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Review Article

A comprehensive review on phytochemistry, nutritional and pharmacological properties of *Momordica charantia*

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ABSTRACT

Momordica charantia is known as the bitter gourd or bitter melon and is a member of the family Cucurbitaceae. It is a medicinal plant and its fruit is consumed as a food also. This plant is grown in tropical as well as subtropical areas around the world, mainly in Asia, India, China, South America and Brazil. Due to the presence of bioactive compounds like charantin, α-momorcharin and cucurbitacins, some of which possess potent biological actions, this plant is used in folk medicine all over the world and has many pharmacological activities, like antidiabetic, anticancerous, antimicrobial, antioxidant, antiviral, antimalarial, antihelmintic etc. This plant has been used as traditional medicine in various diseases treatments like syphilis, rheumatism, gout, and illness of the liver and spleen. But mainly *M. charantia* is famous for its effectiveness in the treatment of diabetes due to the presence of polypeptide-p and is also known as p-insulin due to very similarity in function against diabetes.

1. Introduction

In the field of medicine, herbal medicines are becoming more popular day by day in recent years, because they are naturally present in the environment and have fewer side effects on human health.[1,2] Synthetic drugs available markets are associated with toxic effects and cause cellular injury to the organ due to formations of free radicals.[3,4] *Momordica charantia* (MC) is additionally referred to as bitter melon, bitter gourd, gourd vine, karela, pare and is a flourishing plant placed under the family Cucurbitaceae (Figure 1). It is widely distributed in tropical areas of the Amazon, East Africa, Asia, India, South America, and Caribbean (tropical and sub tropical area).[5,6] This plant contains an elongated fruit which has a bitter taste and its bitterness increases after ripening and used as vegetable. Vegetables are rich source of important nutrients such as vitamins, minerals and phytochemicals.[7–9] *M. charantia* contains chemicals which are biologically active including, triterpens, proteins, steroids, alkaloids, saponins, flavonoids, acids and due to which, plant possesses antidiabetic, antifungal, antibacterial, antiparasitic, antiviral, antifertility, antitumorous and anti-carcinogenic properties.[10] It is also used as a standard medicine in various diseases like Rheumatism, Gout, Colic, illness of liver and spleen. According to Bortolotti et al.[11] *M. charantia* has been used in a wide range of medical applications, which

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include the treatment of T2DM (Type 2 diabetes mellitus), hypertension, obesity, cancer, bacterial and viral infections, and even AIDS (Acquired Immuno-Deficiency Syndrome). *M. charantia* has been used as ayurvedic medicine since ancient times. Each part of this plant, i.e., seeds, roots, leaves, as well as its fruits have important pharmacological properties and have diuretic, laxative and antipyretic activities. Its fruit has a bitter taste which is used in cooking and also used as traditional medicine in the treatment of various diseases. It is a climbing perennial that usually grows up to 16 ft. The fruit has an elongated shape with an uneven surface. It is a useful medicinal and vegetable plant for human health and one of the most promising plants for diabetes treatment.[12] The juice of *M. charantia's* fruit is useful in the treatment of many illnesses, like joint pain relief, against chronic fever, helpful in the treatment of jaundice, hepatic illness, digestive disorders. It is also helpful in the treatment of burn, rashes and chronic skin diseases. The use of the entire plant as food is suggested for the treatment of T2DM. The leaf decoction is additionally used for the treatment of high vital sign (body temperature, blood pressure, respiration rate, pulse rate), womb infections, malaria, dysentery, and worm infection.

