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Review Article

Antimicrobial Activity and Chemical Composition of *Momordica Charantia*: A Review

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ABSTRACT

Momordica charantia L. (bitter melon) is a plant belonging to the Cucurbitaceae family and is widely distributed in tropical and subtropical areas around the world, mainly in Asia, India, China and Brazil, where it is traditionally used as a medicinal plant, and the fruits of some varieties of *M. charantia* are consumed as food. Studies have determined that this plant contains a great diversity of bioactive compounds with therapeutic potential like charantin, α-momorcharin and MAP30, and highlighting its properties as antidiabetic, antiulcer, antioxidant, antimicrobial, anthelmintic, antihyperglycemic and anticancer. Review shows the complete botanical description of the plant (fruits, leaves, stem, etc.), the bioactive chemical compounds reported in the plant species, the antimicrobial activity of the extracts or fractions of *M. charantia*, emphasizing the antibacterial and antifungal activities, with respective values of MIC (Minimum Inhibitory Concentration) reported according to the methodology used in each study. The review seeks to update the phytochemical and pharmacological knowledge of *M. charantia*, which would be useful for researchers in their search for new chemical compounds of the plant, studies of its safety and efficacy, as well as the evaluation of its possible synergistic action in combination with other antimicrobials, in order to find new therapeutic alternatives against bacterial resistance.

Key words: Cucurbitaceae; Phytochemicals; Antifungal; Antibacterial; Charantin; Cucurbitane.

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INTRODUCTION

Plants are a very rich source of new chemical entities[1], so much so that, to date[2], new prototypes with various therapeutic potentials are still being sought.[3] No stranger to it, bitter melon (*Momordica charantia* L.) is a plant species that has attracted researchers' interest in recent years (Figure 1). Chemical and pharmacological studies on the *Momordica charantia* L. (*M. Charantia*) plant have been in existence since 1963 and have had a growing interest, deduced by the increase in the amount of research work over the years to the present; since 1993, investigations were initiated on its antibacterial activity and since 1997, on its antifungal activity (Figure 1).

The fruits of *M. Charantia* are consumed daily as a food and as a medicinal plant for traditional use in Southeast Asia, Indo-China[4], as well as in Brazil.[5] *M. Charantia* is a plant belonging to the Cucurbitaceae family and is widely distributed in tropical and subtropical areas around the world.[5-7]

Studies have determined that this plant contains a great diversity of primary and secondary metabolites[8,9] with therapeutic potential as antiulcer properties[6,10], antioxidant[11-14], antimicrobial[6,8,12,15-17], anthelmintic[18,19], antidiabetic[6,11,20,21], anti-inflammatory[21,22], antihyperglycemic[6,21,23] and anticancer[4,19,21,24], and nutritional as antilipolytic.[11,25]

Bacterial resistance is one of the main problems around the world, it is thought that by 2050 bacterial resistance will be one of the leading causes of death in the world.[26-28] Currently there are bacteria that are resistant to almost all existing antibacterials.[29] That is why the search for new entities with antibacterial potential is a worldwide research focus[30] and *M. Charantia* is a species with great possibilities. Several studies have demonstrated antifungal and antibacterial activity in *M. Charantia*[9,31-34], as well as antimicrobial activity in leaves[8,35-40], and fruit.[41]

In the last two years there has been a significant increase in publications of scientific articles on *M. charantia* (Figure 1), generating a large amount of information about it and its antimicrobial activity, which is why the organization and selection of this information become necessary and important in order to provide interested researchers with updated information on this species.

Taxonomic classification

M. charantia is an annual or perennial, mono-climber, herbaceous, 3-4 m long plant, which belongs to the Cucurbitaceae family. It contains almost sixty species that grow in tropical and subtropical regions (Figure 2).[4,42,43]

Botanical description

Bitter melon, bitter cucumber or bitter gourd are some of the names given to *M. charantia.* It belongs to the Cucurbitaceae family.[44] *M. charantia* is a vegetable with many culinary uses, especially in Asia and Africa, and is commonly cultivated in Africa, India, Malaysia, China and South America.[44,45] *M.*

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charantia is a slender and slightly hairy or hairless plant that can be grown at high altitude.[4,46] A description of each part of the *M. charantia* is shown in Table 1.

