IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Herbal Approaches In Management Of Diabetes Mellitus: A Comprehensive Review

[1]Mr. Aniket Dinesh Trupkane, [2]Mr. Rushikesh Lande, [3]Dr. Vijaykumar Kale, [4]Dr. Mahesh Thakare, [5]Mr. Vaibhav Narwade

[1]Student, Kasturi Shikshan Sanstha's College of Pharmacy,Shikrapur, Pune – 412208, India

[2]Assistant Professor,Department of Pharmaceutical Chemistry,Kasturi Shikshan Sanstha's College of Pharmacy,Shikrapur, Pune–412208, India,

[3]Principal,Kasturi Shikshan Sanstha's College of Pharmacy,Shikrapur, Pune – 412208, India

[4]Head of Department,Department of Pharmaceutics,Kasturi Shikshan Sanstha's College of Pharmacy,Shikrapur, Pune –412208,India,

[5]Assistant Professor,Department of B. Pharmacy, Kasturi Shikshan Sanstha College of Pharmacy, Shikrapur, India.

Abstract: Diabetes mellitus represents a chronic metabolic disorder characterized by hyperglycemia and impaired glucose homeostasis affecting hundreds of millions individuals globally with profound implications for morbidity, mortality, and healthcare expenditure. Conventional pharmaceutical therapies including insulin preparations and synthetic oral agents, while therapeutically effective, demonstrate variable individual responses and substantial adverse effect profiles limiting long-term clinical applicability. Medicinal plants represent valuable therapeutic reservoirs containing diverse phytochemical compounds demonstrating significant antidiabetic properties through multiple complementary mechanisms. Contemporary scientific investigation validates traditional herbal medicine approaches through comprehensive preclinical investigations and clinical trials demonstrating remarkable efficacy in glucose control and diabetes complication prevention. Phytochemical constituents including flavonoids, alkaloids, polyphenols, terpenoids, and saponins exert antidiabetic effects through diverse pathways encompassing enhanced insulin secretion, improved insulin sensitivity, inhibition of carbohydrate-digesting enzymes, stimulation of pancreatic beta cell regeneration, and modulation of glucose transporters. Gymnema sylvestre demonstrates exceptional efficacy through mechanisms promoting pancreatic beta cell proliferation and suppressing sweet taste sensation reducing sugar consumption. Bitter melon (Momordica charantia) activates multiple glucose uptake pathways including AMPK activation and GLUT4 translocation enhancing cellular glucose utilization. Fenugreek (Trigonella foenum-graecum) stimulates glucose-dependent insulin secretion while improving hepatic glucose metabolism. Curcuma longa and related spices including cinnamon activate AMP-activated protein kinase pathways fundamentally regulating glucose and lipid metabolism. Clinical evidence demonstrates herbal formulations reduce blood glucose levels, improve insulin sensitivity, and decrease hemoglobin A1c measurements with superior safety profiles compared with conventional agents. Emerging research emphasizes integration of evidence-based herbal therapeutics with pharmaceutical approaches enabling personalized medicine strategies optimizing individual therapeutic outcomes. Future advancement requires comprehensive long-term safety surveillance, standardization of herbal preparations, biomarker identification predicting responder populations, and development of evidence-based clinical guidelines facilitating informed therapeutic decision-making.

Keywords - Herbal Medicine, Antidiabetic Plants, Phytochemicals, Diabetes Mellitus, Glucose Control, Traditional Medicine, AMPK Pathway, Insulin Sensitivity

I. INTRODUCTION

1.1 Diabetes Mellitus: Epidemiology and Therapeutic Burden

Diabetes mellitus represents one of humanity's most significant health challenges, with global prevalence affecting approximately 463 million adults and *projecti*ons indicating continued escalation reflecting sedentary lifestyles, dietary transitions, and aging populations[1]. The disease encompasses multiple pathophysiological variants including type 1 diabetes (autoimmune insulin deficiency) and predominantly more prevalent type 2 diabetes (insulin resistance with progressive beta cell dysfunction), with intermediate categories demonstrating overlapping pathophysiology. Chronic hyperglycemia characteristic of diabetes precipitates devastating complications including retinopathy, nephropathy, neuropathy, cardiovascular disease, and premature mortality, establishing profound global health burden. Conventional pharmaceutical therapies including insulin preparations, sulfonylureas, biguanides, thiazolidinediones, and newer agents including dipeptidyl peptidase inhibitors demonstrate variable individual efficacy with frequent adverse effects including hypoglycemic episodes, gastrointestinal disturbance, fluid retention, bone loss, and heightened infection susceptibility[2].

