

Antiobesity Potential and Complex Phytochemistry of *Momordica charantia* Linn. with Promising Molecular Targets

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Karale *et al.*: Antiobesity potential of bitter melon

Momordica charantia L. grows in many tropical and subtropical regions, the fruits of which are gradually becoming popular for treating diabetes and associated diseases. *Momordica charantia* L. appears to be an inimitable species that synthesizes a diverse range of chemical constituents in the fruits, leaves, stem and roots. Over 248 compounds belonging to the lipids, phenolics and terpenoids classes have been reported in various studies. The cucurbitane types of triterpenes exist in various parts of this plant as aglycones as well as glycosylated forms. *Momordica charantia* L. has been comprehensively studied worldwide for therapeutic properties to treat a number of diseases like diabetes, dyslipidaemia, obesity and certain cancers. The bitter melon seems to exert lipid lowering and antiobesity effects via several mechanisms like PPARs, LXRs, SREBPs, and Sirt1-mediated fat metabolism in various tissues, prevent adipocyte hypertrophy and visceral fat accumulation. This article presents an extensive literature review on the vast potential of bitter melon as antiobesity agent with supporting data on complex phytochemistry.

Key words: Obesity, phytochemicals, bitter melon, cucurbitane-type terpenoids

Momordica charantia L. is a tropical or subtropical creeper belonging to family Cucurbitaceae and widely used as a medicinal herb from ancient time (fig. 1). *M. Charantia* L. or bitter melon, also known as balsam pear or *Karela*, is a vegetable and common food in Indian cuisine and has been used comprehensively in folk medicine^[1]. The Latin name *Momordica* means 'to bite' referring to the serrated edges of the leaf, which appear as if they have been bitten^[2]. The major regions of *M. charantia* L. cultivation are Asia including China, India, Sri Lanka and Thailand, Central and South America and North America^[3]. In Ayurveda, the fruit is considered as tonic, stomachic, stimulant, emetic, antibilious, laxative and alterative^[4]. Bitter melon has been used in various Asian traditional medicine systems for a long time. It is well recognized, the plant is extensively in use in the Chinese, Ayurvedic and Indonesian systems of medicines as well as in Japan^[5].

The therapeutic significance of the plant is symbolized by the fruits which contain about half a dozen seeds per gram of the fresh fruit. As the name implies, the fruits are bitter and bitterness enhance with the level of

maturity and hence earlier harvesting required to battle bitter taste. The leaves and young shoots of bitter melon recognized to be used in traditional medicine as a herbal tea. The range of pharmacological activities reported for bitter melon is rapidly increasing in recent years and its claimed uses and potential applications for cancer and other diseases have been extensively reviewed^[3]. Likewise, the range of medicinal claims range from diabetes, hypertension, obesity, cancer as well as AIDS.

During the past 2 decades, it has been reported that *M. charantia* L. possessed various beneficial effects, including antiinflammatory^[6], antioxidant^[7], cytotoxic^[8], anticancer^[9-11], antiobesity^[12], antiviral^[13], antiHIV^[14], antiulcer^[15], cholesterol lowering^[16], inhibition of protein tyrosine phosphatase 1B^[17] and

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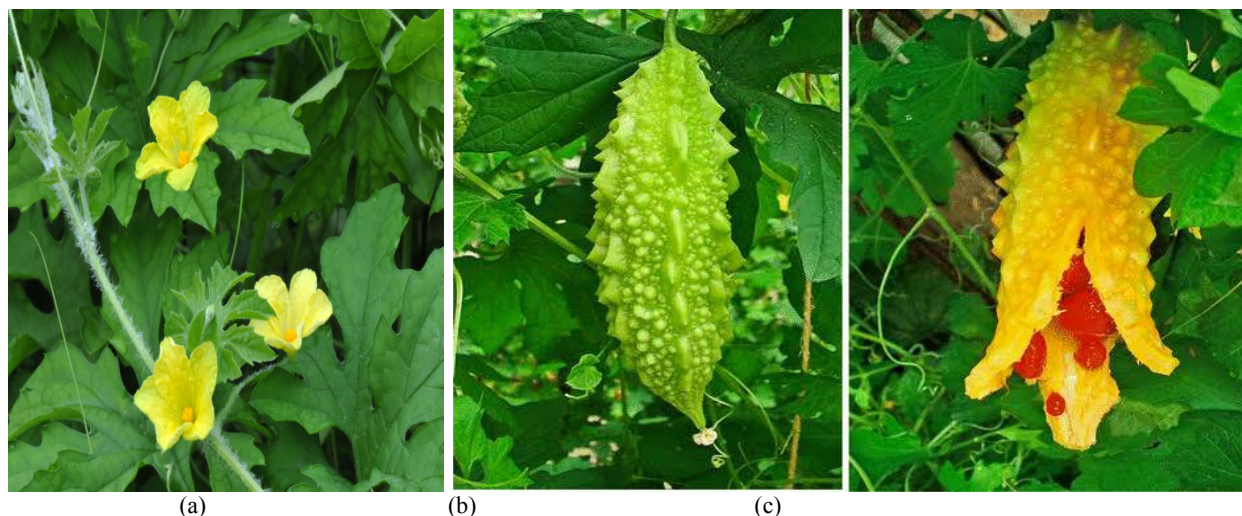


Fig. 1: Plant parts of *M. charantia* L.

