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REVIEW ARTICLE

Bitter Gourd: A Bitter Body With A Sweet Soul

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ABSTRACT
Momordica charantia commonly known as bitter melon/gourd, a member of Cucarbitaceae, is a slender, tendril climbing, annual vine. Bitter melon is a common food in tropics and is widely used as medicinal plants in countries like India, Brazil, China, Africa etc. In M. charantia primary metabolites are common sugars, proteins and chlorophyll while secondary metabolites are alkaloids, flavonoids, tanins, saponins, disogenin, proteins, calcium, copper etc. Secondary metabolites are responsible for medicinal activity of Momordica charantia. The medicinal values of bitter melon lies in the bioactive phytochemical constituents that are non nutritive chemicals that produce definite physiological effects on human body and protect them from various diseases. Qualitative phytochemical analysis of Momordica charantia confirms the presence of phytochemicals like flavanoids, saponins, terpenoids, coumarins, emodins, alkaloids, proteins, cardiac glycosides, anthraquinones, anthocyanins, steroids etc.
Keywords: *Charantins, Diabetes mellitus, Hypoglycemic, Momordica charantia, Phytochemicals*

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INTRODUCTION

India is the second largest producer of vegetables in the world next to China with a production of 66 million tonnes. Nearly 3,40,000 ha are devoted to bitter gourd cultivation annually in Asia and 60% of this production area is in India. More than 50 varieties of vegetable crops are grown in India and the estimated area under vegetable crops is 6.2 million hectares (13). Vegetable production in India accounts for 12 per cent of world's production, but the per capita vegetable consumption in India is only 135 g/day compared to the minimum requirement of 250 g/day (34). Bitter gourd (*M. charantia*) is usually used as a hypoglycemic and antidiabetic agent (37) and many such components have been identified from it (59). The hypoglycemic effect of bitter gourd is equivalent to some of the antidiabetic drugs like Tolbutamide. At least three different groups of constituents in bitter gourd have been reported to have hypoglycemic actions which have potential benefits in controlling diabetes mellitus, these include steroidal saponins known as charantin, insulin like peptides and alkaloids (4). The hypoglycemic activity of the bitter gourd fruit has been shown in both spontaneous and chemically induced diabetes mellitus in experimental animals as well as in human patients (40, 3).

The immature fruits called bitter gourd, bitter melon or balsam pear, are harvested at developmental stages up to seed hardening. The bitter principle, for which the fruit is named, is due to the alkaloid momordicine, not to cucurbitacins as in other members of the Cucurbitaceae (83). The bitter gourd is also important for its medicinal properties (45, 82). Carotenoids increase greatly during the ripening process, with the fruit changing from green to yellow, and the seed cavity becoming bright red (68). Coincident with colour changes, the fruit pulp loses bitterness and becomes sweet and the fruit splits or ruptures at the blossom end (45). The bitter gourd is cooked with other vegetables, stuffed, stir-fried, or added in small quantities to beans and soups to provide a slightly bitter flavour. However, for most food preparation, bitter gourds are blanched, parboiled, or soaked in salt water before cooking to reduce the bitter taste. In addition to frying or cooking (eg. for curries), the fruits can be dehydrated, pickled or canned. Young *Momordica* shoots and leaves are also cooked and eaten as leafy vegetables, and leaf and

fruit extracts are used in the preparation of tea (76, 65). Unlike other cucurbitaceous vegetables, the bitter fruit flavour of *M. charantia* is considered desirable for consumption, and thus bitter flavour has been selected during domestication (46).

Origin

Bitter gourd (*Momordica charantia* L.) belongs to the family Cucurbitaceae. There are more than 60 species, of which only two are (*charantia* and *cochinchinensis*) important vegetables. It is believed to have originated in the tropics and is widely distributed in China, Malaysia, Indo-Pakistan and tropical Africa. *Momordica charantia* is a cucurbit vine native to Asia and now widely cultivated throughout the world for the immature fruits and sometimes for the tender leafy shoots or the ripe fruits (87).