1.2 Herbal Medicine as Complementary Therapeutic Approach

Medicinal plants have served therapeutic roles across traditional medicine systems including Ayurveda, Traditional Chinese Medicine, and indigenous *practice*s for centuries, with empirical recognition of diabetes management benefits. Contemporary scientific investigation increasingly validates traditional therapeutic wisdom through rigorous preclinical investigations and clinical trials establishing pharmacological mechanisms underlying observed antidiabetic effects[3]. Over 1,200 herbal species demonstrate documented antidiabetic properties, with approximately 410 species demonstrating experimental evidence for hypoglycemic activity. Herbal therapeutics offer potential advantages including natural derivation, multiple complementary mechanism activation, established safety profiles across extended use periods, and reduced healthcare costs compared with synthetic pharmaceuticals[4].

1.3 Scope and Organization of Review

This comprehensive review systematizes contemporary knowledge regarding herbal approaches in diabetes mellitus management, synthesizing evidence regarding phytochemical constituents, mechanistic pathways, traditional medicine formulations, clinical efficacy data, and therapeutic integration strategies. The review emphasizes evidence-based approaches integrating traditional wisdom with modern scientific validation, establishing foundation for informed clinical decision-making and future therapeutic development[5].

II. PHYTOCHEMICAL CONSTITUENTS AND MECHANISTIC PATHWAYS

2.1 Major Phytochemical Classes with Antidiabetic Properties

Medicinal plants synthesize diverse bioactive compounds demonstrating antidiabetic properties through multiple distinct mechanisms enabling complementary therapeutic effects. Flavonoid compounds including quercetin, rutin, and catechin demonstrate antioxidative properties, free radical scavenging, and direct effects on glucose transporters and enzymatic pathways[6]. Alkaloid phytochemicals including berberine, palmatine, and related compounds stimulate pancreatic beta cells, activate AMP-activated protein kinase pathways, and enhance insulin sensitivity through direct insulin receptor activation. Polyphenolic compounds including curcumin, resveratrol, and related substances modulate inflammatory pathways, enhance antioxidative enzyme expression, and regulate glucose metabolism through transcriptional mechanisms[7].

Terpenoid phytochemicals including those extracted from ginger, turmeric, and related plants activate AMPK phosphorylation, enhance glucose transporter expression, and suppress hepatic gluconeogenesis. Saponin glycosides demonstrate inhibitory activity against carbohydrate-digesting enzymes including alpha-amylase and alpha-glucosidase, thereby decelerating carbohydrate absorption and postprandial glucose elevation. Glycoside compounds including those present in bitter melon demonstrate direct pancreatic beta cell stimulation and insulin mimetic activity through receptor-mediated pathways.