(a) Leaves; (b) unripe fruit; and (c) ripe fruit and seeds of plant

antiosteoporosis^[18]. This review aims to highlight the complex phytochemistry and extensive review on antiobesity potential of bitter melon with possible targets.

Botanical description:

M. charantia L. was known previously by several synonyms including the *Cucumis argyi* H.Lev., *Cucumis intermedius* M. Roem., *Momordica anthelmintica* Schumacher & Thonn., *M. charantia* subsp. *abbreviata* (Ser.) Greb., *M. charantia* var. *abbreviata* Ser., *M. charantia* f. *muricata* (Willd.), *M. charantia* var. *muricata* (Willd.) Chakrav., *M. charantia* var. *pseudobalsamina* Griseb., *M. charantia* var. *zeylanica* Hitchc., *M. elegans* Salisb., *M. indica* L., *M. jagorana* K.Koch., *M. muricata* Willd., *M. papillosa* Peckolt ex Rosenthal., *M. roxburghiana* G. Don., *M. senegalensis* Lam., *M. thollonii* Cogn., *M. zeylanica* Mill. The botanical description of different parts of the plant is presented in Table 1^[19].

Cucurbitaceae family is known to comprise some 101 accepted genera and the genus *Momordica* L. itself comprises of some 50 accepted species within the family^[20]. The taxonomic hierarchy of bitter melon within the plant kingdom is as follows: Kingdom: Plantae; Subkingdom: Viridiplantae; Superdivision: Embryophyta; Division: Tracheophyta; Subdivision: Spermatophytina; Class: Magnoliopsida; Super order: Rosanae; Order: Cucurbitales; Family: Cucurbitaceae; Genus: *Momordica* Linn.; Species: *Momordica charantia* L.-balsampear.

The existence of many varieties of bitter melon has been noted^[21], for example, it was reported that the fruits of the wild variety of *M. charantia* L. growing in Trinidad

and Tobago were of one-fifth in size as compared to the cultivated Indian ones.

Phytochemistry:

The main constituents of bitter melon are triterpenoids, saponins, protein, polysaccharides, steroids, alkaloids, lipids, and phenolic compounds^[22]. Several bioactive compounds of *M. charantia* L. have been recorded and literature reported that these are responsible for various pharmacological effects as depicted in Table 2^[23-49].

Triterpenoids:

The most abundant phytochemical components of bitter melon fruits are the triterpenoid class of secondary metabolites and are well-known for their bitterness and toxicity. These are divided in 2 types primarily the cucurbitane-type and to a less extent oleanane-type, which may occur either in their glycosylated or aglycone forms (fig. 2). The fruits are predominant source of terpenoids with great deal of structural diversity but the leaves, stems and roots have also been shown to be good sources of these compounds^[23]. An extremely large number (193) of cucurbitane-type triterpenes were isolated from bitter melon that exhibited various pharmacological effects (Table 3). The sugar monomers as β -D-glucopyranosyl, β -D-allopyranosyl, β -D-xylopyranosyl occur in cucurbitane-type triterpenes either by their own as O-linked glycosides, or in different combinations as disaccharides or polysaccharides. The rare glycoside in these compounds is the 3-keto-glucoside^[50].

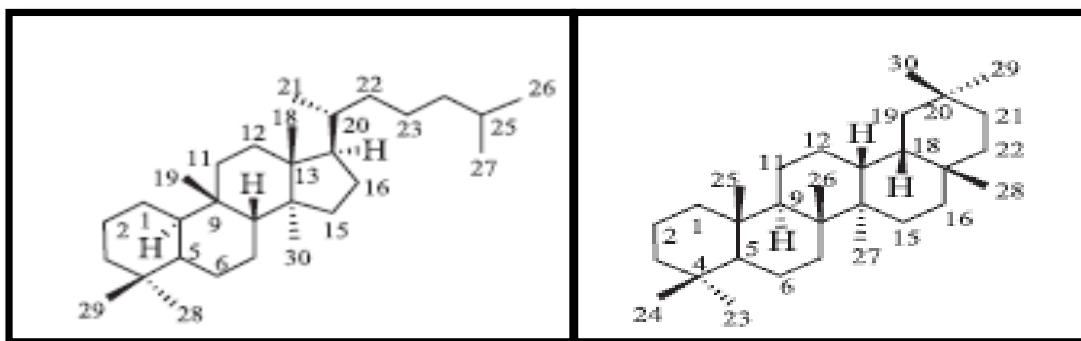
Momordicosides A and B were isolated firstly from the seeds of bitter melon fruits^[51]; while, momordicosides C, D and E were isolated as minor components of

TABLE 1: BOTANICAL DESCRIPTION OF MOMORDICA CHARANTIA LINN.