Importance

The fruit of bitter gourd is similar in nutritional value compared to other cucurbits with the notable exceptions that it is much higher in folate and vitamin C content. The vine tips are an excellent source of vitamin A. The medicinal value of the gourd in the treatment of infectious diseases and diabetes is attracting scientists worldwide. From the literatures, it is known to contain compounds such as momorcharins, momordenol, momordicilin, momordicins, momordicinin, momordin, momordolol, charantin, charine, cryptoxanthin, cucurbitins, cucurbitacins, cucurbitanes, cycloartenols, diosgenin, elaeostearic acids, erythrodiol, galacturonic acids, gentisic acid, goyaglycosides and goyasaponins (27), caffeic acid and ferulic acid (60), fisetin and isorhamnetin (39). Its MAP30 protein exhibited anti-HIV and anti-tumor activities, momorcharins and momordins showed activities in inactivating ribosomes, momordin 1-c and oleanolic acid glycoside in altering gastrointestinal transit time and blood glucose (16, 27).

Physical properties of bitter gourd

Table 1: Physical properties of bitter gourd fruit (36)

Parameters	Bitter gourd
Length (cm)	12.50-20.00
Breadth (cm)	3.00-3.60
Diameter (cm)	7.50-10.80
Weight (g)	23.20-64.20
Volume (ml)	30.00-80.00
Bulk density (g/ml)	0.77-1.07
Seed (No.)	14-26
Colour	Dark green

Chemical composition of bitter gourd

Bitter gourds are good source of carbohydrates, proteins, vitamins, and minerals and have the highest nutritive value among cucurbits (47, 20). The vitamin C content of Chinese bitter gourd varies significantly (440-780 mg/kg edible portion). Considerable variation in nutrients, including protein, carbohydrates, iron, zinc, calcium, magnesium, phosphorous, and ascorbic acid, has been observed in bitter gourd (33, 90). Moreover, the crude protein content (11.4-20.9 g/kg) of bitter gourd fruits is higher than that of tomato and cucumber (85). The nutritional composition of bitter gourd fruit is given in Table 2.

Table 2: Proximate and Nutrient composition of bitter gourd (25**)**

Proximate value	Quantity
Moisture (g/100g)	83.20
Carbohydrates (g/100 g)	10.60
Proteins (g/g)	2.10
Fibre (g/100g)	1.70
Calcium (mg/100g)	23.00
Phosphorus (mg/100 g)	38.00
Potassium (mg/100g)	171.00
Sodium (mg/100g)	2.40
Iron (mg/100g)	2.00
Manganese (mg/100 g)	0.08
Zinc (mg/100g)	0.46
B Carotene	126.00
Vitamin C	96.00

Mixture of steroidal saponins known as charantins, insulin-like peptides and alkaloids are the hypoglycemic chemicals of *Momordica charantia* and these chemicals are concentrated in fruits of Momordica charantia, therefore fruit of *M. charantia* has shown most effective hypoglycemic property. Major photochemical in bitter gourd (Momordica charantia) fruit and their health benefits is given in Table 3 and Table 4.

Momordicine: It is the primary bitter compound of bitter gourd; the structure is given in Fig. 1.

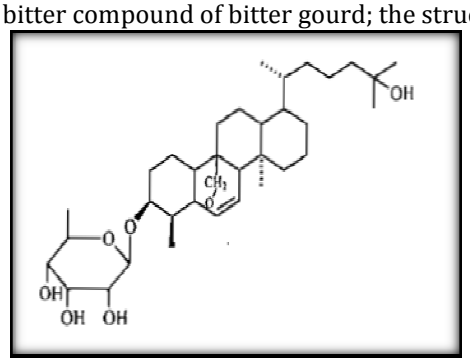

Fig. 1: Basic structure of momordicine

Steroids, Charantin

Charantin (Fig. 1) is one of the hypoglycemic compounds, which can be isolated from *Momordica charantia* fruit. It is a mixture of two compounds (1:1) sitosteryl glucoside ($C_{35}H_{60}O_6$) and stigmasteryl glucoside ($C_{35}H_{58}O_6$), both of which are steroidal saponins. Lolitkar and Rao (43) have shown charantin when taken either orally or intravenously in rabbits, it produces hypoglycaemic effects.

