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REVIEW ARICLE

Emerging Pharmaceutical Applications of Bioactive Compounds from Bitter Gourd: Mechanistic Insights and Therapeutic Perspectives

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Abstract

Bitter gourd (*Momordica charantia* L.) is a medicinal vegetable which has gained significant interest due to its nutritional properties, phytochemical content, and various pharmacological properties. It has traditionally been used for the management of diabetes, gastrointestinal disorders, infections, and inflammatory diseases. The present review summarizes the detailed information on phytochemical constituents, ethnomedicinal uses, pharmacological activities, pharmaceutical uses, and safety of bitter gourd. The therapeutic properties of the plant are due to the presence of numerous bioactive constituents such as charantin, polypeptide-p, cucurbitane-type triterpenoids, flavonoids, phenolic compounds, saponins and alkaloids. In addition, bitter gourd is of great interest in the pharmaceutical field, as it is used in herbal products, nutraceutics, functional foods, and new drug delivery systems. Resuming, although it seems to have some therapeutic potential, there are still problems to solve regarding its standardization, bioavailability, quality control, and long-term clinical validation. Bitter gourd is a rich source of natural compounds with potential pharmaceutical applications, particularly in the creation of medications with therapeutic value. It is crucial to carry out additional multidisciplinary research and to design good clinical studies, in order to confirm its clinical effectiveness and to make it successfully effective in evidence-based healthcare.

Key words: Bioactive compounds, *Momordica charantia,* Pharmaceutical applications, Pharmacological activities, Phytochemicals

INTRODUCTION

Medicinal plants are important sources of therapeutic agents and have continued to be used for centuries in prescribing medicines. The rising incidence of chronic diseases like diabetes mellitus, cardiovascular diseases (CVDs), cancer, and infectious diseases has created a great interest in bioactive compounds derived from plants for their medicinal properties worldwide. Medicinal plants are regarded as promising alternatives to synthetic drugs because they are rich in phytochemicals with various biological activities and produce fewer side effects compared to synthetic drugs.[1-3] Bitter gourd which belongs to the Cucurbitaceae family and are popular in subtropical and tropical regions. In the part of nutritional value, bitter gourd is well known for its medicinal value and has been applied in Ayurveda and Chinese Medicine for diabetes, gastrointestinal diseases, skin diseases, and

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infections.[4-6] These bioactive compounds are reported to exhibit pharmacobiological activities, including antidiabetic, antioxidant, anti-inflammatory, antimicrobial, antiviral, hepatoprotective, and anticancer actions, with various modes of action.[1,3,5,7] The phytochemical analysis, pharmacological research, and pharmaceutical formulation technology have been developed recently, which broadened the therapeutic potentials of bitter gourd. To improve the bioavailability, efficacy, and clinical application of its biologically active substances, novel approaches including nanoformulations, standardized herbal extracts, and functional food products are being investigated.[8] Bitter gourd has emerged as a promising natural source of molecules that can be used to create potential pharmaceutical products in the future.[5,9,10]

TRADITIONAL MEDICINAL APPLICATIONS AND ETHNOPHARMACOLOGICAL SIGNIFICANCE

Bitter gourd has been widely used in traditional medicine for centuries to treat various diseases. The fruits, leaves, seeds, and roots are used in Ayurvedic, Traditional Chinese, and African medicine for treating diabetes, digestive and skin disorders, liver disorders, fever, and microbial infections.[4,11,12] Bitter gourd fruit juice is used to help regulate blood glucose level and digestion, and leaf extracts are used for wound healing and treatment of skin infections.[13,14] It has been used traditionally in Traditional Chinese Medicine for its cooling and detoxifying effects, its antidiabetic activity in African and Southeast Asian countries as treatment for malaria, high blood pressure, gastrointestinal diseases, and metabolic diseases.[14-16] Many of these traditional uses have been substantiated by isolation of biologically active substances like charantin, polypeptide-p, and cucurbitane-type triterpenoids, making bitter gourd a potential medicinal vegetable for pharmaceutical applications.[1,5]

PHYTOCHEMICAL CONSTITUENTS AND BIOACTIVE METABOLITE PROFILE

Bitter gourd is a rich source of diverse bioactive phytochemicals that contribute significantly to its nutritional, medicinal, and pharmaceutical properties.[17] Different plant parts, including fruits, leaves, roots, and stems, contain both primary metabolites (proteins, amino acids, and carbohydrates) and secondary metabolites such as cucurbitane-type triterpenoids, saponins, flavonoids, phenolic compounds, alkaloids, and glycosides. Among these phytochemicals, cucurbitane-type triterpenoids represent the major characteristic bioactive constituents and are considered chemotaxonomic markers of bitter gourd. Over 200 triterpenoids, including momordicosides, momordicines, momordicins, and karavilosides have been identified and demonstrated to possess antidiabetic, anticancer, inflammation suppressing and hepatoprotective properties.[3] These compounds regulate several cellular Regulatory networks controlling glucose metabolism, apoptosis, and oxidative stress.[16,18-20] Charantin is a steroidal saponin mixture composed mainly of β-sitosterol glucoside and stigmasterol glucoside and is considered as the principal marker compounds responsible for the hypoglycemic activity of bitter gourd.[21] It enhances glucose uptake, improves insulin sensitivity, and promotes glycogen synthesis, thereby contributing to blood glucose regulation. Moreover, the peptide-p, mainly extracted from the fruits and seeds of bitter gourd, has been found to have a considerable antihyperglycemic effect in experimental models, validating its traditional use for diabetes management.[4,13,22] Bitter gourd also contains abundant phenolic acids and flavonoids, including gallic acid, catechin, chlorogenic acid, caffeic acid, quercetin, and rutin. These phytochemicals possess strong antioxidant capabilities, which include scavenging of reactive oxygen species, reduction in heightened lipid peroxidation, together with enhanced antioxidant defense enzyme activities. As a result, they are also important in preventing cells from oxidative damage caused by chronic diseases.[5,23] In addition, bitter gourd is rich in various chemical compounds, including alkaloids, tannins, sterols, dietary fibre and essential amino acids, which further contribute to its nutritional and therapeutic benefits. The vitamin and mineral composition of bitter gourd, including vitamins A, C and E and minerals such as calcium, magnesium, potassium and iron, is presented in Table 1. Together, these phytochemicals achieve a broad spectrum of biological activities observed *in vitro* and *in vivo*.[8] Advanced analytical techniques including high-performance liquid chromatography, Ultra-HPLS- Quadrupole Time-of-flight mass spectrometry (UHPLC-QTOF-MS), liquid chromatography-tandem/MS, Gas chromatography, and nuclear magnetic resonance spectroscopy have enabled the identification, bitter gourd thereby facilitating phytochemical standardization and pharmaceutical development.[1,24,25] The major phytochemical constituents of bitter gourd and their associated pharmacological properties are summarized in Figure 1.