Plant parts	Description
Leaves	Broadly ovate to orbicular in outline, cordate, narrowly decurrent on to petiole, sparsely pubescent to densely villous on veins beneath, deeply palmately 3-7-lobed, lobes variously sinuate-dentate or lobulate. Leaf lamina 10×12.5 cm. Flowers are monoecious and solitary.
Flowers	Male flowers: peduncle 0.3-5 cm long; bract 2-17 mm long, broadly ovate or reniform, sessile, cordate, amplexicaul, pedicel 2-9.5 cm long. Receptacle-tube 1-5 mm long; lobes 3-7 mm long, ovate-lanceolate. Petals 1.0-2.5 cm long, pale to deep yellow, ovate to obovate. Female flowers: peduncle 0.2-5 cm long; bract 1-12 mm long; pedicel 1-10 cm long; ovary 8-11×2-4 mm, ovoid-rostrate to fusi-form, ridged, pilose on ridges, tuberculate; receptacle-tube 1-3 mm long, lobes 2-5 mm long, lanceolate; petals 0.7-1.2 cm long.
Fruits	Fruit 2.5-4.8×1.5-2.3 cm, ovoid-rostrate or ellipsoid, longitudinally ribbed and tuberculate, bright orange-red, dehiscent into 3 valves; fruit-stalk 3.4-15 cm long.
Seeds	Seeds 8-11, 4.5-8× 2-3.5 mm, enveloped in sticky red pulp, ovate-elliptic to oblong in outline; faces flattened, sculptured, with sinuate edges; margins grooved.
Petiole	Petiole 0.5-7 cm long.

TABLE 2: BIOACTIVE COMPONENTS OF MOMORDICA CHARANTIA LINN. AND THEIR PHARMACOLOGICAL EFFECTS

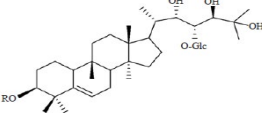
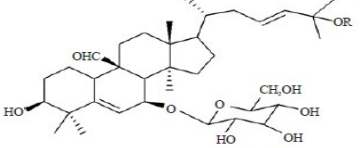
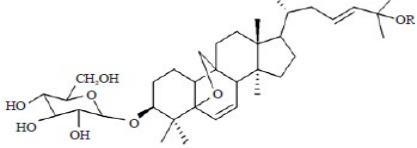
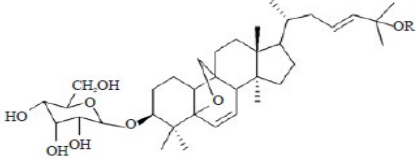
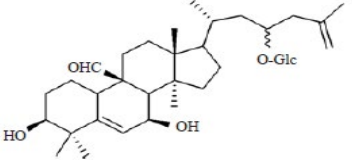
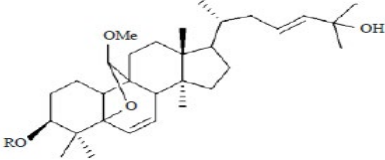
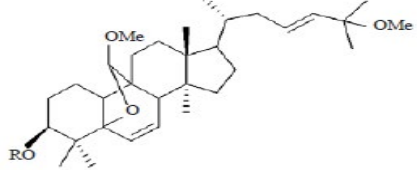
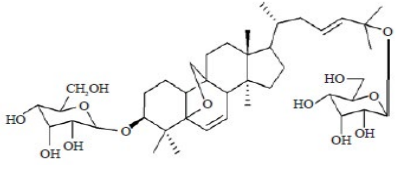
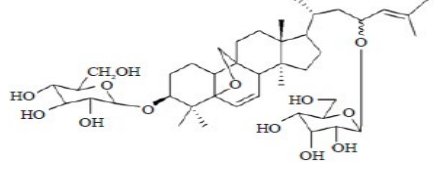
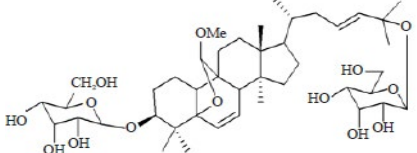
Bioactive compounds	Distribution	Pharmacological effects	References
Triterpenoids	Leaves, stem, fruits	Cancer chemo protective, anticancer antioxidant, antidiabetic	[23-26]
Peptides and proteins	Seed	Antiviral, anti-tumour, immune suppressant, antimicrobial	[27-30]
Phenolics	Fruit and seed	Antioxidant, anti-inflammatory, immunostimulant	[31-34]
Saponin	Fruit, root, seed	Antihyperglycemic, hypolipidemic, antiviral, bacteriostatic	[35-39]
Polysaccharide	All parts of plant	Antioxidant, antidiabetic, immune enhancement, neuroprotective, antitumor	[40-44]
Lipid	Seed	Anti-tumor, antioxidant	[45,46]
Steroids	Fruit and pericarp	Antimicrobial	[47-49]