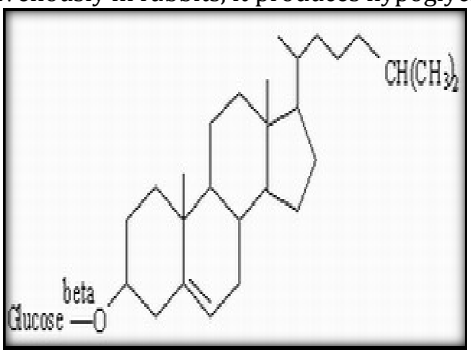

Fig. 2: Structure of charantin

Protein, P-insulin

Protein P-insulin is a polypeptide with molecular weight of about 11,000 Dalton and consists of 166 amino acids. Clinical study revealed that the polypeptide-p-$ZnCl_2$ produced blood sugar lowering effect.

Alkaloids

According to Pantastico (55), seeds of bitter gourd contain pyrimidine nucleoside vicine. Vicine has been found to induce hypoglycemia in rats, when administered intraperitoneally.

Table 3: Phytochemicals and constituents of bitter gourd (*Momordica charantia*)

Source	Phyto chemicals	Reference
Plant body	Momorcharins, momordenol, momordicilin, momordicins, momordicinin, momordin, momordolol, charantin, charine, cryptoxanthin, cucurbitins, cucurbitacins, cucurbitanes, cycloartenols, diosgenin, elaeostearic acids, erythrodiol, galacturonic acids, gentisic acid, goyaglycosides, goyasaponins, multiflorenol,	30 86, 57 50
Plant body	Glycosides, saponins, alkaloids, fixed oils, triterpenes, proteins and steroids	61
Fruit	Momordicine, charantin, polypeptide- p insulin, ascorbigen, Amino acids – aspartic acid, serine, glutamic acid, threonine, glutamic acid, threonine, alanine, g-amino butyric acid and pipecolic acid, luteolin, Fatty acids – Lauric, myristic, palmitic, palmitoleic, stearic,oleic,linoleic, linolenic acid	43 90
Seeds	Urease, Amino acids – valine, threonine methionine, isoleucine, leucine, phenylalanine, glutamic acid	54

Table 4: Major phytochemicals in bitter gourd (*Momordica charantia*) and their health benefits

Phytochemicals	Plant parts	Usefulness	References
β-momorcharin	Seeds	Glycoprotein that acts as midterm abortifacient	15
Vicine	Seeds	Hypoglycaemic glycoalkaloid	22
Charatine	Fruits	Non nitrogenous substance having hypoglycaemic principle	44
Momordicosides A and B	Seeds	Triterpene glycosides that inhibit tumor growth	52
MAP30	Seeds, Fruits	Basic protein that inhibits HIV	41
Polypeptide –p	Seeds, fruits	Hypoglycaemic peptide, called plant insulin	38
Phenols	Seeds	Antioxidants that reduce blood pressure and lower incidence of cancer and cardiovascular diseases	29
Carotenoids	Seeds, Fruits	Antioxidents that lower the incidence of cancer and cardiovascular diseases	68