PHARMACOLOGICAL PROPERTIES AND THERAPEUTIC MECHANISMS

Antidiabetic potential and molecular mechanisms

Diabetes mellitus is a long-term metabolic condition in which the level of sugar in the blood is too high due to insufficient insulin production, a problem with insulin sensitivity, or a combination of the two. Considering its rising prevalence worldwide and its associated complications, the search for plant-derived antidiabetic agents with a better safety profile is growing interest. Bitter gourd is one of the medicinal vegetables receiving much attention due to its strong antihyperglycemic effects, supported by various experimental and clinical studies.[11,36,37] The hypoglycemic effect of bitter gourd is mainly believed to be attributable to its diverse bioactive constituents

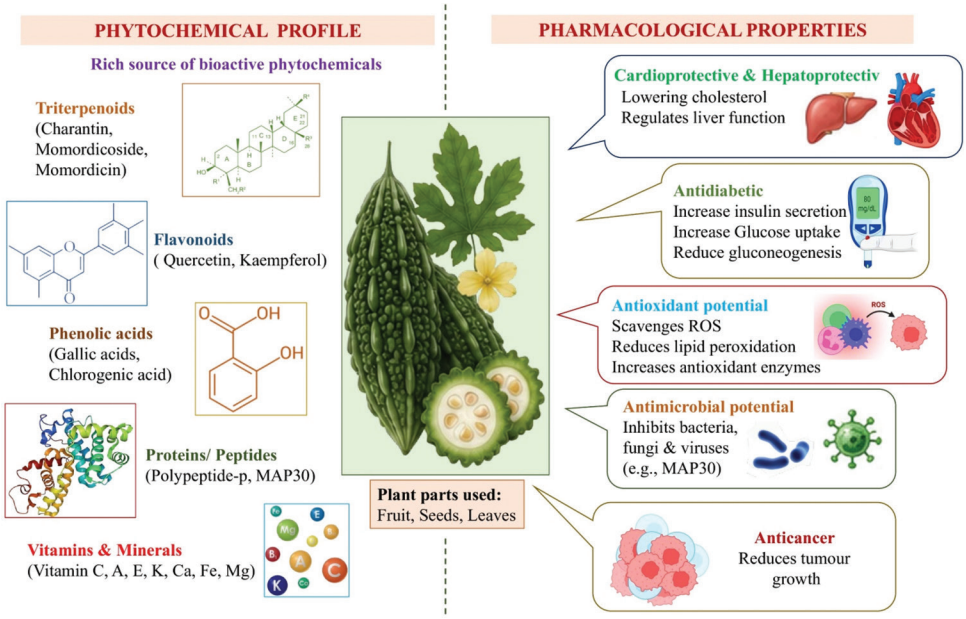


Figure 1: Phytochemical profile and major pharmacological properties of *Momordica charantia* (bitter gourd)

Table 1: Vitamins and minerals composition of bitter gourd[26,27]

Vitamins and minerals	Concentration (ppm)
Vitamin A	Traces
Vitamin E	800±14
Vitamin C	66000±141
Calcium	20510.00±5.77
Magnesium	255.00±0.69
Potassium	413.00±1.45
Iron	98.00±0.23

such as charantin, polypeptide-p, vicine and cucurbitane-type triterpenoids. The major phytochemical constituents of bitter gourd and their chemical characteristics are summarized in Table 2. The compounds can regulate glucose homeostasis by several mechanisms, including insulin secretion, increased peripheral glucose uptake, decreased hepatic gluconeogenesis, and increased insulin sensitivity. Unlike the majority of the conventional antidiabetic drugs, bitter gourd multitarget mode of action provides a new therapeutic approach.[4,5,13] The bioactive compounds of bitter gourd activated AMP-activated protein kinase, thereby enhancing glucose uptake and augmenting insulin signaling.[38] The molecular mechanism of bitter gourd is found to affect various pathways in carbohydrate metabolism. Bitter gourd extracts prevented the induction of oxidative stress, apoptosis of pancreatic β-cells, and improved pancreatic function by enhancing insulin secretion.[39] Thus, more extensive and rigorously randomized clinical trials are necessary to establish standardized pharmaceutical formulations and to demonstrate their long-term effectiveness and safety.[31,40,41] On the whole basis of the available evidence, bitter gourd has a tremendous potential for the use as a complementary drug for diabetes mellitus.