**Fig. 2: The cucurbitane and oleanane type triterpene skeleton of *M. charantia* L.**

the seeds^[52]. The study on the fruits of *M. charantia* L. further added a momordicosides F1, F2, G, I, K and L as novel compounds in previously reported ones^[53]. The momordicosides I and momordicosides M along with other compounds have also been isolated from the fruits of bitter melon^[54]. Further additions of momordicosides M-O as new compounds were confirmed by chemical examination of the fresh fruits^[55]. The Vietnamese origin dried fruits of *M. charantia* had shown existence of an auxiliary three pioneering momordicosides U, V and W^[56].

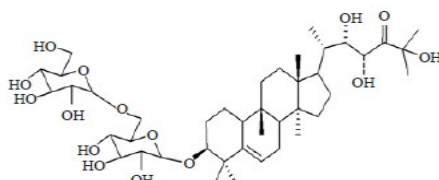
The cucurbitane-type triterpenes, which are known to be responsible for the bitterness of the leaves and vines of the *M. charantia* L. are momordicines^[57]. The momordicine IV and the malonyl derivative of momordicine II, momordicine V are readily available in the leaves of bitter melon^[58]. The isolation of momordicines VI, VII, and VIII were first confirmed from the stems and leaves of bitter melon^[59]. The goyaglycosides-a, -b, -c, -d, -e, -f, -g, and -h were isolated from the fresh fruits of Japanese *M. charantia* L.^[60]. A novel compound goyaglycoside I was an

TABLE 3: CUCURBITANE TYPE OF TRITERPENOIDS OF *MOMORDICA CHARANTIA* L.

Phytochemical Name	Plant parts	Chemical structure	Pharmacological effects
Momordicoside A & B	Fruits and seeds		Antidiabetic, antiobesity, anticancer
Momordicoside K	Leaves, fruits and roots		Antiproliferative, hypoglycemic, antiobesity, antioxidant
Momordicoside I & F1	Fruits		Antiproliferative, hypoglycemic, antiobesity, disaccharidase
Momordicoside G & F2	Leaves and fruits		Antiproliferative, hypoglycemic, antiobesity
Momordicine I & II	Leaves, vines and fruits		Cytotoxic, antiinflammatory, antiviral, immunomodulatory, antioesity
Goyaglycoside-a & b	Leaves and vines		Antiproliferative, hypoglycemic, antiobesity, anticancer
Goyaglycoside-c & d	Fruits		Antiproliferative, hypoglycemic, antiobesity, anticancer
Goyaglycoside-e	Fruits		Cytotoxic, antiobesity, antidiabetic
Goyaglycoside-f	Fruits		Antiobesity, antidiabetic
Goyaglycoside-g	Fruits		Hypoglycemic, antiobesity