Chemical composition

M. charantia contains triterpenoids[11,39,47], saponins[48], polypeptides[49], flavonoids[14,50,51], alkaloids[40,52,53] and sterols[13,54-56], which are distributed throughout the entire plant. The seed is not edible, it contains extractable oils, mostly a conjugated triene *cis*-9, *trans*-11, *trans*-13 (*c*9, *t*11, *t*13) conjugated isomer of linolenic acid, known as α-elestearic acid (α-ESA). It is known that α-ESA has anti-cancer and anti-obesity properties.[57]

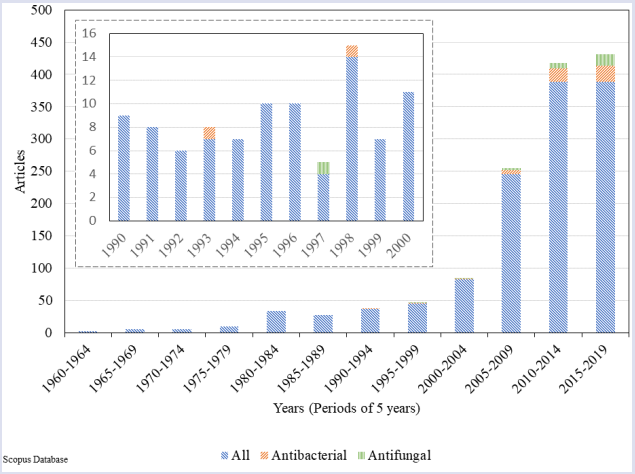

Figure 1. Number of scientific articles published on *M. charantia*. Search Date: 2019-04-02.

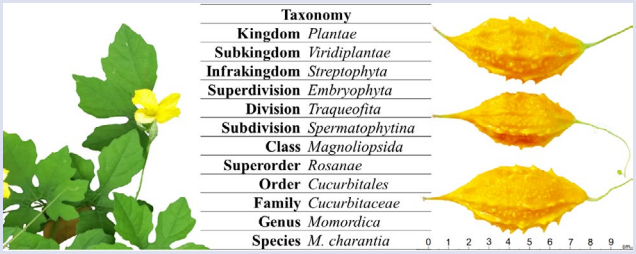

Figure 2. Taxonomic classification of *M. charantia*.

Research on *M. charantia* has revealed that its components with pharmaceutical importance are phenolic compounds (such as phenylpropanoids and flavonoids), triterpenes and carotenoids.[50,58] Several bioactive compounds of the fruit of *M. charantia* have been registered in the literature; they are classified into carbohydrates, proteins, lipids and more.[46,56,59]

Cucurbitane-type triterpenoids such as charantin have been related to antimicrobial activity.[60] Charantin is a 1:1 mixture of two steroidal saponins (Figure 3), stigmasterol glycoside and β-sitosterol glycoside.[61] Although cucurbitane-type triterpenoids have been found in almost the entire plant, charantin has only been located in the root, leaves and fruit.[18,39,46,53]

Proteins such as α-momorcharin (Leaf and seed) and MAP30 (fruit and seed) have also been linked to antimicrobial activity.[62,63] MAP30 and α-momorcharin (Figure 4) are ribosome inactivating proteins (RIP) and have demonstrated antibacterial and antiviral activities.[49,63]

Antimicrobial activity

Sankaranarayanan and Jolly (1993) have clinically demonstrated the existence of antimicrobial activity on leaf extracts of *M. charantia*. This activity of *M. charantia* is attributed to its content of antimicrobial proteins, seed oil, tannins, triterpenoids, alkaloids, cardiac glycosides and steroids.[11,46,52,64-90] The bioactive components of *M. charantia* showed antimicrobial activity against *Helicobacter pylori*[10], *Sindbis*, *Herpes simplex virus* type 1[11,82] and anthelmintic activity against *Caenorhabditis elegans*.[82]

The leaf and stem extracts of *M. charantia* in methanol have a remarkable activity against *Escherichia coli*, *Staphylococcus aureas*[83], *Pseudomonas aeruginosa*, *Bacillus subtilis* and *Klebsiella pneumonia*[84], while leaf extracts in ethanol showed antimicrobial activity against *Trypanosoma cruzi*, in addition to enhancing the antifungal effect of metronidazole[85], *E. coli*, *Salmonella parathyphi*, *Shigella dysenterae*[86]