Effect of peeling and cooking on composition of bitter gourd

Nutritional importance of vegetables cannot be neglected in our daily meals. Vegetables are the major source of vitamins and minerals, but vegetable protein is poor in quality. Vitamins and minerals are the chief regulator in metabolism in human (66). Some of the vegetables are used in raw form as salad, but most of them require cooking for the improvement of digestibility and palatability. Some other vegetables require peeling to decrease their useless fibrous (77). Minerals and other nutrients are affected by both peeling (removal of outer coarse covering) and cooking. Peeling is considered as an inevitable treatment for rendering them more digestible and may result in fairly heavy loss of some nutrient, especially of vitamins. Peeling before boiling, increases the loss of ascorbic acid, folic acid and other vitamins of group B (12). Methods, temperature and duration of cooking may also effect significantly on the nutritive values of vegetables. Some of the important nutrients such as ascorbic acid and folic acid which are susceptible to oxidation are readily oxidized by brisk cooking. Minerals are also affected by high temperature, in some cases flavour may be lost by brisk cooking. Excessive cooking may cause an adverse affect on the digestibility of the vegetables.

The loss of protein in bitter gourd was estimated 12.85% for peeling, 14.28% for cooking and 22.85% for peeled cooking. The loss of ash for above concentration was found to be 11.11, 36.66 and 60.0% respectively. Percentage losses for the minerals in their peeled, cooked and both peeled and cooked forms were 13.157, 24.368 and 32.1578 % for calcium, 4.76, 11.56 and 14.965 % for magnesium, 9.256, 17.355 and 31.30 % for phosphorus and 8.88, 22.22, 27.47 % for potassium. The percentage losses of ascorbic acid and folic acid for above mentioned three parameters were 13.26, 53.42, 89.75 and 13.33, 30.52 and 63.15 % respectively (73). The effect of peeling and cooking on compositional analysis of bitter gourd is given in Table 5.

Table 5: Compositional analysis of bitter gourd after peeling and cooking (73)

Parameters	Raw unpeeled	Raw peeled	Raw cooked	Peeled cooked
Protein	0.70 g/100g	12.85	14.28	22.85
Crude fibre	1.00 g/100g	20.00	28.00	32.00
Ash	0.90 g/100g	11.11	36.36	60.00
Calcium	19.00 g/100g	13.157	24.368	32.1578
Magnesium	22.05 g/100g	4.76	11.56	14.96
Phosphorus	30.25 g/100g	9.25	17.35	31.30
Potassium	270.00 mg/100g	8.88	22.22	24.47
Ascorbic acid	18.25 mg/100g	13.26	53.42	89.75
Folic acid	2.85 g/100g	13.13	30.52	63.15

Medicinal properties and health benefits of bitter gourd

Bitter gourd has been used for centuries in the ancient traditional medicine of India, China, Africa, and Latin America. Bitter gourd extracts possess antioxidant, antimicrobial, antiviral, antihepatotoxic and antiulcerogenic properties while also having the ability to lower blood sugar (84, 61). These medical activities are attributed to an array of biologically active plant chemicals, including tri-terpenes, pisteins and steroids (27). Ethno-medical reports of *M. churuntici* indicate that it is used in folkloric medicine for

treatment of various ulcers, diabetes, and infections (28, 71, 11). While the root decoctions have abortifacient properties, leaf and stem decoctions are used in treatment of dysentery, rheumatism and gout (75). In addition, the juice of *M. charantia* drawn directly from fruit traditionally has been used for medicinal purposes worldwide. Likewise, the extracted juice from leaf, fruit and even whole plant are routinely used for treatment of wounds, infections, and parasites such as worms, measles, hepatitis, and fever (10). Medicinal properties of *M. Charantia* are summarized in Table 6.