Goyaglycoside-h

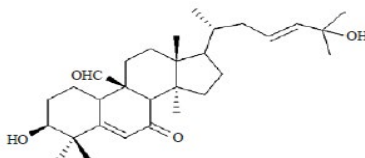
Fruits



Hypoglycemic, antiobesity

Kuguacin B

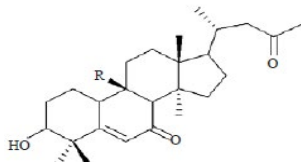
Roots



Anticancer, antidiabetic

Kuguacin C & D

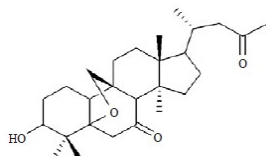
Roots



AntiHIV-1, antidiabetic

Kuguacin E

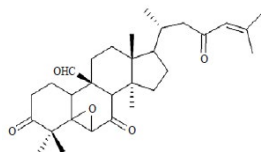
Roots



AntiHIV-1, hypoglycemic

Kuguacin F

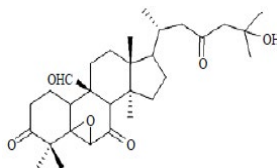
Leaves and vines



Hypoglycemic, lipid lowering

Kuguacin G

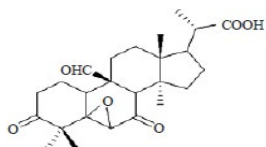
Leaves and vines



Antidiabetic, antiobesity, anticancer

Kuguacin K

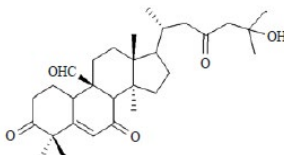
Leaves and vines



Anticancer, antiproliferative, hypoglycemic

Kuguacin H

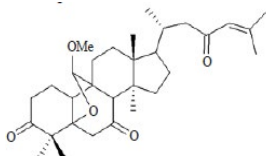
Leaves and vines



Hypoglycemic, antiproliferative

Kuguacin I

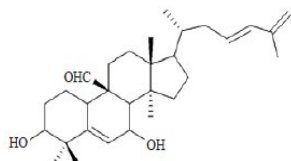
Leaves and vines



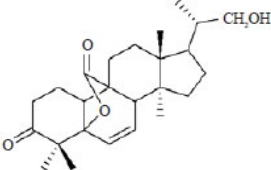
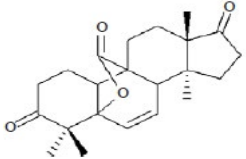
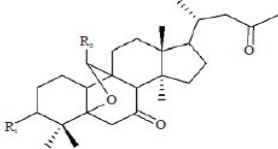
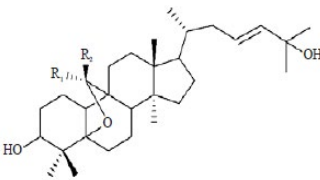
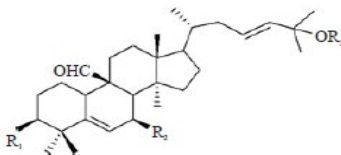
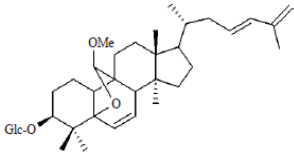
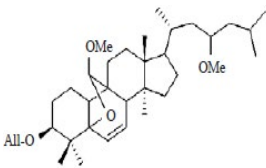
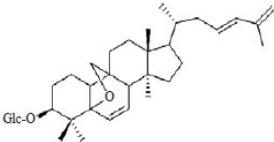
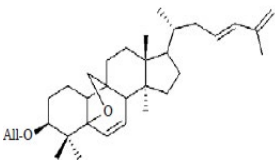
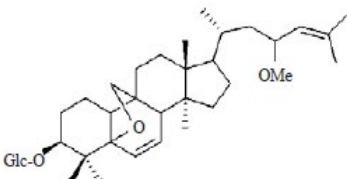
Anticancer, lipid lowering

Kuguacin J

Leaves and vines

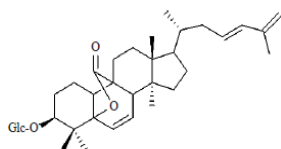


Anticancer, hypoglycemic

Kuguacin L	Leaves and vines		Antiproliferative, hypoglycemic
Kuguacin M	Leaves and vines		Hypoglycemic, anticancer
Kuguacin P & Q	Leaves and vines		Hypoglycemic, antiproliferative
Kuguacin R	Leaves, stems and fruits		Antioxidant, hypoglycemic, lipid lowering
Kuguacin S	Leaves and vines		Lipid lowering, hypoglycemic
Charantoside I	Fruits		Hypoglycemic, Antiobesity
Charantoside II	Fruits		Hypoglycemic, antiobesity
Charantoside III	Fruits		Hypoglycemic, Antiobesity
Charantoside IV	Fruits		Hypoglycemic, antiobesity
Charantoside V	Fruits		Hypoglycemic, antiobesity