Anticancer properties and cellular targets

Cancer remains a significant global health challenge due to its high rates of illness and has been a subject of great research interest for naturally derived novel agents for the treatment of cancer. The presence of bioactive phytochemicals such as cucurbitane-type triterpenoids, momordicosides, ribosome-inactivating proteins (RIPs), flavonoids, and phenolic compounds has led to interest in bitter gourd for its potential anticancer properties.[5,9,42] Extracts of bitter gourd have been shown to inhibit cancer cell growth by inducing apoptosis, arresting the cell cycle, and suppressing tumor development. In particular, bitter gourd extract has demonstrated a strong ability to inhibit the proliferation of breast cancer cells and promote their apoptosis, thereby preventing further cancer progression.[43,44] The extract of bitter gourd was also found to suppress the proliferation of pancreatic cancer cells by modulating several pathways of cell survival and apoptosis.[44-46] Bitter gourd exerts anticancer effects through various molecular mechanisms. The bioactive components of bitter gourd have been shown to affect important signaling pathways like the PI3K/Akt pathway, the mitogen-activated protein kinase (MAPK) pathway, and the nuclear factor-kappa B (NF-κB) pathway, which leads to decreased cell proliferation, inhibition of angiogenesis, and programmed cell death. These compounds have antioxidant and anti-inflammatory properties, which are associated with the initiation and progression of cancer.[5,38] Bitter gourd has also been seen to be involved in the prevention of cancer metastasis in recent investigations. The plant extracts regulate matrix metalloproteinases and epithelial–mesenchymal transition related proteins, which inhibit metastatic spread and tissue penetration of cancer cells.[47] Several bitter gourd-derived triterpenoids called cucurbitanes have shown selective toxicity against the liver,

colon, prostate, and leukemia cell lines with negligible toxicity toward normal cells.[8,18,42]

Antioxidant defense mechanisms and free radical scavenging activity

The phytochemical profile of bitter gourd is rich in antioxidants, making it a highly promising natural source of antioxidants.[1,5,8] Phenolic compounds, flavonoids, Vitamin C, carotenoids, and the presence of cucurbitane-type triterpenoids underlie the antioxidant capacity of bitter gourd. These bioactive components possess good scavenging activity against reactive oxygen species (ROS), good antioxidant enzyme activity, and inhibit lipid peroxidation, helping to prevent damage to cellular components due to oxidative stress. The fruit has been found to have high total phenolics, flavonoids, and the two were correlated with its free radical neutralization capacity.[23,46] The extracts of bitter gourd significantly enhanced antioxidant activity through increasing the activities of antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and glutathione (GSH) peroxidase and while simultaneously reducing the level of malondialdehyde.[48] The antioxidant agents of bitter gourd exert their antioxidant activity are mediated not only by directly scavenging free radicals but also by regulating the body's cellular antioxidant defenses through activation of the nuclear factor erythroid 2-related factor 2 (Nrf2) signaling pathway.[8] Nrf2 activation stimulates the production of multiple cytoprotective enzymes that help cells withstand oxidative stress and minimize inflammatory damage.[3,8,38] The antioxidant activity is one of the major phytochemical activities attributed to bitter gourd, which further explains its pharmacological properties such as antidiabetic, hepatoprotective, cardioprotective, and anticancer effects.

Anti-inflammatory effects and immunological regulation

Inflammation is a complicated biological reaction to tissue damage, infection and oxidative stress. Acute inflammation protects the host from infection and helps repair the damage, but chronic inflammation is linked with the occurrence of illnesses such as diabetes, cardiovascular conditions, arthritis and cancer.[9] Natural products that possess anti-inflammatory activity have been of great interest in terms of therapeutic agents. The bitter gourd, studied for its anti-inflammatory properties on the basis of its various bioactive compounds, including cucurbitane-type triterpenoids, flavonoids, phenolic acids, and saponins.[5,13,49] The extracts of bitter gourd can inhibit inflammatory responses by inhibiting the secretion of pro-inflammatory mediators.[50] A plant extract was found to inhibit the release of tumor necrosis factor-alpha, interleuking-1 beta, interleuking-6 and prostaglandin E2, which help to reduce inflammation.[20,38] The anti-inflammatory effects of bitter gourd are also associated with the inhibition of key pathways involved in the inflammatory response.[8] Bitter gourd phytochemicals have been shown to inhibit the activation of NF-κB and MAPK pathways, thereby decreasing the expression of inflammatory genes and enzymes like cyclooxygenase-2 and inducible nitric oxide synthase.[1,16,51] The antioxidant properties of bitter gourd contribute to its anti-inflammatory effects by reducing oxidative stress, a major factor in the development of chronic inflammation.[8] These phenolic compounds and flavonoids also have display a capacity to scavenge ROS and augment endogenous antioxidant enzyme functions, which reduce oxidative stress and the inflammatory response.[23]

Broad-spectrum about antimicrobial activity

The antimicrobial activity of bitter gourd is observed to be very broad spectrum against different bacterial and fungal pathogens, attributed to the presence of triterpenoids, flavonoids, saponins and phenolic compounds.[29,34] Fruits extracts are to be inhibitory against *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa,* and *Salmonella* spp. while leaves and seed extracts are to be inhibitory against *Candida albicans* and *Aspergillus niger*.[15,23,52] Antimicrobial proteins also have been shown to have antiviral activity, blocking viral replication.[50,53] The results obtained support the use of bitter gourd as an effective natural antimicrobial source for incorporation into pharmaceutical and complementary medicine products.[6] It is, however, necessary to pursue additional clinical research to establish its therapeutic value.[1,40]

Antiviral potential and mechanisms of viral inhibition

Viral diseases still remain a major public health problem globally, and new antiviral drugs from natural origin are still needed. The plants bitter gourd have been the object of renewed interest attributed to the abundance of bioactive molecules, including RIPs, cucurbitane-type triterpenoids, flavonoids, and phenolic compounds.[8,50] *Momordica* anti-HIV protein (MAP30) is one of the most well-studied antiviral constituents of bitter gourd. MAP30 is a RIP that blocks viral protein synthesis and depurination of viral nucleic acids. MAP30 has proven to have strong anti-HIV activity and low non-toxicity to normal cells. Moreover, some Momorcharin enzymes are found with antiviral activity by inhibiting viral RNA translation and replication.[54,56] Under experimental conditions, these proteins have exhibited significant activity against HIV, herpes simplex virus, and some plant viruses. Their anti-virus activity has led to further research for their pharmaceutical applications.[29,56,57]