Hypoglycaemic Activity

Bitter gourd extracts traditionally used as vegetable insulin possess hypoglycaemic, antioxidative, and antidiabetic agents (81, 18) that are useful in the treatment of diabetes (9). The hypoglycaemic effects (*i.e.,* blood sugar lowering) of extracts have been well documented in animal (63, 69; 64, 48, 26, 62, 35, 17, 70, 74) and human (7, 40, 84) experiments. The beneficial hypoglycaemic properties in fruit pulp, seed, and whole plant extracts have also been documented in rat analyses (32, 35), and the medicinal attributes of such extracts have received broad review (8, 75). One study cites that there was a significant increase in the number of cells in the pancreas of streptozotocin-induced diabetic rats after 8 weeks of bitter gourd fruit juice treatment (1). In a parallel in vivo clinical human study, oral ingestion of all parts of the bitter gourd plant resulted in low patient toxicity (62). A mixture of steroidal saponins known as charantin (insulin like peptides), as well as alkaloids, appears to be responsible for the hypoglycaemic actions in bitter gourd extracts. Some studies have shown that at least three components (steroidal saponins, insulin like compounds and alkaloids) were found in bitter gourd plant parts that elicited hypoglycaemic potential and other benefits for sufferers of diabetes mellitus. The hypoglycaemic effect of these chemicals is more pronounced in fruit, where they are present in great abundance. Of the rich mixture of hypoglycaemic compounds in bitter gourd fruit, charantin, vicine, and polypeptide-P are thought to provide the major diabetic medical benefits (88). Polypeptide- P, previously unidentified insulin like protein similar to bovine insulin, was identified in bitter gourd fruit and seed and in tissue culture (38). Although the mechanism of action of these hypoglycaemic compounds is still debated, they either regulate insulin release directly or alter glucose metabolism and its insulin like effect.

Anticarcinogenic activity

It has been shown that *M. charantia* fruit juice, peel, pulp, seed and whole fruit extract modulate detoxification pathways in diabetic rats, specifically altering P450 and GSH dependent metabolism. Modulation of biotransformation system enzymes may be the cause of anti carcinogenic properties of *M. charantia.* The study by Kusamran *et. al.,* 1998 determined the effects of *M. charantia* on the levels of phase I enzymes, which include cytochrome P450 (P450), aniline hydroxylase (ANH) and aminopyrine-N-demethylase (AMD) and to induce the phase II enzymes [glutathione S-transferase (GST)] in rat liver. It was demonstrated that bitter-gourd fruits contain phases I and II enzyme inducers and compounds capable of repressing some monooxygenases, especially those involved in the metabolic activation of chemical carcinogens.

Antioxidant Activity

The antioxidant properties of carotenoids that protect plants during photosynthesis may also protect humans from carcinogens and mitigate free radical effects associated with heart disease. Natural antioxidants, primarily plant phenolics and polyphenolic compounds in fruits and seeds of bitter gourd are alternatives to synthetic antioxidants for alleviating oxidative deterioration in fruit. For instance, bitter gourd fruit contains as many as 14 carotenoids depending on stage of maturity (5, 6, and 14 in the immature, mature-green, and ripe stage, respectively), where cryptoxanthins becomes the principal chloroplast and chromoplast pigment found in ripe fruit (68). Other carotenoids, such as 3-carotene, zeaxanthmn and lycopene (at ripe stage), and lutein and a-carotene (immature fruit) are also prevalent in the fruits, where they could serve as a model for studying carotenogenesis during ripening (68). For instance, carotenogenesis in bitter gourd is not affected by temperatures above 30°C (78); in contrast, in tomato, high temperatures inhibit lycopene but not il-carotene synthesis. Likewise, the total carotenoid concentration of bitter gourd seeds can be a 100 fold higher in the ripe than the immature stage, which is exclusively attributable to lycopene (96% of the carotenoids in ripe seeds (67). Other chemo-preventive antioxidants in plants include vitamin C, vitamin B, phenolic acids, and organosulfur compounds (72). Bitter gourd is also a rich source of phenolic compounds, where gallic acid, gentisic acid, catechin, chlorogenic acid, and epicatechin are typically abundant. While the concentration of phenolics varies with plant organ (fruit, leaf and root) and cultivar type, the highest content has been found in the Indian white fruited followed by China white-fruited,

China green-fruited, and last India green-fruited (29). These plant phenolic compounds are potentially excellent natural sources of food antioxidants, given their abilities to reduce total cholesterol/triglycerides (32, 1), blood pressure, and the incidence of cancer and cardiovascular diseases.