Charantoside VII

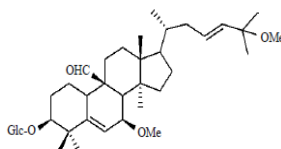
Fruits



Hypoglycemic, antiobesity

Charantoside VIII

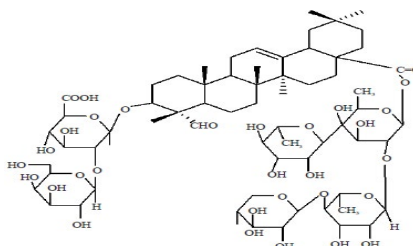
Fruits



Hypoglycemic, antiobesity

Goyasaponin I

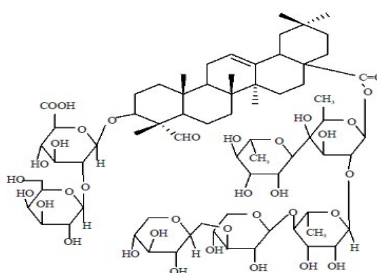
Fruits



Hypoglycemic, antiobesity

Goyasaponin II

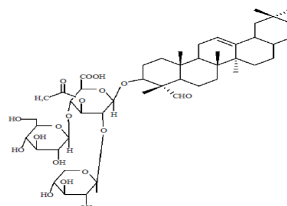
Fruits



Hypoglycemic, antiobesity

Goyasaponin III

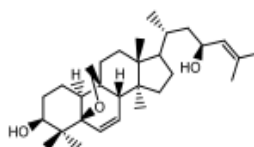
Fruits



Hypoglycemic, antiobesity

Karavilagenin C

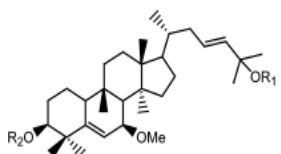
Fruits



Antidiabetic

Karaviloside I, II & III

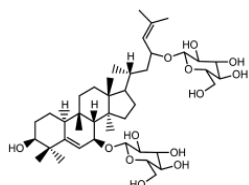
Fruits



Antiproliferative, antidiabetic, hypolipidemic

Kuguaglycoside G

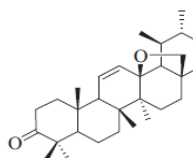
Roots



Cytotoxic, antiproliferative, hypoglycemic, anticancer

Momordicin

Fruits



Antidiabetic, antiobesity, lipid lowering

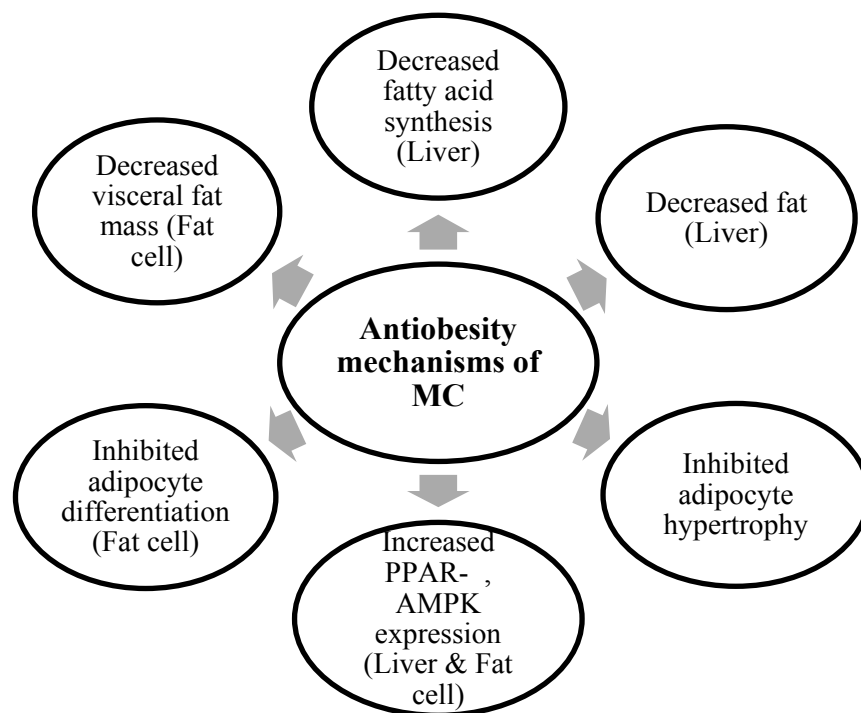


Fig. 3: Probable molecular targets and antiobesity mechanism of *Momordica charantia* L.

additional triterpene isolated from the immature fruit of bitter melon^[61]. The novel cucurbitane-type triterpene called karavilagenins A-C and 5 new triterpene glycosides called karavilosides I-V were isolated from the dried fruit of *M. charantia* L.^[62].

The methanol extracts of the fruits of Japanese *M. charantia* L. showed charantosides I, II, III-VI, VII and VIII, however charantoside IX and X were the other novel compounds reported^[63]. The 3 novel compounds, charantosides A, B and C were obtained from fruits of bitter melon^[22]. Another group of interesting triterpenoids are those known by their trivial names kuguacins. kuguacins A-E and kuguacins F-S were isolated from the roots and the leaves of bitter melon plant, respectively^[64]. Kuguacins II-VI were novel compounds isolated together with various other known compounds from the fruit of *M. charantia* L.^[65]. From the aqueous ethanol extracts of fresh fruits 8 novel cucurbitane-type glycosides were isolated, which were named kuguasaponins A-H^[8]. The ethanol extract of fruits of *M. charantia* L. identified 15 cucurbitane-type triterpene glycosides including 4 new compounds, kuguasosides A-D^[35].

Flavonoids and phenolic compounds:

A number of phenolic compounds with many biological activities have been isolated from bitter melon including, coumaric, caffeic, and ferulic acids as well as the caffeic acid ester, chlorogenic acid, benzoic, gallic and gentisic

acid^[66]. The major flavonoids and phenolic acids in the dried leaves of bitter melon were also analyzed and found to be rutin, gentisic acid and coumaric acid^[67]. While the phenolic acids and flavonoids as well as their glycosides could be readily extracted with water, their non-polar derivatives may be present in the oil components of the plant^[68].

Other components:

Other than the bioactive compounds, unsaturated fatty acids, alkaloids, amino acids minerals and vitamins are also present in bitter melon^[69-71]. The extracts of bitter melon showed the presence of 9 kinds of unsaturated fatty acids^[72]. It has also been demonstrated that 12, 13 and 12 fatty acids are found in the young, mature and senescent leaves of *M. charantia* L. representing 87.3, 95.25, and 83.11 % of the total fatty acids^[73]. The contents of total amino acids and the free amino acids of *M. charantia* L. were 11.99 and 2.36 % as determined by acid hydrolysis and amino acid analysis^[74]. In addition, bitter melon is a natural source for vitamins; ascorbic acid was detected in the range of 440-780 mg in the fruit fraction^[75]. Vicine, an alkaloidal agent was isolated from the seeds of bitter melon, which is responsible for hypoglycemic activity^[76].