Hepatoprotective effects and liver function enhancement

The hepatoprotective activity of bitter gourd is significant attributed to the presence of high concentrations of triterpenoids, flavonoids, phenolic compounds, and other antioxidant phytochemicals.[56] hepatoprotective activity of bitter gourd extracts against chemically induced liver injury is due to their antioxidant action and reversion to normal

liver function. It was found that bitter gourd extract markedly protected against liver injury caused by carbon tetrachloride in experimental animals.[57]

Cardioprotective benefits in cardiovascular health

The CVDs are major causes of illness and death in the world, with hyperlipidemia, hypertension, oxidative stress, and chronic inflammation being major risk factors. Cardioprotective effects of natural products with antioxidant and lipid-lowering properties have been a great attraction. Bitter gourd is a promising medicinal vegetable due to its lipid metabolism-improving properties, antioxidant and anti-inflammatory effect on CVDs.[13,29] The primary effects are ascribed to cucurbitane-type triterpenoids, saponins, and flavonoids, compounds demonstrated to modulate lipid metabolism and decrease the buildup of lipids in the liver.[4,51,58] The antioxidant activity of bitter gourd is also beneficial for cardiovascular protection. Phenolic compounds and flavonoids neutralize reactive oxygen species, reduce lipid peroxidation, and elevate the activity of endogenous antioxidant enzymes.[8,34] The mechanisms help to prevent oxidative stress of vascular endothelial cells and promote endothelial function.[23]

Gastroprotective activity and gastrointestinal protection

The protection of gastric mucosa using bitter gourd extracts, which involves increasing mucus production, diminishing oxidative stress and inflammatory processes. The extract was found to be effective in reducing ethanol-induced gastric ulcers by suppressing lipid peroxidation and inflammatory cytokines, an effect associated with enhanced antioxidant enzyme activity. Antioxidant enzyme activity, including those of SOD, CAT, GSH, promoting ulcer healing and maintains gastric mucosal integrity.[29,59]

Immunomodulatory properties and immune system regulation

Bitter gourd has been found to possess potent immunomodulatory properties, due to its composition of polysaccharides, triterpenoids, flavonoids and RIPs.[29] Bitter gourd stimulates macrophage activation and promoting lymphocyte proliferation and cytokine production, which collectively enhance immune function.[60] Bioactive proteins like MAP30, α-momorcharin and β-momorcharin also have immunomodulatory and antiviral effects by modulating immune cell functions and inflammatory signaling pathways.[37,53,61]

PHARMACEUTICAL TRANSLATION OF BITTER GOURD BIOACTIVE COMPOUNDS

Bitter gourd is commercially produced in various pharmaceutical and nutraceutical formulations like capsules, tablets, powder, teas, fluid extract, and decoction, which will aid in therapeutic administration and improve patient compliance. Capsules and tablets are generally manufactured with extracts from fruits or seeds that are standardized for important bioactive compounds, while powder formulations are made from dried fruits, seeds, or dried whole plants. Herbal teas and also aqueous decoctions are still in widespread use and are used in traditional medicine and they are also commercially produced. Several bitter gourd-based pharmaceutical and nutraceutical products are marketed worldwide, particularly for their potential roles in glycemic control and metabolic health. Examples of commercially available products and their formulations are presented in Table 3. The products Charantia, Solaray Bitter Melon Extract, Himalaya Bitter Melon Capsules, Nature's Goodness Australia Bitter Melon, Puritan's Pride Bitter Melon Capsules, and Ampalaya Tea are commercially available throughout the world, most notably for their role in glycemic control and metabolic health. Apart from these herbal preparations, there are also some patented RIPs like MAP-30 which have demonstrated antiviral and antitumor properties, indicating their potential for future clinical applications, but it needs more clinical studies to prove its safety and efficacy.[14,27]

Other developments in the pharmaceutical development of bitter gourd have gone toward improving the quality of products, standardization, and safety. There are commercial formulations that are available as capsules, tablets, powdered formulations, juices, decoctions, and standardized aqueous extracts, some containing 0.17% of insulin receptor-binding protein motif that was explored for its antidiabetic activity. The traditional preparation, karela juice and cerasee decoction, is still commonly used for medicinal purposes. The amount of bioactive triterpenoids varies considerably between commercial products; however, there is a need for quality standardization; around 3 mg of cucurbitane-type triterpenoids per day was suggested. Furthermore, the concentrated extracts have been reported to have higher therapeutic efficacy compared to powdered extracts, and the use of seed-free bitter gourd extracts is recommended to reduce the toxicity related with the bitter gourd seed's constituents (vicine and lectins), which could improve the safety and quality of the bitter gourd-based pharmaceutical products.[62]

TOXICOLOGICAL EVALUATION AND CLINICAL SAFETY ASSESSMENT

Preclinical toxicological evaluation

Bitter gourd is considered safe for use as a food or at therapeutic dosages but may be toxic at high doses or concentrated extracts. Acute toxicity studies revealed dose-dependent adverse effects such as manifestations of respiratory distress, convulsions, and congestion of organs at high doses, but not significant hepatic or renal toxicity

Table 2: Major phytochemical constituents of Bitter gourd and their chemical characteristics