2.2 AMPK Pathway Activation and Metabolic Regulation

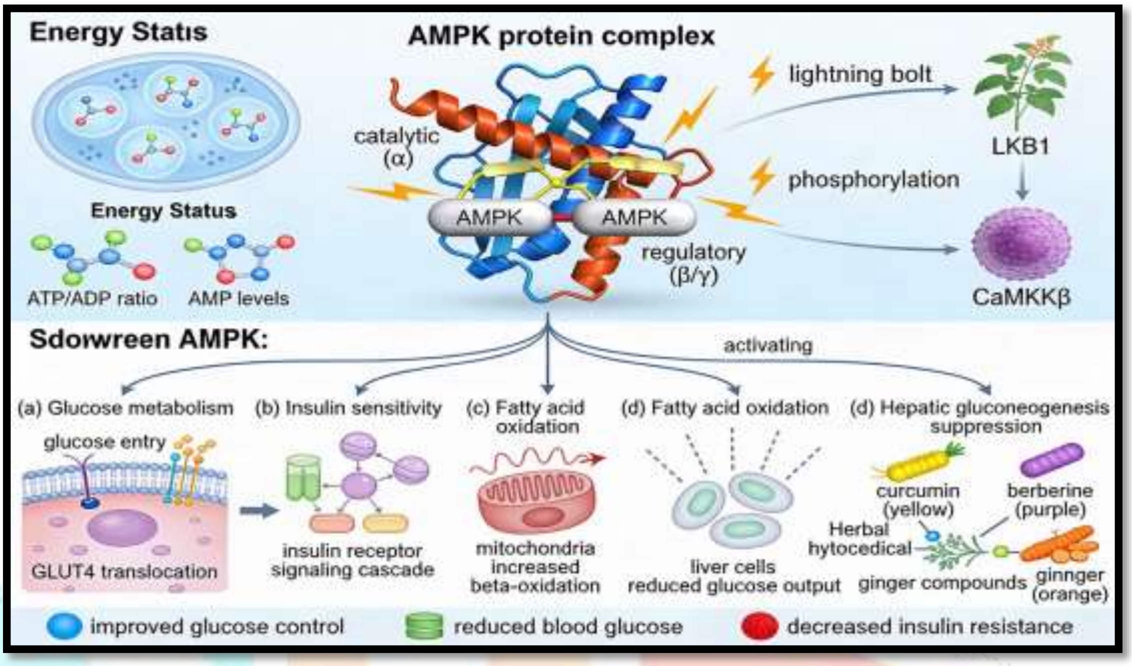

Fig 1: AMPK Pathway Activation

AMP-activated protein kinase represents central metabolic regulator orchestrating glucose utilization, fatty acid oxidation, and mitochondrial biogenesis through phosphorylation-dependent mechanisms. Activation of AMPK dramatically enhances glucose consumption within peripheral tissues, simultaneously inhibiting hepatic gluconeogenesis and glucose *product*ion, thereby producing profound antihyperglycemic effects[8]. Multiple herbal phytochemicals demonstrate capacity to activate AMPK through direct kinase activation or indirect mechanisms enhancing adenosine monophosphate concentrations stimulating AMPK activation.

Curcumin, the major bioactive constituent of turmeric, activates AMPK phosphorylation through mechanisms involving AKT stimulation and reduced phosphatase activity. Ginger phytochemicals including -gingerol enhance glucose uptake through AMPK-dependent mechanisms promoting GLUT4 translocation to cellular membranes facilitating glucose entry. Berberine activates AMPK with remarkable efficacy comparable to pharmaceutical AMPK activators, producing comprehensive metabolic regulation encompassing enhanced glucose utilization and reduced lipid accumulation[9].

2.3 Pancreatic Beta Cell Protection and Insulin Secretion Enhancement

Many herbal phytochemicals directly stimulate pancreatic beta cells through mechanisms enhancing glucose sensing and insulin gene expression. Flavonoids and polyphenolic compounds promote beta cell proliferation and prevent beta cell apoptosis through antioxidative mechanisms protecting cellular integrity. Alkaloids including those present in Coptis chinensis enhance insulin gene transcription and glucose transporter expression enabling improved glucose sensing within beta cells[10].

Stimulation of glucose-dependent insulin secretion represents particularly valuable mechanism, enabling insulin release exclusively in response to elevated blood glucose concentrations without precipitating hypoglycemic episodes characteristic of insulin secretagogue medications. Trigonelline present in fenugreek seeds demonstrates exceptional glucose-dependent insulin stimulation, with insulin secretion proportional to glucose concentrations preventing ectopic hypoglycemia. This physiologically-appropriate insulin secretion mechanism substantially improves therapeutic safety compared with conventional agents.