Antiobesity and lipid lowering effects:

The action of bitter melon in lowering fat has been supported by plentiful studies, its effect on the level

of serum FFAs have been contradictory with some authors showing reduction, some shown same level, and others reported an increased levels. For example, the serum FFAs concentration increased in obese rats treated with bitter melon as reported by Chen *et al.*^[77]. An increased level of TG and LDL-C in the serum that is representative of either overproduction by the liver or defective removal from the circulation or the overall dyslipidaemia in diabetes. It is not clear why bitter melon increases the serum level of FFAs. It may facilitate fat mobilization due to suppression of lipogenesis or lipid deposition. While other studies revealed that *M. charantia* L. could lower the serum and liver TG levels^[78]. Various experimental studies reported a decrease in serum TC, TG and LDL-C concentrations and an increase in serum high density lipoprotein-cholesterol (HDL-C) by bitter melon^[79,80].

The findings of experimental research concluded that *M. charantia* L. might reduce fasting insulin, TG, cholesterol and epididymal fat, which were increased by HFD. The dwindling of insulin resistance, improved glucose tolerance, and increased insulin signaling under HFD-induced insulin-resistance and elevated serum lipids may also been shown by bitter melon. Administration of an aqueous extract of unripe fruits of bitter melon improved glucose and insulin tolerance together with inhibition of plasma apoB-100 and apoB-48. An animal study had shown evidence for a potent inhibitor of apoB secretion and TG synthesis as well as plasma lipid and VLDL levels in bitter melon juice^[81]. Overall many studies on the fruits, seeds and aerial parts of *M. charantia* Linn have shown reduced adiposity, lowered serum insulin and normalized glucose tolerance in rats fed with a HFD. The body weight and visceral fat mass of bitter melon-treated obese rats were shown to be lowered^[77,82].

While another study revealed that bitter melon supplementation into HFD notably suppressed the levels of fatty acid synthase (FAS), acetyl-CoA carboxylase-1 (ACC-1), lipoprotein lipase (LPL) and adipocyte fatty acid binding protein^[83]. Water extract of *M. charantia* L. fruits at a dose of 1 g/kg revealed to be effective in improving the obesity-induced hyperglycaemia and hyperleptinemia^[84], indicating that bitter melon can reduce insulin resistance, visceral fat accumulation and adipocyte hypertrophy probably by down-regulating the expression of key lipogenic genes or proteins in adipose tissues. Aqueous fruit extract of *M. charantia* L. significantly reduced levels of serum TG, TC, LDL and VLDL at a dose of 350 mg/kg in

experimental rats^[85]. Numerous animal studies have reported efficacy of bitter melon in ameliorating the weight gain and regulation of lipid metabolism^[86,87].

The methanol extract of fruits of bitter melon showed antidiabetic and antihyperlipidemic action during different seasons of the year, this suggested that antidiabetic and hypolipidemic activity of *M. charantia* L. may fluctuate according to the quantity and quality of active constituents during different seasons of the year and reach the peak during spring^[88]. Bitter melon seed oil had shown significantly decreased in body weight, Lee's index, fat index and adipose size in the HFD mice. Meanwhile, serum FFAs levels returned to normal at a dose of 10 g/kg^[89]. *M. charantia* L. extracts have antiobesity effects and the ability to modulate lipid prolife of mice fed a HFD by suppressing body weight gain, visceral tissue weight, plasma and hepatic lipid concentrations, and lipid peroxidation along with increasing lipid metabolism. The plasma TG, TC, and LDL-C levels along with hepatic TG and TC concentrations were considerably lowered in HFD-fed mice by *M. charantia* L. extracts. Also elevated plasma HDL-C levels and fecal TG concentration were shown to be elevated in animals treated with these extracts. The extracts exhibited antiobesity effects in HFD-fed mice by inhibiting lipid peroxidation while increasing lipid metabolism^[90]. Bitter melon extract showed useful benefit on body weight gain and fat deposition, 3 shows the probable molecular targets for improving obesity. Mechanism of action of *M. charantia* L. extracts for antiobesity effect appeared to be, increasing fatty acid oxidation, which could be responsible for reducing weight; decrease in weight of epididymal white adipose tissue (WAT) and adipose leptin; enhanced hepatic and muscle mitochondrial carnitine palmitoyl transferase-I (CPT-I) and acetyl-CoA dehydrogenase enzyme; prevent adipocyte hypertrophy; reduce visceral fat accumulation through dropping mRNA level of fatty acid synthase, lipoprotein lipase, adipocyte fatty acid binding protein and decreasing the lipogenic genes in adipose tissue; downregulation of PPAR γ , SREBP and perilipin mRNA gene expression.