Plant part	Chemical class	Major compound	Chemical formula	Molecular Mass (g/moL)	Abundance level	References
Fruit	Triterpenoid glycoside	Charantin	$C_{42}H_{62}O_{16}$	801.93	High	[28,29]
Fruit	Cucurbitane triterpenoid	Momordicoside K	$C_{36}H_{58}O_{9}$	634.84	Moderate	[16,29]
Fruit	Triterpenoid	Momordicin I	$C_{30}H_{48}O_{5}$	488.70	Moderate	[5,28]
Seeds	Pyrimidine glycoside	Vicine	$C_{10}H_{16}N_{4}O_{7}$	304.26	Moderate	[13,29,30]
Seeds	Peptide	Polypeptide-p	Peptide	~11 kDa	Low	[11,30,31]
Leaves	Flavonoid	Quercetin	$C_{15}H_{10}O_{7}$	302.24	Moderate	[16,23]
Leaves	Flavonoid	Kaempferol	$C_{15}H_{10}O_{6}$	286.24	Moderate	[23]
Fruit	Phenolic acid	Gallic acid	$C_{7}H_{6}O_{5}$	170.12	Low	[32,33]
Fruit	Phenolic acid	Chlorogenic acid	$C_{16}H_{18}O_{9}$	354.31	Moderate	[16,32,33]
Fruit	Vitamin	Ascorbic acid	$C_{6}H_{8}O_{6}$	176.12	High	[5,34,35]

Table 3: Commercial pharmaceutical and nutraceutical products of Bitter gourd

Product category	Dosage form	Major bioactive component(s)	Therapeutic application	References
Herbal capsules	Capsules	Charantin, triterpenoids	Blood glucose management	[11,13]
Standardized extract	Tablets	Charantin, polypeptide-p	Antidiabetic supplement	[31]
Herbal powder	Powder	Phenolics, flavonoids	Antioxidant and nutraceutical	[16,23]
Bitter gourd juice	Oral liquid	Vitamins, polyphenols, charantin	Functional food for metabolic health	[50,63]
Herbal tea	Tea bags	Phenolics, flavonoids	Antioxidant and digestive support	[23]
Functional food products	Fortified foods	Bioactive phytochemicals	General health promotion	[29]

upon therapeutic administration; instead, it improved the metabolic parameters in diabetic rats.[46,64] In zebrafish embryos, the extracts of the seeds showed embryotoxicity and extracts from fruits exhibited cardiac abnormalities, indicating that the bitter gourd preparations need to be used with some caution when pregnant.[65] heavy metal analysis, negligible levels of toxic elements were found in fruits, grown under an uncontaminated environment, thus reflecting low potential for metal toxicity.[66] Moreover, the extracts from bitter gourd showed selective cytotoxicity effect on cancer cells at high concentrations, and overconsumption of bitter gourd may lead to gastrointestinal discomfort and may also potentiate hypoglycemia when used along with antidiabetic drugs.[67,68]

Safety assessment and therapeutic margin

Bitter gourd has been shown to be safe at recommended therapeutic doses and as a dietary vegetable.[69] The comprehensive reviews also suggest that the adverse effects of bitter gourd products are linked to poor product quality, contamination, lack of standardization, and excessive consumption, emphasizing the necessity for standardized production and strict quality assurance to ensure safe usage.[20,62,70] In addition, it is recommended to incorporate standardized bitter gourd preparations in functional foods at adequate concentrations to reduce any negative impact on the foods while retaining the nutritional and therapeutic benefits.[70] Despite promising preclinical and clinical evidence supporting the overall safety of bitter gourd preparations, further well-designed clinical studies are necessary to establish standardized dosages and assess long-term safety and efficacy before it is widely recommended for clinical use.[62,71]

Potential adverse effects and herb–drug interactions

Combination may lead to herb–drug interactions with prescription drugs, and reports of acute pancreatitis with the combination of bitter melon extract and pazopanib exist. Hence, it is advised to take bitter gourd with precautionary measures along with regular medicines.[43,72,73]

Clinical evidence supporting therapeutic efficacy

Bitter melon extract is a 12-week randomized, placebo-controlled clinical trial involving individuals with prediabetes; it was found to significantly affect postprandial blood glucose and glucagon levels, demonstrating improved glycemic control and good tolerability.[46,74,75] A comprehensive systematic review and meta-analysis

involving nine randomized clinical trials found, however, found that the available evidence is not sufficient to conclude consistent enhanced fasting blood glucose control, HbA1c and other metabolic parameters were seen, mainly as a result of limited sample sizes in the studies and the short duration of the studies and the variation in study designs.[76,77]

FUTURE PERSPECTIVES, EMERGING TRENDS AND RESEARCH OPPORTUNITIES

Bitter gourd is a plant that has been widely studied for its phytochemistry and pharmacological effects, but there are still some gaps in the current research. Most of the studies have been carried out *in vitro* or in animal experimental conditions, while well-designed randomized clinical trials in humans remain limited.[78] These findings should be confirmed by multi-center clinical trials with standardized formulation and dosage of bitter gourd in the future.[11,29] Standardization of extraction protocol and identification of active phytochemicals and quality control of herbal products are key to provide the reproducibility and therapeutic consistency.[1,52,79] In the future, the long-term safety of bitter gourd formulations, its pharmacokinetics, and interactions with drugs should also be investigated.[9] The combination of modern pharmaceutical approaches and traditional medicinal knowledge could be helpful for the development of safe, effective, and evidence-based phytopharmaceutical products, which could help to extend the therapeutic application of bitter gourd in the modern healthcare system.

CONCLUSION

Bitter gourd is a medicinal vegetable with high pharmaceutical value, which is a good medicinal plant because of its abundant phytochemical content and various pharmacological activities. The bioactive compounds have antidiabetic, antioxidant, anti-inflammatory, antimicrobial, anticancer and hepatoprotective activities, which facilitates it to be used in herbal medicines, nutraceuticals and functional foods. While the existing research shows significant therapeutic promise, more research on standardization, bioavailability, and clinical validation is needed to ensure the safe and effective use of this drug. Hence, overall, bitter gourd is an important natural source for new pharmaceutical products and future evidence-based healthcare.