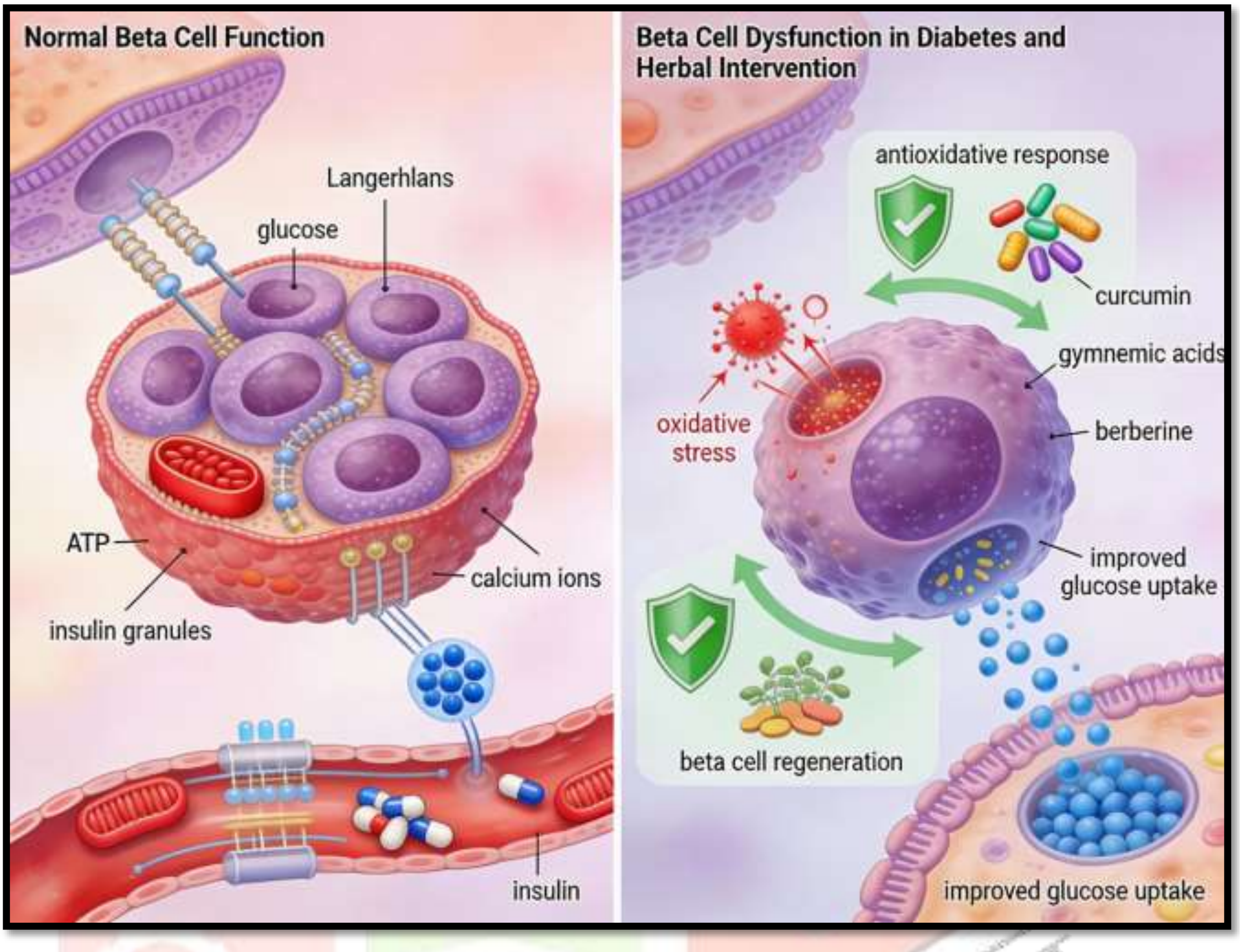

Fig 2: Pancreatic Beta Cell Mechanisms

III. EVIDENCE-BASED HERBAL PLANTS FOR DIABETES MANAGEMENT

3.1 Gymnema sylvestre: Pancreatic Beta Cell Regeneration and Sweet Taste Suppression

Gymnema sylvestre leaves represent exceptionally effective antidiabetic botanical with historical documentation of therapeutic benefits spanning millennia across Ayurvedic medical traditions. Active phytochemical constituents including gymnemic acids, saponins, and alkaloids exert multiple complementary antidiabetic mechanisms. Gymnemic acids suppress sweet taste sensation through molecular mechanisms blocking sweet taste receptors, thereby reducing sugar consumption and facilitating glycemic control through behavioral modification[11]. Contemporary mechanistic studies establish that gymnemic acids directly stimulate pancreatic beta cell regeneration and proliferation, restoring compromised insulin secretion capacity in type 2 diabetes.

Clinical investigations demonstrate that administration of Gymnema sylvestre extracts reduces fasting blood glucose concentrations approximately 23%, produces hemoglobin A1c reduction comparable to conventional antidiabetic medications, and enables substantial medication dose reductions in established diabetic patients. The herb demonstrates particular utility for type 2 diabetes management through complementary mechanisms addressing both behavioral factors (reduced sugar consumption) and pancreatic function restoration.

3.2 Momordica charantia: Multiple Glucose Uptake Pathways and Beta Cell Regeneration

Bitter melon fruit represents valuable antidiabetic botanical demonstrating multiple distinct mechanisms enhancing glucose utilization and controlling hyperglycemia. Charantin, a triterpenoid compound extracted from bitter melon, demonstrates insulin-mimetic activity stimulating glucose uptake through mechanisms activating glucose transporter expression and translocation. Additional bitter melon constituents including polypeptide-P demonstrate remarkable insulin-releasing activity[12]. Meta-analytic evidence demonstrates three-month bitter melon supplementation produces hemoglobin A1c reductions and improvements in postprandial glucose responses. Furthermore, bitter melon administration improves cardiovascular risk factors including triglyceride reduction and blood pressure normalization, addressing metabolic complications accompanying diabetes.

Bitter melon activates AMP-activated protein kinase pathways promoting glucose uptake while simultaneously increasing GLUT4 expression enabling enhanced cellular glucose utilization. This multi-pathway activation produces synergistic glucose-lowering effects exceeding single-mechanism approaches. Additionally, bitter melon stimulates pancreatic beta cell proliferation and insulin secretion, addressing underlying pathophysiology in type 2 diabetes.