Fig. 1: *M. charantia* **A**. Plant **B**. Leaf and Flower **C**. Fruit **D**. Seed

1.1. Plant's taxonomy

Classification of *M. charantia:*

Kingdom - Plantae
Division - Magnoliophyta
Family - Cucurbetaceae
Genus - Momordica
Species - Charantia
Duration - Annual
Scientific name - *Momordica charantia*

2. Nutritional Value of *M.charantia*

The nutritional value of *M. charantia* plant in among all the cucurbits, it contain the highest nutritional value and have good amount of carbohydrate, proteins, fibers, vitamins and minerals. The fruit contains 93.2% of water while protein and lipids covered 18.02% of its dried weight. The green part of fruit possesses high amounts of vitamin C, vitamin A, vitamin E, vitamin B1, B2, B3 as well as vitamin B9 (folate). It is also enriched with minerals like potassium, calcium, zinc, magnesium, phosphorus and iron. It contains high antioxidant properties because of the presence of phenolics, flavonoids, isoflovonoids, terpenes, anthroquinones and glucosinolates.[6]

3. Phytochemistry of plant *M.charantia*

M. charantia contains proteins, fatty acids, sterols, volatile constituents, and glycosides.[13] The plant contains the alkaloids momordicin, which are present in the fruit and leaves. The plant carries a saponin-like material, glycosides, aromatic volatile oil, mucilage, and glue-like material which are very distasteful. The seed holds urease and alkaloids and the fruit carries ascorbigen, a bound form of ascorbic acid.[14] The fruit also carries free amino acids, which are glutamic acid, serine, aspartic acid, alanine, threonine, pipecolic acid. The green part of the fruit holds luteolin, which is a type of flavonoid. The fruit pulp contains galactouronic acid and soluble pectin. The fruit of *M. charantia* also carries reducing sugar alkaloids, saponins, resins and phenolics constituents. In this plant, the presence of non-identified alkaloids and 5-hydroxytryptamine is also reported. *M. charantia* primarily carries charantin, cucurbitacins, sterols, triterpenoids and vicine. Charantin is responsible for the hypoglycaemic effect in the *M. charantia*. In charantin, steroidal saponins, and β- sitosteryl glucoside is present in 1:1 ratio. They are highly polar and moderately water soluble. Seeds of *M. charantia* contain a glycol alkaloid, vicine. It is a pyrimidine nucleoside. The presence of vicine in bitter melons leaves, seeds and fruits was determined by HPLC for the first time.

M. charantia also contains polypeptide-p, which is used to control diabetes naturally. Polypeptide–p is a hypoglycaemic protein which is similar to insulin and known as p-insulin. After injecting it into humans and langurs, it showed that it helps in lowering the blood glucose level. Polypeptide–p can be used as plant based insulin in type-1 diabetes patients because it works similarly to human insulin.[6] Terpenoids are a naturally occurring wide group of chemicals, which are acquired from five carbon isoprene units. Cucurbitane are triterpenoids which are present in the Cucurbitaceae family and they are responsible for the bitter taste. Momorcidine I is a bioactive triterpenoid which is extracted from bitter melon.[15] Momordicine II is also isolated from the leaves of *M. cahrantia*.

4. Pharmacological Activities of *M.charantia*

Bitter melon is a valuable vegetable. Epidemiological literature has shown that there is a direct correlation between a high dietary intake of fruits and vegetables with reduced risk of developing acute and chronic diseases, such as cardiovascular disease, cancer, diabetes, hepatotoxicity

etc.[16–18] It is useful in most metabolic and physiological processes of the human body. *M. charantia* has a number of pharmacological activities as represented in Figure 2.