Antifertility Effects

Excessive consumption of the fruit and leaves of bitter gourd can reduce sperm production (58). Bitter gourd ethanol seed extracts have also shown to have potent male antifertility effects (8) when administered to dogs (21) and guinea pigs (80).

Antiviral Activity

In recent years, a number of chemical components that possess medicinal attributes have been isolated from bitter gourd, such as c-momorcharin, which inactivates ribosome function (23, 42) and stimulates MAP30 (*Momordica* anti-HIV protein) production, which in turn, simultaneously suppresses HIV (human immunodeficiency virus) activity (41). Interestingly momordicoside A and B present in bitter gourd inhibit tumor growth (52), and several bitter gourd phytochemicals have in vitro antiviral activity against viruses including Epstein-Barr, herpes, and HIV viruses (79, 41, 51).

Antimicrobial Activity

The leaf extracts of bitter gourd possess antimicrobial activity principally against *Escherichia coli, Staphylococcus, Pseudomonas, Salmonella, Streptobacillus,* and *Streptococcus* (53). Moreover, whole plant extracts have shown antiprotozoal activity against *Entamoeba histolytica.* Generally, fresh fruit extracts have similar antibacterial properties, more specifically the fruit extracts of *M. charantia* L. have demonstrated activity against tuberculosis and the stomach ulcer causing bacteria *Helicobacter pylon* (31, 53, 89). Application of bitter gourd fruit powder to wound sites is similarly effective in stimulating tissue regeneration and wound healing in rats (56).

Table 6: Medicinal properties of *M. Charantia*

Property	Active phytochemicals/ extract administered	Test system	Mechanism of action/ Targeted against an organism	References
Anti-viral	MAP 30 (Momordica Anti HIV Protein) in seed and fruit extracts	Viral cell line, H9	Anti -HIV1 (Human Immunodeficiency Virus) activity	41
	Anti-HIV proteins MAP30	Human lung fibroblasts	Anti -HSV (Herplex Simplex Virus) activity	14
	Alpha and beta momorcharin from seeds, fruits and leaf extracts	Rabbit reticulosyte lysate	Anti- HIV activity	5
	Methanol extract	Shrimp	White spot syndrome virus	6
	Leaf extract	-	*Eshcherichi coli*, *Salmonella paratyphi and Shigella dysenterae*	53
	Essential oil	-	*Bacillus subtilis, Proteus mirabilis, Aspergillus niger, Aspergillus flavus and Escherichia coli*	2
Anti-malarial	Aerial part extract	Rat	*P*lasmodium v*inckei petteri* 279BY (rodent malarial parasite)	49
	Leaf extract	Rat	*Plasmodium falciparum*	24
Anti-Helminthic	Lyophilised plant extract	-	*Caenorhabditis elegans*	11
	Plant extract	-	Free living nematodes	19
Anti-diabetic	Seed powder	Human	Fall in blood glucose level	43
	Chloroform extract Administered Intravenously	Alloxan induced rabbit	Fall in blood glucose Level	3

CONCLUSION

The medicinal plants find application in pharmaceutical, cosmetic, agricultural and food industry. Three active constituents in bitter melon know as steroidal saponins (charntin, insulin-like peptides, and alkaloids) are believed to be responsible for the blood-sugar lowering actions that could potential benefit individuals with diabetes mellitus. Fruits and leaves of bitter melon are a good source of vitamins and minerals such as iron, calcium, phosphorus and vitamin B. Bitter melon is also good digestive agent and helps in stimulating the secretion of gastric juices. It is very helpful in stimulating liver for secretion of bile juices that are very essential for metabolism of fats. It helps in improving the peristaltic movements hence it is very helpful in avoiding gastric disturbances.

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