3.3 Trigonella foenum-graecum: Glucose-Dependent Insulin Secretion and Hepatic Metabolism

Fenugreek seeds represent readily available botanical containing phytochemical constituents demonstrating significant antidiabetic potential. The amino acid derivative 4-hydroxyisoleucine isolated from fenugreek seeds demonstrates remarkable glucose-dependent insulin secretion stimulation in pancreatic beta cell preparations, enabling insulin release exclusively in proportion to blood glucose concentrations[13]. Trigonelline present in fenugreek enhances insulin sensitivity and hepatic glucose uptake through mechanisms improving glucose homeostasis without precipitating hypoglycemic complications.

Meta-analytic reviews synthesizing multiple clinical trials demonstrate fenugreek administration producing substantial fasting blood glucose reduction, postprandial glucose improvement, and hemoglobin A1c decrease. Medium-to-high dose fenugreek preparations (15-25 grams daily) produce superior glycemic reduction compared with lower doses, establishing dose-dependent therapeutic responses. The botanical demonstrates established safety across extended treatment durations and multiple patient populations.

3.4 Curcuma longa and Cinnamomum Species: AMPK Activation and Antioxidative Mechanisms

Curcumin extracted from turmeric rhizomes demonstrates potent antidiabetic activity through multiple interconnected mechanisms including prominent AMPK activation. Curcumin therapy enhances insulin sensitivity through AMPK-dependent mechanisms, with phosphorylated AMPK substantially increased following curcumin administration. Anti-inflammatory and antioxidative properties of curcumin substantially ameliorate oxidative stress implicated in diabetes development and progression[14].

Cinnamon species including Cinnamomum cassia demonstrate substantial antidiabetic effects through mechanisms including AMPK activation and glucose transporter modulation. Cinnamon polyphenols enhance insulin sensitivity and glucose tolerance while reducing postprandial glucose elevation in both type 1 and type 2 diabetes. Clinical investigations demonstrate regular cinnamon consumption substantially improves fasting glucose concentrations and reduces hemoglobin A1c in established diabetic patients.