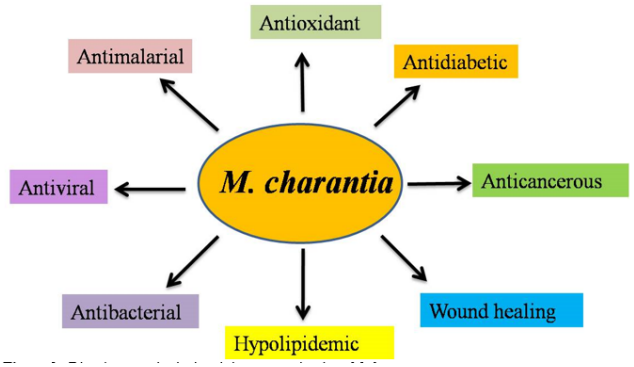

Fig. 2: Bio-pharmacological activity present in plant *M.charantia*

4.1. Antioxidant activity

M. charantia can act as a natural source of antioxidants due to the presence of phenolics and polyphenolics compounds in the fruits and seeds of the plant. It can act as a substitute to synthetic antioxidants for alleviating oxidative deterioration in the human body. According to the different stages of maturity, bitter gourd contains fourteen different types of carotenoids, cryptoxanthin in unripe fruit chloroplast and chromoplast in ripe fruit.[19] Phenolic compounds are a very good source of natural antioxidant which help in the reduction of cholesterol, blood pressure and helpful in prevention of cancer and cardiovascular disease. One of the most efficacious free radical scavenger and antioxidant from bitter gourd are Flavonoids.[20] It was reported that there is a direct correlation between the antioxidant activity and flavonoids content as it's antioxidant capacity increases gradually with the increase of flavonoids concentration. Gourd vine pulp and its extracts, followed by seed powder and its ethanol/water extracts exhibited stronger anti-oxygenic activity than different solvent extracts, which were determined by many in vitro models.[21]

4.2. Antidiabetic activity

Diabetes mellitus, one of the fastest growing disease thoughout the world, could be a cluster of metabolic disorders, characterized by symptoms ensuing from defects in insulin hormone secretion and hormone action.[22] Many studies revealed that *M. charantia* extract is used as a remedy for the treatment of diabetes. It has been used as an antidiabetic drug in numerous countries form thousands of years.[23] According to Mishra et al.[24] liquid extract of bitter gourd fruits might considerably lowered glucose level in streptozotocin (STZ) induced diabetic rats through oral passage. Liquid extract of bitter gourd fruit has capacity to stimulate production of insulin hormone by β-cells in the pancreas which is isolated from obese-hyperglycemic mice.[25] Liquid extract of bitter gourd has the capacity to decrease glucose concentrations independently and decreases intestinal glucose absorption.[26]

M. charantia holds chemicals like charantin, vicine, arabinosides and glycosides along with polypeptide-p plant insulin. These phytochemicals improve blood sugar levels by reducing intestinal glucose absorption, increasing glucose uptake from blood and induces glycogen synthesis in the liver, muscles and fat cells and causing hypoglycemic effect. According to the reports, it is believed that they can improve the release of insulin from the beta-cells of the pancreas, and also promote growth of insulin secreting beta-cells. *M. charantia* also contains the bioactive compound lectin which has insulin-like activity. Lectin has insulin like bioactivity because of its linking together two insulin receptors and showed hypoglycemic effects after eating *M. charantia*. Lectin acts on peripheral tissues and due to this action, blood glucose concentration decreases. Charantin is present in *M. charantia*, which is extracted by alcohol is a potent hypoglycemic agent composed of mixed steroids which are sometimes used in the treatment of diabetes to lower the blood sugar levels.[15]

4.3. Anticancer activity

Grover et al.[27] reported that extracts and monomer components of *M. charantia* have strong anticancerous effect on several tumors for instance, lymphoma, leukemia, choriocarcinoma, carcinoma, melanoma, and prostatic adenocarcinoma (Figure 3). It has been reported that momordin, a protein filtered from bitter gourd, may have ribosome deactivating capacity; linked with Anti-CD5 monoclonal antibodies better acts than other anti-CD5-based immune conjugates containing ricin-A sequence on human T-lymphocyte leukemia jurkat.[28] Seeds of bitter gourd also showed strong inhibitory effect against tumor cell *in vivo*. Eleostearic acid is a crucial constituent in bitter gourd's seeds and its dihydroxy derivative with ethanol extract has been proved to be the foremost efficacious antitumor agent.[29] It can suppress growth of some cancer and fibroblast lines, counting those of HL60 leukemia and HT29 colon carcinoma. According to research reported by Grossmann et al.[30] showed that eleostearic acid repressed the multiplication of both breast cancer cell line of estrogen receptor (ER) α- negative and ER α- positive, and can block G2-M within the cell cycle and apoptosis. The extract of *M. charantia* modulates signal transduction pathways for the inhibition of carcinoma cell growth and might be used as a dietary supplement for prevention of carcinoma.[31] Asiamah et al., reviewed the chemo-preventive properties of *M. charantia* on azoxymethane induced cancer in male rats and determined its effect on selective hepatic detoxification and antioxidant enzyme.[32] The green leaves, fruits, seeds

and stems of plant contains a lot different proteins and steroids which are chemically active. These proteins are alpha and beta momorcharins, which have anticancer and anti HIV properties.[33]

