on this wonder herb, it is without a doubt that it still has more potential to unlock and more uses yet to be discovered in modern medicine. Diabetes is a drastic non-communicable disease with a number of complications which can be effectively managed, not cured, with curcumin, Asia's wonder herb. Truly, the "wonder drug of life" is an intriguing nickname for this natural polyphenol as it is universally known.

REFERENCES

Agrawal, N., & Jaiswal, M. (2022). Bioavailability enhancement of curcumin via esterification processes: A review. *European Journal of Medicinal Chemistry Reports*, *6*: 100081. https://doi.org/10.1016/j.ejmcr.2022.100081

Ahmad, R. S., Hussain, M. B., Sultan, M. T., Arshad, M. S., Waheed, M., et al. (2020). Biochemistry, safety, pharmacological activities, and clinical applications of turmeric: A mechanistic review. *Evidence-Based Complementary and Alternative Medicine*, *2020*: 1-14. https://doi.org/10.1155/2020/7656919

Arli, M., & Celik, H. (2020). The Biological Importance of Curcumin. *Eastern Anatolian Journal of Science*, *6*(1): 21-34.

Caponio, G. R., Lippolis, T., Tutino, V., Gigante, I., De Nunzio, V., et al. (2022). Nutraceuticals: Focus on anti-inflammatory, anti-cancer, antioxidant properties in gastrointestinal tract. *Antioxidants*, *11*(7): 1274. https://doi.org/10.3390/antiox11071274

Fu, Y., Chen, T., Weng, L., Huang, L., Lai, D.,et al. (2021). Pharmacological properties and underlying mechanisms of curcumin and prospects in medicinal potential. *Biomedicine & Pharmacotherapy*, *141*: 111888. https://doi.org/10.1016/j.biopha.2021.111888

Hussain, Y., Khan, H., Alotaibi, G., Khan, F., Alam, W., et al. (2022). How curcumin targets inflammatory mediators in diabetes: Therapeutic insights and possible solutions. *Molecules*, *27*(13): 4058. https://doi.org/10.3390/molecules27134058

Jabczyk, M., Nowak, J., Hudzik, B., & Zubelewicz-Szkodzińska, B. (2021). Curcumin in metabolic health and disease. *Nutrients*, *13*(12): 4440. https://doi.org/10.3390/nu13124440

Jeong, I., & Kang, C. (2022). Time to diagnosis and treatment of diabetes mellitus among Korean adults with hyperglycemia: Using a community-based cohort study. *International Journal of Environmental Research and Public Health*, *19*(19): 12090. https://doi.org/10.3390/ijerph191912090

Liu, S., Liu, J., He, L., Liu, L., Cheng, B., et al. (2022). A comprehensive review on the benefits and problems of curcumin with respect to human health. *Molecules*, *27*(14): 4400. https://doi.org/10.3390/molecules27144400

Mahmoudi, A., Atkin, S. L., Nikiforov, N. G., & Sahebkar, A. (2022). Therapeutic role of curcumin in diabetes: An analysis based on Bioinformatic findings. *Nutrients*, *14*(15): 3244. https://doi.org/10.3390/nu14153244

Pateiro, M., Gómez, B., Munekata, P. E., Barba, F. J., Putnik, P., et al. (2021). Nanoencapsulation of promising Bioactive compounds to improve their absorption, stability, functionality and the appearance of the final food products. *Molecules*, *26*(6): 1547. https://doi.org/10.3390/molecules26061547

Racz, L. Z., Racz, C. P., Pop, L., Tomoaia, G., Mocanu, A., et al. (2022). Strategies for improving bioavailability, Bioactivity, and physical-chemical behavior of curcumin. *Molecules*, *27*(20): 6854. https://doi.org/10.3390/molecules27206854

Sahoo, J. P., Behera, L., Praveena, J., Sawant, S., Mishra, A., et al. (2021). The golden spice turmeric (<i>Curcumalonga</i>) and its feasible benefits in prospering human health—A review. *American Journal of Plant Sciences*, *12*(3): 455-475. https://doi.org/10.4236/ajps.2021.123030

Sharifi-Rad, J., Rayess, Y. E., Rizk, A. A., Sadaka, C., Zgheib, R., et al. (2020). Turmeric and its major compound curcumin on health: Bioactive effects and safety profiles for food, pharmaceutical, biotechnological and medicinal applications. *Frontiers in Pharmacology*, *11*. https://doi.org/10.3389/fphar.2020.01021

Silva, P. A., Arawwawala, L. D., Kumari, M. W., & Galappatthy, P. (2021). Effect of curcuma longa L. and curcumin on diabetes and it's complications: A review. *Journal of Ayurvedic and Herbal Medicine*, *7*(2): 109-118. https://doi.org/10.31254/jahm.2021.7209

Singh, A., Shafi, Z., Mahto, S.K., Yadav, S. & Sankhwar, R. (2020). Role and Application of Curcumin as an Alternative Therapeutic Agent. *Advances in Microbiology Research,* 4: 014 DOI: 10.24966/AMR-694X/100014

Tesoriere, L. (2021). Update on nutraceuticals. *Nutraceuticals*, *1*(1): 1-1. https://doi.org/10.3390/nutraceuticals1010001

Ugo, C. H., Nnaemeka, M., Arene, E. C., Anyadike, I. K., Opara, S. O., et al. (2022). Nutritional composition, bioavailability, medicinal functions and uses of turmeric: A review. *Scholars Bulletin*, *8*(8): 248-260. https://doi.org/10.36348/sb.2022.v08i08.003

Utura, T., & Fikrie, A. (2022). Prevalence and associated factors of diabetes mellitus among governmental civil servants at Guji zone, Oromia Region, Ethiopia, 2021. A community-based cross-sectional study. *Plos one*, *17*(4): e0267231. https://doi.org/10.1371/journal.pone.0267231

Westman, E. C. (2021). Type 2 diabetes mellitus: A Pathophysiologic perspective. *Frontiers in Nutrition*, *8*: 1-5. https://doi.org/10.3389/fnut.2021.707371

Zhang, H. A., & Kitts, D. D. (2021). Turmeric and its bioactive constituents trigger cell signaling mechanisms that protect against diabetes and cardiovascular diseases. *Molecular and Cellular Biochemistry*, *476*(10): 3785-3814. https://doi.org/10.1007/s11010-021-04201-6