REFERENCES

1. Atanasov AG, Zotchev SB, Dirsch VM, International Natural Product Sciences Taskforce, Supuran CT. Natural products in drug discovery: Advances and opportunities. Nat Rev Drug Discov 2021;20:200-16.
2. Ekor M. The growing use of herbal medicines: Issues relating to adverse reactions and challenges in monitoring safety. Front Pharmacol 2014;4:177.
3. Bachheti RK, Bachheti A, Husen A. Phenolic Compounds from Medicinal Plants: Pharmaceutical and Health Benefits. United Kingdom: Routledge;CRC Press; 2026.
4. Joseph B, Jini D. Antidiabetic effects of *Momordica charantia* (bitter melon) and its medicinal potency. Asian Pac J Trop Dis 2013;3:93-102.
5. Mukherjee S, Karati D. Exploring the phytochemistry, pharmacognostic properties, and pharmacological activities of medically important plant *Momordica Charantia*. Pharmacol Res Mod Chin Med 2023;6:100226.
6. Abbas A, Tabassum I, Vohra S, Weiskirchen R, Shoukat A, Khurram Afzal M, *et al*. *Momordica charantia* L.: Nutritional composition, advanced extraction methods, phytochemistry, molecular mechanisms and industrial applications. Antioxidants 2026;15:839.
7. Ahmed SR, Rabbee MF, Roy A, Chowdhury R, Banik A, Kubra K, *et al*. Therapeutic promises of medicinal plants in Bangladesh and their bioactive compounds against ulcers and inflammatory diseases. Plants (Basel) 2021;10:1348.
8. Husen A. Plant Secondary Metabolites in Ecological, Biochemical, and Agricultural Systems. United States: CRC Press; 2026.
9. Bagchi D, Bhupathiraju K, Banik SP. Health Benefits of *Asparagus racemosus* (Shatavari): A Comprehensive Guide to the Medicinal and Nutritional Potential of Shatavari. United Kingdom: Routledge; 2026.
10. Sharma A, Sharma C, Shah OP, Chigurupati S, Ashokan B, Meerasa SS, *et al*. Understanding the mechanistic potential of plant based phytochemicals in management of postmenopausal osteoporosis. Biomed Pharmacother 2023;163:114850.
11. Basch E, Gabardi S, Ulbricht C, Bitter melon (*Momordica charantia*): A review of efficacy and safety. Am J Health Syst Pharm 2003;60:356-9.
12. Dinç R. Natural Health Sciences: A Comprehensive Guide. United States: CRC Press; 2025.
13. Grover JK, Yadav SP. Pharmacological actions and potential uses of *Momordica charantia*: A review. J Ethnopharmacol 2004;93:123-32.
14. Akbar S. Handbook of 200 Medicinal Plants. United Kingdom: Springer Nature; 2020.
15. Beloin N, Gbeassor M, Akpagana K, Hudson J, De Soussa K, Koumaglo K, *et al*. Ethnomedicinal uses of *Momordica charantia* (Cucurbitaceae) in Togo and relation to its phytochemistry and biological activity. J Ethnopharmacol 2005;96:49-53.
16. Tan SP, Kha TC, Parks SE, Roach PD. Bitter melon (*Momordica charantia* L.) Bioactive composition and health benefits: A review. Food Rev Int 2016;32:181-202.
17. Sharma HK, Kumar N, Sheikh MA. Nutraceutical Values and Processing Techniques of Gourds as Vegetables.