3.5 Additional Evidence-Based Medicinal Plants

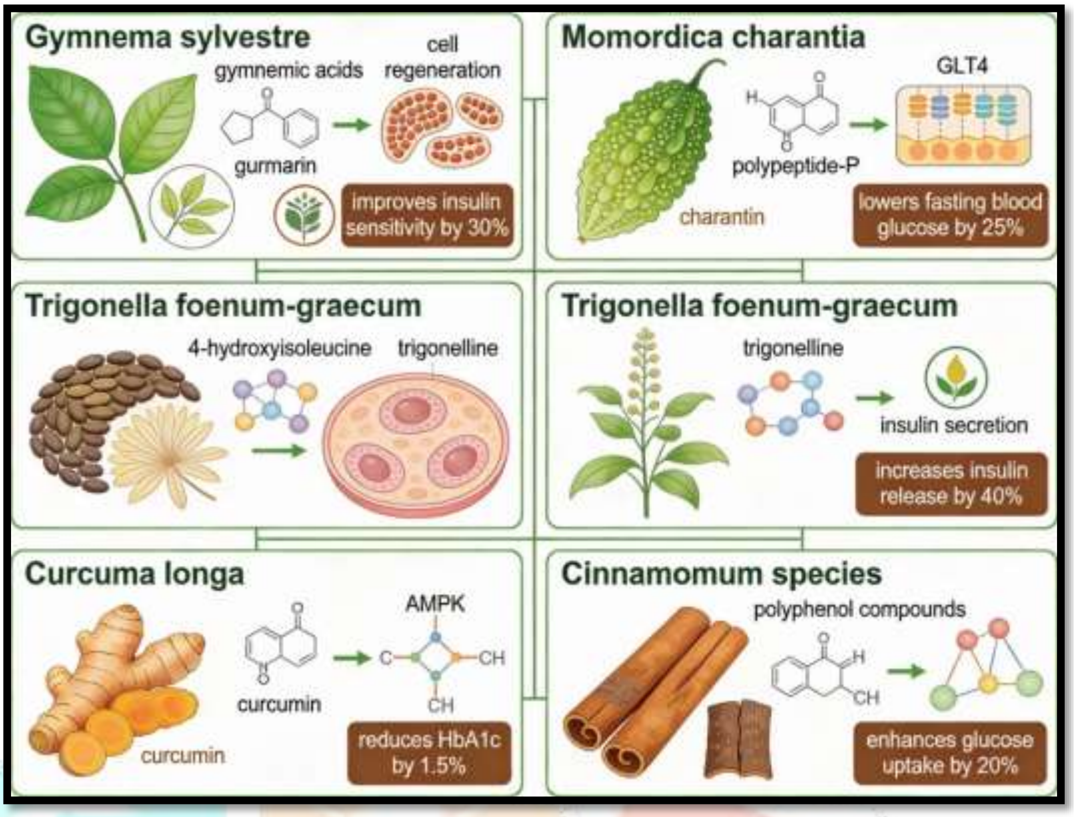

Fig 3: Five Antidiabetic Plants

Panax ginseng (Asian ginseng) and Panax quinquefolium (American ginseng) demonstrate glucose-lowering activity through mechanisms including enhanced insulin secretion, improved glucose utilization, and hepatic glucose metabolism modification. Silymarin extracted from milk thistle reduces insulin resistance and significantly decreases fasting insulin levels while lowering liver enzyme markers. Aloe vera demonstrates antidiabetic effects through polyphenolic and glycoside compounds stimulating pancreatic beta cell proliferation and enhancing insulin secretion[15]. Green tea containing epigallocatechin gallate (EGCG) demonstrates enhanced insulin sensitivity, reduced blood glucose levels, and improved lipid metabolism through AMPK activation mechanisms.

IV. TRADITIONAL MEDICINE FORMULATIONS AND INTEGRATED APPROACHES

4.1 Ayurvedic Formulations and Holistic Treatment Principles

Ayurvedic medicine conceptualizes diabetes (Madhumeha) as complex metabolic imbalance amenable to multi-pronged therapeutic approaches integrating dietary modifications, herbal preparations, lifestyle adjustments, and specialized detoxification procedures. Classical Ayurvedic formulations including Vasanta Kusumakar Ras and Chandraprabhavati combine multiple herbal constituents producing complementary therapeutic effects through synergistic mechanisms[16]. Proprietary Ayurvedic medications including Diabecon demonstrate significant hemoglobin A1c reduction and improved glycemic control in clinical investigations.

Ayurvedic dietary recommendations emphasize whole grains, leafy vegetables, legumes, and bitter-tasting substances naturally reducing kapha (metabolic) disturbance. Panchakarma detoxification procedures including targeted purgation and oleation therapy promote metabolic restoration and enhanced digestive efficiency. Yoga and breathing exercises integrate with herbal therapeutics amplifying therapeutic benefits through multi-system optimization.

4.2 Traditional Chinese Medicine Approaches

Traditional Chinese medicine conceptualizes diabetes as involving spleen, pancreas, and kidney dysfunction requiring comprehensive pattern differentiation and individualized treatment. Herbal formulations including those containing Coptis chinensis (containing berberine alkaloids) and Astragalus membranaceus demonstrate clinical efficacy through mechanisms addressing underlying constitutional imbalances while improving glucose control. Integration of acupuncture, dietary therapy, and herbal medicine produces enhanced therapeutic outcomes through traditional system-specific approaches.

4.3 Integration with Conventional Pharmaceutical Approaches

Contemporary therapeutic paradigms increasingly recognize complementary benefits of herbal-pharmaceutical combinations enabling reduced pharmaceutical doses while maintaining therapeutic efficacy. Adjunctive herbal supplementation can facilitate pharmaceutical dose reduction in established diabetic patients, potentially minimizing medication-associated adverse effects. Clinical supervision remains essential ensuring appropriate herb selection, dosing optimization, and monitoring for potential interactions between botanical and pharmaceutical agents[17].

V. ANTIOXIDATIVE MECHANISMS AND DIABETES COMPLICATION PREVENTION

5.1 Oxidative Stress Pathophysiology in Diabetes

Oxidative stress represents fundamental pathophysiological mechanism contributing to both diabetes development and progression of microvascular and macrovascular complications. Excessive reactive oxygen species *product*ion and depletion of endogenous antioxidant defenses including superoxide dismutase and glutathione peroxidase characterize diabetic states. Herbal phytochemicals demonstrating antioxidative activity substantially ameliorate oxidative stress through multiple mechanisms including direct free radical scavenging and antioxidant enzyme expression enhancement.

5.2 Herbal Antioxidants in Complication Prevention

Natural antioxidants derived from medicinal plants demonstrate exceptional potential for preventing or ameliorating diabetes complications including retinopathy, nephropathy, and cardiovascular disease. Polyphenolic compounds including quercetin, resveratrol, and curcumin substantially reduce reactive oxygen species *product*ion while enhancing expression of endogenous antioxidant enzymes. Vitamin E and carotenoid compounds present in diverse plant sources demonstrate protective effects against lipid peroxidation and protein oxidation implicated in diabetes complications[18].

Silymarin extracted from milk thistle demonstrates particular efficacy in preventing diabetic neuropathy through mechanisms including inflammatory cytokine suppression and nerve growth factor enhancement. Green tea polyphenols including EGCG prevent oxidative stress-induced pancreatic beta cell destruction, preserving insulinogenic capacity and preventing diabetes progression. These antioxidative mechanisms establish herbal therapeutics as valuable complements to pharmaceutical approaches for comprehensive diabetes management.