Moreover, bitter melon extracts reduced lipid accumulation during differentiation from a pre-adipocyte to adipocyte and down-regulated PPAR^[91]. PPAR γ is considered the master regulator of adipogenesis during differentiation of pre-adipocyte to adipocyte^[92]. Bitter melon juice inhibited adipocyte differentiation by reducing PPAR γ , SREBP, and perilipin mRNA gene expression and by increasing

lipolysis in primary human adipocyte^[93]. Another study showed that bitter melon reduced TG and LDL levels and increased HDL levels in high sucrose fed rats^[94]. Female Zucker rats supplemented with ground bitter melon seeds showed decreased TC and LDL-C and increased HDL-C^[95]. Several transcriptional regulatory factors like AMPK, PPAR- γ , and PGC-1 α regulate the mitochondrial biogenesis, which would be a possible way of increasing lipid metabolism and utilization in energy demanding cells and tissues^[96,97].

AMPK synchronized PPAR- γ and PGC-1 α activation encouraged most of the transcriptional signal to augment fatty acid oxidation and mitochondrial function^[98-100]. PGC-1 α stimulates mitochondrial biogenesis and respiration in multiple cell types and modulates biological programs normally associated with increased oxidative metabolism. Also decreased plasma level of TGs, cholesterol, and FFA was found in plasma of rats fed a HF diet revealed by bitter melon supplementation due to up regulation and activation of PGC-1^[101]. A recent investigation also reported that increased hepatic AMPK p, AMPK α 1, AMPK α 2, and Sirt1 content in HFD-fed mice with supplementation of 1.2 % bitter melon extract^[102].

LXRs were first recognized as orphan members of the nuclear receptor plays an important role in lipid and cholesterol metabolism and oxidized derivatives of cholesterol act as ligands for the LXRs. A high cholesterol diet fed mice develop enlarged fatty livers, degeneration of liver cells, high cholesterol levels in liver, and impaired liver function by LXR α knockout^[103]. The *M. charantia* L. extract supplementation decreased hepatic LXR α , which was responsible for decreased serum TC and LDL-C, HDL-C in high cholesterol diet Wistar rats^[104]. Bitter melon extract was a potent inhibitor of lipogenesis and stimulator of lipolysis in 3T3-L1 pre-adipocyte shown by researcher. The study shown that increasing the ethanol extract concentration led to a decrease in lipid accumulation in adipocyte both during and after differentiation in adipogenesis assay with a near 50 % reduction^[105].

Toxic effects:

Severe adverse reactions were not reported during short term studies while extensive data on the potential toxic effect of bitter melon are not available. Bitter melon fruits are edible and assumed to be well tolerated, at the same time toxicological evidences were reported to discover its therapeutic potential for diabetes. Two cases of acute intoxication reported after taking bitter

melon tea^[106]. Abdominal pain as a side effect has also been reported in some studies^[107]. The antifertility and abortifacient effects of the *M. charantia* L. reported in animals also suggests further investigation^[108-111]. An acute disease favism characterized by hemolytic anemia, in individuals with a hereditary loss of the enzyme glucose-6-phosphatase has been shown by vicine found in fava bean^[112]. Consequently, the presence of vicine in bitter melon seeds was also suggested to put patients with glucose-6-phosphatase deficiency at risk^[113]. Although there have been no reports on favism induced by bitter melon, individuals susceptible to the disease should avoid eating the fruit.

Current research is directed to reduce the bitterness of *M. charantia* L. preparations attributes to the triterpene compounds and increasing tolerability by the general public through various formulation approaches. Some recent studies used β -cyclodextrin at 0.25-2 % concentrations to improve sensory quality, total phenolic content, antioxidant activity and antidiabetic potential of *M. charantia* L. juice^[114]. Various encapsulation methods of bitter melon extracts along with optimized spray-drying techniques were also scrutinized to obtain the powder^[115].

To date, *M. charantia* L. has been broadly studied globally for its medicinal properties and to treat a number of diseases like diabetes, dyslipidemia, obesity, and certain cancers. Isolated compounds from this plant like cucurbitane type terpenoids, flavonoids and phenolic acid and extracts possess antiobesity potential similar to its crude extracts. The extracts of fruits and different compounds seem to exert their beneficial effects via several mechanisms like PPARs, LXRs and SREBPs mediated fat metabolism in various tissues, reduces visceral fat accumulation and adipose hypertrophy. These mechanisms will be directly related to controlling and treating diabetes mellitus, dyslipidemia, obesity and related cardiovascular complications. Thus, further studies are required to conduct more double blind randomized trials with bitter melon extracts in obese population. Numerous *in vitro* studies have also been employed to demonstrate these effects and further establish. In this review, we summarized phytoconstituents of bitter melon and its antiobesity potential with mechanism of action. This compilation of phytochemicals and antiobesity activity of *M. charantia* L. would help the researchers in dereplication and designing new untried strategies.

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