United Kingdom: Springer Nature; 2026.
18. Gao Y, Chen JC, Peng XR, Li ZR, Su HG, Qiu MH. Cucurbitane-type triterpene glycosides from *Momordica charantia* and their α-glucosidase inhibitory activities. Nat Prod Bioprospect 2020;10:153-61.
19. Islam MS. Organic Acids in Diabetes: Applications and Mechanisms. United States: CRC Press; 2025.
20. Haider KH. Stem cell-free therapy: Engineering exosomes and secretomes for next-generation therapeutics. United States: CRC Press; 2026.
21. Mansoori N, Shukla R. Role of bioactive compounds in the glycemic control effects of *Momordica charantia* and *Trigonella foenum-graecum*: A review. Orient J Chem 2026;42.
22. Lawal TA, Sholadoye QO, Adeyemo KA, Segba DE. Antidiabetic and antioxidant potentials of the ethyl acetate fraction of *Momordica charantia* leaf methanolic extract: *In vitr*o and *in silico* studies. Bioorg Chem 2026;179:110007.
23. Kubola J, Siriamornpun S. Phenolic contents and antioxidant activities of bitter gourd (*Momordica charantia* L.) leaf, stem and fruit fraction extracts *in vitro*. Food Chem 2008;110:881-90.
24. Harinantenaina L, Tanaka M, Takaoka S, Oda M, Mogami O, Uchida M, *et al*. *Momordica charantia* constituents and antidiabetic screening of the isolated major compounds. Chem Pharm Bull (Tokyo) 2006;54:1017-21.
25. Aytar EC. Coffee Science and Biotechnology: Genomic, Biochemical and Nano technological Perspectives. United States: CRC Press; 2026.
26. Bakare RI, Magbagbeola OA, Akinwande AI, Okunowo OW. Nutritional and chemical evaluation of *Momordica charantia*. J Med Plants Res 2010;4:2189-93.
27. Anilakumar KR, Kumar GP, Ilaiyaraja N. Nutritional, pharmacological and medicinal properties of *Momordica charantia*. Int J Nutr Food Sci 2015;4:75.
28. Akihisa T, Higo N, Tokuda H, Ukiya M, Akazawa H, Tochigi Y, *et al*. Cucurbitane-type triterpenoids from the fruits of *Momordica charantia* and their cancer chemopreventive effects. J Nat Prod 2007;70:1233-9.
29. Jia S, Shen M, Zhang F, Xie J. Recent advances in *Momordica charantia*: Functional components and biological activities. Int J Mol Sci 2017;18:22555.
30. Adewale IO, Adebiyi V, Famutimi O, Dada OV. Kinetics of trypsin inhibition by methanolic and solvent-partitioned fractions of two medicinal plants-*Momordica charantia* and *Xylopia aethiopica*. S Afr J Bot 2023;152:174-81.
31. Leung L, Birtwhistle R, Kotecha J, Hannah S, Cuthbertson S. Anti-diabetic and hypoglycaemic effects of *Momordica charantia* (bitter melon): A mini review. Br J Nutr 2009;102:1703-8.
32. Shahidi F, Ambigaipalan P, Chandrasekara A. Recent Advances in Phytochemicals in Fruits and Vegetables. Phytochemicals: Chemistry and Human Health 2017; 1323-56.
33. Horax R, Hettiarachchy N, Chen P. Extraction, quantification, and antioxidant activities of phenolics from pericarp and seeds of bitter melons (Momordica charantia) harvested at three maturity stages (immature, mature, and ripe). J Agric Food Chem 2010;58:4428-33..
34. Sharma V, Sharma L, Sandhu KS. Antioxidants in vegetables and nuts-properties and health benefits: Springer; 2020:341-53.
35. Horax R, Hettiarachchy N, Chen P. Extraction, quantification, and antioxidant activities of phenolics from pericarp and seeds of bitter melons (*Momordica charantia*) harvested at three maturity stages (immature, mature, and ripe). J Agric Food Chem 2010;58:4428-33.
36. Duncan BB, Magliano DJ, Boyko EJ. IDF Diabetes Atlas 11th edition 2025: Global prevalence and projections for 2050. Nephrol Dial Transplant 2025;41:7-9.
37. Kole C, Matsumura H, Behera TK, editors. The bitter gourd genome. Cham Switzerland: Springer; 2020: 978-3.
38. Mahwish, Saeed F, Sultan MT, Riaz A, Ahmed S, Bigiu N, *et al*. Bitter melon (*Momordica charantia* L.) Fruit bioactives charantin and vicine potential for diabetes prophylaxis and treatment. Plants (Basel) 2021;10:730.
39. Liu Y, Mu S, Chen W, Liu S, Cong Y, Liu J, *et al*. Saponins of *Momordica charantia* increase insulin secretion in INS-1 pancreatic β-cells via the PI3K/Akt/FoxO1 signaling pathway. Endocrinol Diabetes Nutr (Engl Ed) 2021;68:329-37.
40. Goyal MR, Chauhan A, Raja K. Holistic Approaches for Women's Sustainable Health: Herbs, Spices, Phytochemicals, and Cereals: Body Care, Cancer Prevention, and Hormonal Health. United States: Apple Academic Press; 2026.
41. Ooi CP, Yassin Z, Hamid TA. *Momordica charantia* for type 2 diabetes mellitus. Cochrane Database Syst Rev 2012;2012:CD007845.
42. Kao PF, Cheng CH, Cheng TH, Liu JC, Sung LC. Therapeutic potential of momordicine I from *Momordica charantia*: Cardiovascular benefits and mechanisms. Int J Mol Sci 2024;25:10518.
43. Ray RB, Raychoudhuri A, Steele R, Nerurkar P. Bitter melon (*Momordica charantia*) extract inhibits breast cancer cell proliferation by modulating cell cycle regulatory genes and promotes apoptosis. Cancer Res 2010;70:1925-31.
44. Oliveira MS, Da Costa WA, Bezerra FW, Araújo ME, Ferreira GC, de Carvalho Junior RN. Phytochemical profile and biological activities of *Momordica charantia* L. (Cucurbitaceae): A review. Afr J Biotechnol 2018;17:829-46.
45. Pitchakarn P, Ohnuma S, Pintha K, Pompimon W, Ambudkar SV, Limtrakul P, *et al*., Kuguacin J isolated from *Momordica charantia* leaves inhibits P-glycoprotein (ABCB1)-mediated multidrug resistance. J Nutr Biochem 2012;23:76-84.
46. Lim TK. Edible Medicinal and Non-Medicinal Plants.