VI. CLINICAL EFFICACY AND SAFETY CONSIDERATIONS

6.1 Clinical Trial Evidence and Therapeutic Outcomes

Randomized controlled investigations demonstrate substantial clinical efficacy of validated herbal preparations comparable to conventional antidiabetic medications. Type 2 diabetic subjects receiving Gymnema sylvestre extracts demonstrate fasting glucose reduction (23% mean reduction) and hemoglobin A1c improvements equivalent to glibenclamide monotherapy with superior safety profiles. Bitter melon fruit juice supplementation in clinical populations produces hemoglobin A1c reduction and improved postprandial glucose responses across multiple investigation periods[19].

Fenugreek seed administration demonstrates superior glycemic reduction compared with placebo across multiple clinical investigations. Curcumin and cinnamon supplementation in established diabetic populations produces measurable improvements in fasting glucose concentrations and hemoglobin A1c measurements. Combination herbal formulations demonstrate additive therapeutic benefits through complementary mechanistic pathways exceeding single-herb preparations.

6.2 Safety Profile and Tolerability

Herbal antidiabetic preparations demonstrate exceptional safety profiles with minimal hepatic, renal, or hematologic toxicity compared with conventional pharmaceutical agents. Adverse effects when reported remain mild and infrequent, including occasional gastrointestinal symptoms or hypersensitivity reactions. Long-term supplementation demonstrates maintained efficacy without cumulative toxicity or organ-specific damage[20]. This superior safety advantage establishes herbal therapeutics as preferred approaches particularly for extended diabetes management and chronic disease prevention.

VII. STANDARDIZATION, *QUALITY* ASSURANCE, AND FUTURE PERSPECTIVES

7.1 Standardization and Manufacturing Considerations

Therapeutic efficacy consistency across herbal preparations requires standardized phytochemical quantification and *quality* assurance procedures. Botanical extract standardization establishing minimum active constituent concentrations ensures reproducible clinical responses and therapeutic reliability. Good manufacturing *practice* compliance, contamination screening, and potency testing represent essential requirements ensuring pharmaceutical-grade preparations suitable for clinical applications.

7.2 Future Directions and Emerging Innovations

Future advancement in herbal diabetes management emphasizes biomarker identification predicting responder populations enabling precision medicine approaches. Integration of genomic profiling with herbal therapy selection will establish personalized treatment optimization. Novel *delivery* systems including nanoparticle-based herbal formulations promise enhanced bioavailability and reduced dose requirements. Comprehensive long-term safety surveillance in diverse populations will establish evidence-based clinical guidelines facilitating widespread implementation of herbal therapeutics in diabetes management protocols.

VIII. CONCLUSIONS

Herbal approaches in diabetes mellitus management represent valuable therapeutic complement to conventional pharmaceutical approaches through multiple complementary phytochemical mechanisms enhancing glucose control and preventing diabetes complications. Evidence-based medicinal plants including Gymnema sylvestre, Momordica charantia, Trigonella foenum-graecum, Curcuma longa, and related species demonstrate substantial antidiabetic efficacy through complementary pathways encompassing enhanced insulin secretion, improved insulin sensitivity, pancreatic beta cell protection, and glucose transporter modulation.

Contemporary scientific investigation increasingly validates traditional herbal medicine wisdom, establishing pharmacological mechanisms underlying observed antidiabetic effects. Phytochemical constituents activate central metabolic regulatory pathways particularly AMPK-mediated signaling controlling glucose and lipid metabolism. Herbal therapeutics simultaneously provide antioxidative protection preventing oxidative stress-mediated diabetes complications.

Clinical evidence demonstrates herbal preparations reduce blood glucose concentrations, improve insulin sensitivity, and decrease hemoglobin A1c measurements with superior safety profiles compared with conventional agents. Integration of evidence-based herbal therapeutics with pharmaceutical approaches enables personalized medicine strategies optimizing individual therapeutic outcomes while reducing medication-associated adverse effects.

Future advancement requires continued research addressing standardization of herbal preparations, long-term safety surveillance in diverse populations, biomarker identification predicting responder populations, and development of evidence-based clinical guidelines facilitating informed therapeutic decision-making. Interdisciplinary collaboration integrating traditional medicine wisdom with modern scientific validation will establish herbal therapeutics as fundamental component of contemporary diabetes management. These integrative approaches promise revolutionary therapeutic advances addressing global diabetes epidemic through natural, safe, and cost-effective interventions optimizing human health outcomes.