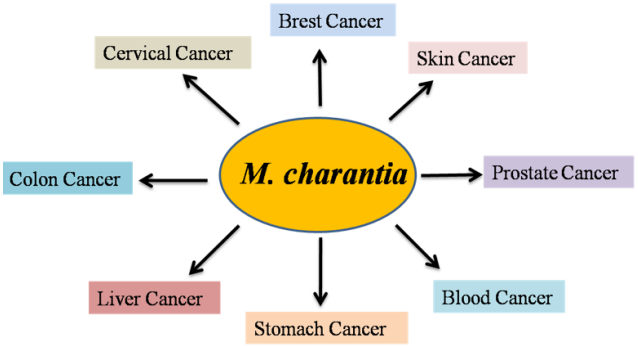

Fig. 3: Types of cancers prevented by *M. charantia*

4.4. Antimicrobial activity

Antimicrobial activity is a process in which inhibition of disease-causing microbes occurs.[34] Bacterial resistance can be a major problem throughout the world and it is a belief that by 2050 it could be a major cause of demise in the world.[35]The search for new entities with antibacterial capacity is important due to the bacteria's resistant behaviour towards existing antibiotics.[36] There are several studies proving that different parts of *M. charantia* contain antimicrobial activity (Table 1).[34,37] According to Wang et al.[38] the antimicrobial activity of *M. charantia* is assigned to its content of seed oil, tannins, triterpenoids, alkaloids, antimicrobial protein, steroids, and cardiac glycolysis.

Antimicrobial activity towards *Heliobacter pylori, Sindbis*, Herpes simplex virus type 1, and antihelmintic activity against *Caenorhabditis elegans* showed by the bioactive component present in *M. charantia* plant.[34]The methanolic extract of leaf and stem of bitter gourd showed exceptional activity against *E. coli* and *Staphylococcus aureus*, *Pseudomonasaeruginosa, Bacillus subtilis*, and *Klebsiella pneumonia* whereas ethanolic extract of leaf showed antimicrobial activity against *Trypanosoma cruzi, Salmonella parathyphi, Shigella dysentery* and *E. coli*.[39–41] Leaf extract of bitter gourd also showed antimicrobial action against *S. typhi* for hepatic- inflammatory movement by decreasing the concentration of total and direct bilirubin, alkaline phosphate, and gamma-glutamyl transferase. Saengsai et al.[42] extracted plumericin, an iridoid lactone from the stem of *M. charantia* which contains antibacterial effects towards *Enterococcus faecalis* and *Bacillus subtilis* and its antimicrobial activity was better than cloxacillin, which is widely used in the treatment of bacterial infections. Patel et al.[43] found that the extract of fresh fruits showed similar antibacterial activity towards the strain of *Bacillus subtilis, Pseudomonas aeruginosa and Saccharomyces cerevisiae*. It has been reported that hydrophilic leaf extract of *M. charantia* exhibit antibacterial effects against *Staphylococcus, E. coli, Salmonella Streptobacillus* and *Pseudomonas*.[44] Prasad et al.[45]in their experiment on rats showed that administration of fruit powder of bitter gourd at the damaged area is efficacious in the stimulation of prosenchyma regeneration and injury healing. According to Makhija et al.[46] the extract of the fruit is more efficacious than leaf and seed extracts. It has also been reported that methanolic extract exhibits antimicrobial activity and may be a good source of antibacterial agent.[47]