United Kingdom: Springer Nature; 2016; 354-457.
47. Datta S, Sharma AK, Saini RV, Saini AK, editors. Understanding Cancer Biology: Genetics, Molecular Biology, and Cellular Signaling Pathways. United Kingdom: CRC Press; 2026.
48. Chen F, Huang G, Yang Z, Hou Y. Antioxidant activity of *Momordica charantia* polysaccharide and its derivatives. Int J Biol Macromol 2019;138:673-80.
49. Hsiao PC, Liaw CC, Hwang SY, Cheng HL, Zhang LJ, Shen CC, *et al*. Antiproliferative and hypoglycemic cucurbitane-type glycosides from the fruits of *Momordica charantia*. J Agric Food Chem 2013;61:2979-86.
50. Kalia P, Singh S. Nutritional enhancement of vegetable crops (with major emphasis on Broccoli: A new cole crop in India). In Vegetables for nutrition and entrepreneurship. Singapore: Springer Nature Singapore 2023;1-29.
51. Ghosh D, Thakurdesai P. Fenugreek: Traditional and Modern Medicinal Uses. United States: CRC Press; 2022.
52. Anand U, Jacobo-Herrera N, Altemimi A, Lakhssassi N. A comprehensive review on medicinal plants as antimicrobial therapeutics: potential avenues of biocompatible drug discovery. Metabolites 2019; 9:258.
53. Spreafico F, Malfiore C, Moras ML, Marmonti L, Filippeschi S, Barbieri L, *et al*. The immunomodulatory activity of the plant proteins *Momordica charantia* inhibitor and pokeweed antiviral protein. Int J Immunopharmacol 1983;5:335-43.
54. Xiong SD, Yu K, Liu XH, Yin LH, Kirschenbaum A, Yao S, *et al*. Ribosome-inactivating proteins isolated from dietary bitter melon induce apoptosis and inhibit histone deacetylase-1 selectively in premalignant and malignant prostate cancer cells. Int J Cancer 2009;125:774-82.
55. Polito L, Bortolotti M, Maiello S, Battelli MG, Bolognesi A. Plants producing ribosome-inactivating proteins in traditional medicine. Molecules 2016;21:1560.
56. Liu L, Lin Z, Cai X, Zhang Y, Yang Y, Yang C, *et al*. The bitterness, biosynthesis, chemical transformation, and antidiabetic activity of cucurbitane-type triterpenoids from bitter gourd (*Momordica charantia* L.). Food Chem 2025;497:147081.
57. Pereira BS, Nunes-Pinheiro DC, Vasconcelos AK, Pinheiro AD, Rodrigues PA. Atividade hepatoprotetora dos extratos etanólico e hexânico das folhas de *Momordica charantia*. Rev Brasil Plantas Med 2010;12:311-6.
58. Wang S, Li Z, Yang G, Ho CT, Li S. *Momordica charantia*: A popular health-promoting vegetable with multifunctionality. Food Funct 2017;8:1749-62.
59. Sharma S, Katoch V, Kumar S, Chatterjee S. Functional relationship of vegetable colors and bioactive compounds: Implications in human health. J Nutr Biochem 2021;92:108615.
60. Manabe M, Takenaka R, Nakasa T, Okinaka O. Induction of anti-inflammatory responses by dietary *Momordica charantia* L. (bitter gourd). Biosci Biotechnol Biochem 2003;67:2512-7.
61. Fang EF, Zhang CZ, Ng TB, Wong JH, Pan WL, Ye XJ, *et al*. *Momordica Charantia* lectin, a type II ribosome inactivating protein, exhibits antitumor activity toward human nasopharyngeal carcinoma cells *in vitro* and *in vivo*. Cancer Prev Res (Phila) 2012;5:109-21.
62. Çiçek SS. *Momordica charantia* L.-Diabetes-related bioactivities, quality control, and safety considerations. Front Pharmacol 2022;13:904643.
63. Nerurkar PV, Johns LM, Buesa LM, Kipyakwai G, Volper E, Sato R, *et al*. *Momordica charantia* (bitter melon) attenuates high-fat diet-associated oxidative stress and neuroinflammation. J Neuroinflammation 2011;8:64.
64. El Batran SA, El-Gengaihi SE, El Shabrawy OA. Some toxicological studies of *Momordica charantia* L. On albino rats in normal and alloxan diabetic rats. J Ethnopharmacol 2006;108:236-42.
65. Khan MF, Abutaha N, Nasr FA, Alqahtani AS, Noman OM, Wadaan MAM. Bitter gourd (*Momordica charantia*) possess developmental toxicity as revealed by screening the seeds and fruit extracts in zebrafish embryos. BMC Complement Altern Med 2019;19:184.
66. Kosanovic M, Hasan MY, Petroianu GA, Marzouqi A, Abdularhman O, Adem A. Assessment of essential and toxic mineral elements in bitter gourd (*Momordica Charantia*) fruit. Int J Food Properties 2009;12:766-3.
67. Fongmoon D, Lalitwongsa S, Keyoonwong W, Nakong M, Iamsaard S. Antioxidant activity and cytotoxicity of bitter melon (*Momordica Charantia* L.) Extract cultured in Lampang Thailand. NU Sci J 2013;10:18-25.
68. Gayathry KS, John JA. A comprehensive review on bitter gourd (*Momordica charantia* L.) as a gold mine of functional bioactive components for therapeutic foods. Food Prod Process Nutr 2022;4:10.
69. Kim SK, Jung J, Jung JH, Yoon N, Kang SS, Roh GS, *et al*. Hypoglycemic efficacy and safety of *Momordica charantia* (bitter melon) in patients with type 2 diabetes mellitus. Complement Ther Med 2020;52:102524.
70. Bara LV, Budau R, Apahidean AI, Bara CM, Iancu CV, Jude ET, *et al*. *Momordica charantia* L.: Functional health benefits and uses in the food industry. Plants (Basel) 2025;14:2642.
71. Deligiannidou GE, Pritsa A, Nikolaou A, Poulios E, Kontogiorgis C, Papadopoulou SK, *et al*. Nutraceutical potential of bitter melon (*Momordica charantia*) on cancer treatment: An overview of *in vitro* and animal studies. Curr Issues Mol Biol 2025;47:425.
72. Al-Worafi YM. Handbook of Complementary, Alternative, and Integrative Medicine: Education, Practice and Research. United Kingdom: Routledge; 2024.
73. Unsal O, Sütcüoğlu O, Yazıcı O. Dangerous interaction of bitter melon (*Momordica charantia*) with pazopanib: A case of acute pancreatitis. J Oncol Pharm Pract 2022;28:486-8.
74. Kim B, Lee HS, Kim HJ, Lee H, Lee IY, Ock S, *et al*.

Momordica charantia (bitter melon) efficacy and safety on glucose metabolism in Korean prediabetes participants: A 12-week, randomized clinical study. Food Sci Biotechnol 2023;32:697-704.
75. Chung WY, Jadhav S, Hsu PK, Kuan CM. Evaluation of acute and sub-chronic toxicity of bitter melon seed extract in Wistar rats. Toxicol Rep 2022;9:1024-34.
76. Laczkó-Zöld E, Csupor-Löffler B, Kolcsár EB, Ferenci T, Nan M, Tóth B, *et al*. The metabolic effect of *Momordica charantia* cannot be determined based on the available clinical evidence: A systematic review and meta-analysis of randomized clinical trials. Front Nutr 2023;10:1200801.
77. Ashraf GM, Rahman MH, Reddy KV, Karthika C, Zari AT, Gowthamarajan K, editors. Therapeutic Potential of Natural Products in Neurodegenerative Disorders. CRC Press; 2026.
78. Khatua S, Acharya K. Pleurotus: From Farm to Pharmacy. United States: CRC Press; 2025.
79. Patra JK, Das G, Fraceto LF, Campos EV, Rodriguez-Torres MD, Acosta-Torres LS, *et al*. Nano based drug delivery systems: Recent developments and future prospects. J Nanobiotechnology 2018;16:71.

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