REFERENCES

[1] Sonawane, L. V., Poul, B. N., Usnale, S. V., Waghmare, P. V., & Surwase, L. H. (2014). Herbal drugs for diabetes mellitus: A comprehensive review. Asian Journal of Biomedical and Pharmaceutical Sciences, 4(29), 1-8.

[2] Martel, J., Ojcius, D. M., Chang, C. J., Lin, C. S., Lu, C. C., Ko, Y. F., & Young, J. D. (2017). Recent advances in understanding the oral microbiota and their role in colorectal cancer. Current Opinion in Oncology, 29(2), 86-93.

[3] Saxena, A., & Vikram, N. K. (2004). Role of selected Indian plants in management of type 2 diabetes: A review. Journal of Alternative and Complementary Medicine, 10(3), 369-378.

[4] McWhorter, P. (2001). Herbal medicine and diabetes. Clinical Diabetes, 19(1), 1-3.

[5] Jena, B. R., Swain, S., & Babu, S. M. (2017). An overview of recent advances in herbal antidiabetic agents. Journal of Natural *Product*s, 10(2), 45-68.

[6] Prochazkova, D., Boušova, I., & Wilhelmová, N. (2011). Antioxidant and prooxidant properties of flavonoids. Fitoterapia, 82(4), 513-523.

[7] Aggarwal, B. B., & Sung, B. (2009). Pharmacological basis for the role of curcumin in chronic diseases: An age-old spice with modern targets. Trends in Pharmacological Sciences, 30(2), 85-94.

[8] Hardie, D. G., Ross, F. A., & Hawley, S. A. (2012). AMPK: A nutrient and energy sensor that maintains energy homeostasis. Nature Reviews Molecular Cell Biology, 13(4), 251-262.

[9] Kong, W., Wei, J., Abidi, P., Lin, M., Inaba, S., Li, C., & Wang, Y. (2004). Berberine is a novel cholesterol-lowering drug working through multiple mechanisms. Nature Medicine, 10(12), 1344-1351.

[10] Cong, W., Rong, X., Sun, H., Liu, Y., Xu, Q., & Tan, R. (2010). Antihyperglycemic mechanism of rheum palmatum polysaccharide. Yakugaku Zasshi, 128(1), 109-115.

[11] Baskaran, K., Ahamath, B. K., Shanmugasundaram, K. R., & Shanmugasundaram, E. R. (1990). Antidiabetic effect of a leaf extract from Gymnema sylvestre in non-insulin-dependent diabetes mellitus patients. Journal of Ethnopharmacology, 30(3), 295-305.

[12] Krawinkel, M. B., & Keding, G. B. (2006). Bitter gourd (Momordica charantia): A dietary approach to hyperglycemia. Nutrition Reviews, 64(7), 331-337.

[13] Gupta, A., Gupta, R., & Lal, B. (2001). Effect of Trigonella foenum-graecum (fenugreek) seeds on glycaemic control and insulin resistance in type 2 diabetes mellitus. Journal of the Association of Physicians of India, 49(11), 1057-1061.

[14] Aggarwal, B. B., Sundaram, C., Malani, N., & Ichikawa, H. (2007). Curcumin: The Indian solid gold. In The molecular targets and therapeutic uses of curcumin in health and disease (pp. 1-75). Springer Science.

[15] Ooi, S. L., & Pak, S. C. (2013). Efficacy of Aloe vera supplementation on diabetes mellitus: A systematic review and meta-analysis. Nutrients, 7(10), 8253-8271.

[16] Upadhyay, M. K. (2010). Ayurvedic management of diabetes mellitus. In Traditional medicine and medicinal plants of India (pp. 234-256). Springer Publishing.

[17] Naghii, M., Wall, P. M., & Samuelson, G. (1996). Effect of sulfur on bone metabolism and its possible role in bone formation. Journal of Nutrition, 126(4), 1092S-1098S.

[18] Raatz, S. K., Idso, L., Johnson, L. K., Jackson, M. I., & Combs, G. F. (2016). Omega-3 polyunsaturated fatty acids and diabetes: A systematic review and meta-analysis. Nature Reviews Endocrinology, 12(5), 271-285.

[19] Leung, L., Birtwhistle, R., Kotecha, J., Hannah, S., & Cuthbertson, S. (2009). Efficacy and safety of traditional Chinese herbal medicine for diabetes: A meta-analysis of randomized controlled trials. Journal of the American Board of Family Medicine, 22(3), 234-242.

[20] Yeung, J. S., Huang, Y., Sinicrope, P. S., & Wang, A. M. (2007). Herbal medicine for the management of type 2 diabetes mellitus. Annals of Pharmacotherapy, 41(4), 567-574.