Table 1: Antimicrobial activity of extracts or fractions of *M. charantia*

Plant's Part	Extract	Antimicrobial activity against
Leaf	Methanolic	*E. coli, Staphylococcus aureus Pseudomonas aeruginosa Bacillus subtilis*
	Ethanolic	*Staphylococcus aureus*
	Acetone	*Pseudomonas aeruginosa Staphylococcus aureus*
Fruit	Methanolic	*Pseudomonas aeruginosa Saccharomyces cerevisiae*
	Ethanolic	*Aspergillus niger Salmonella typhi*
	Choloroform	*E.coli Bacillus subtilis*
Seed	Ethanolic	*Proteus mirabilis E.coli Candida parapsilosis*

(Torre et al., 2020)[34]

4.5. Antiviral activity

In bitter melon, there are several chemical components which consist of medicinal attributes and inhibit the function of ribosomes. It can stimulate production of MAP30 (Momordica anti-HIV protein) which can suppress the activity of HIV. Momordicoside A and B are present in *M. charantia,* which act as inhibitors in the growth of tumors. There are a number of phytochemicals in bitter gourd which have *in vitro* antiviral activity against viruses, including herpes and HIV viruses.

According to Beloin et al.,[48] it was reported that ethanolic extracts of *M. charantia* leaf and stem inhibit the growth of HSV-1 and SINV viruses. It has been reported that compounds separated from bitter gourd has antiviral effects in which most of them are proteins and steroids in nature.[15] Experimental results from one study explored that MAP30 acts as an important constituent for antiviral activity because it cautiously kills those lymphocytes and macrophage which are infected by HIV.[49] It also inhibits DNA replication of HIV -1 virus in monocytes. Similarly, it was also found that MAP30 of bitter gourd proteins can

inhibit HIV activity,depress the expression of the virus core protein p24 and viral associated reverse transcriptase (HIV-RT) enzyme, while having less effect on cellular DNA or protein synthesis in H9 cells.[49] Tian et al.[50] reported that momordicin had direct protective effect on coxsackie virus (CVB3) infected myocardicocyte and depressed RNA transcription and translation of CVB3 in myocardial cells.

4.6. Antimalarial activity

M. charantia has some antimalarial activities. The extract of bitter melon has modest *in vivo* activity against rodent malaria, *Plasmodium vinckei petteri,* and a very good antimalarial activity *in vitro* on *P. falciparum.*[51]

5. Toxicological Impact of *M. Charantia*

Though bitter gourd is mainly non-toxic to the human body in normal conditions, but in adverse conditions, it may be harmful due to high uptakes and without processing methods/ prescribed concentration. It may induce mainly acute, chronic and reproductive toxicity. In the report of Saksena showed that periodic intake of bitter gourd leaves was used to intercept childbirth in India.[52] According to Tam et al.,[53] α - MMC has the capacity to suppress the maturing of morulae, which induces termination of early pregnancy and cause abortion. β – MMC can also affect the embryo adhesion and implantation, and has ability to suppress the development of embryo.[54] Literature showed that the strong dose of bitter gourd's fruit can cause stomach ache and diarrhoea in diabetic conditions. Temitope et al.[55] reported that the aqueous extract caused a remarkably decrease in the concentration of haemoglobin in albino rats. The lectin of *M. charantin* had a cytotoxic effect, which can inhibit DNA and protein synthesis in human peripheral blood lymphocytes of normal or leukaemic cells.[56]

6. Conclusion

Till now, research on the bioactivities of bitter gourd has evolved quickly. The isolated bioactive component of the plant has allured more awareness. Karela is a nutritive food with a distinctive bitter taste and also used in traditional medicine. During the last few years, so many studies have been carried out on bitter gourd to explore its pharmacological activities. *M. charantia* plays an important role in the cure of diabetes. It exhibited favourable outcomes in managing secondary complications of diabetes too. In many other countries, *M. charantia* is used as a traditional medicine because it has antidiabetic, anticancerous, anthelmintic, antimicrobial, antiulcer, antioxidant, and many other activities. It also has abortifacient and antifertility properties which need to be cared, mainly in expecting women.

7. Conflicts of Interests

The authors have no financial interests or conflicts of interests.

8. Source of Funding

None.

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