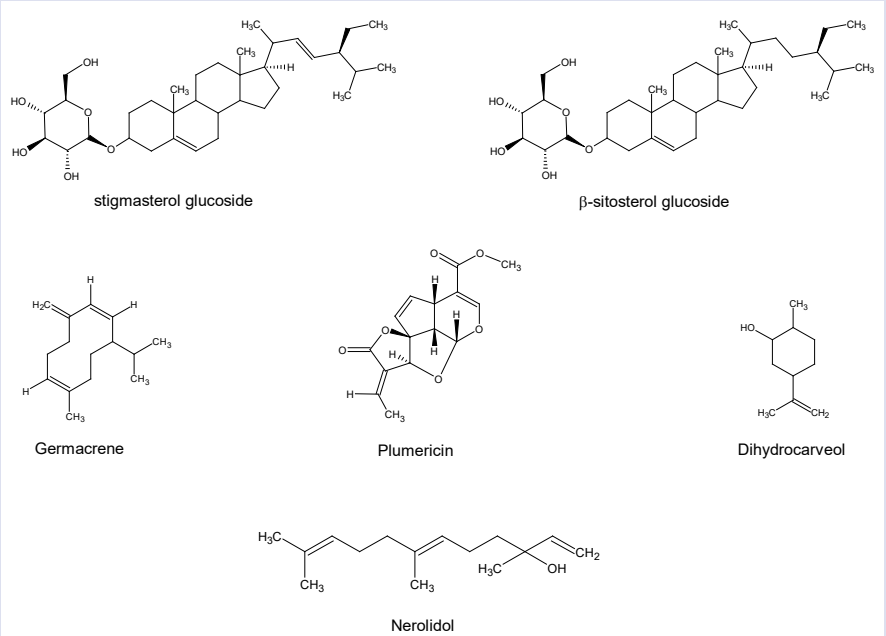

Figure 3. Small molecules structure with antimicrobial activity.

>AAB35194.2 MAP30 [*Momordica charantia*, 286 aa]
MVKCLLLSFLIIAIFIGVPTAKGDVNFDLST
ATAKTYTKFIEDFRATLPFSHKVYDIPLLYS
TISDSRRFILLNLTSYAYETISVAIDVTNVY
VVAYRTRDVSYFFKESPPEAYNILFKGTRKI
TLPYTGNYENLQTAAHKIRENIDLGLPALSS
AITTLFYYNAQSAPSALLVLIQTTAEAARFK
YTERHVAKYVATNFKPNLAIISLENQWSALS
KQIFLAQNQGGKFRNPVDLIKPTGERFQVTN
VDSDVVKGNIKLLLNSRASTADENFITTMTL

>AAB22586.1 alpha-momorcharin [*Momordica charantia*, 263 aa]
DVSFRLSGADPRSYGMFIKDLRNALPFREK
VYNIPLLLPSVSGAGRYLLMHLFNYDGKTI
TVAVDVTNVYIMGYLADTTSYFFNEPAAEL
ASQYVFRDARRKITLPYSGNYERLQIAAGK
PREKIPIGLPALDSAISTLLHYDSTAAAGA
LLVLIQTTAEAARFKYIEQQIQERAYRDEV
PSLATISLENSWSGLSKQIQLAQGNNGIFR
TPIVLVDNKGNRVQITNVTSKVVTSNIQLL
LNTRNIAEGDNGDVSTTHGFSSY

Figure 4. Amino acid sequence of MAP30 and α-momorcharin (FASTA sequence obtained from National Center for Biotechnology Information – NCBI).

Table 1: Botanical description of *M. charantia*.

Part	Description	Image	Reference
Stem	Round, well branched, internodes 5-6 cm, thin, corrugated and has unbranched tendrils in the axillae of the leaf		4,46
Root	It has a primary root that extends to the vertex where the stem is born		4
Leaves	Palmately-lobed, alternating, rounded edge with 3–7 lobes deeply separated and with quite small marginal points. They are distributed individually in petioles 1.5–5 cm long and have no stipules. When they are crushed, they give off a rather unpleasant smell.		4,10
Flowers	Solitary, pubescent and with 5 yellow petals and 5 central stamens. The male flowers have thinner stems and larger petals than the female flowers and, while the male flower sepals are oval-elliptical, those of the female flowers are narrow and oblong lanceolate.		4,42
Fruit	Pendular discoid with ovoid shape, 2 to 10 cm in length, covered with broken or continuous longitudinal ridges and warts. The young fruit is white or emerald green that turns orange when ripe, and its white pulp becomes scarlet during ripening.		4,6,42
Seed	8–15 mm long, rectangular squares, corrugated on the margin, sculpted on both sides, but covered with a white pulp when green and red when ripe.		4,42,46

and *Colletotrichum musae*.[87] An extract of the whole plant has shown antiprotozoal activity against *Entamoeba histolytica*[88], *Salmonella typhi*, *Staphylococcus aureus*, *Streptococcus pyogenes*[16] and *Mycobacterium tuberculosis*[86], and an extract of isolated proteins from leaves demonstrated an antifungal effect.[36,89] MAP30 is an isolated protein of *M. charantia* that can be used in combination with chloramphenicol or erythromycin, and be beneficial in terms of reducing the side effects of antibiotics, as lower concentrations of antibiotics are required due to their antibacterial ability.[63] A synergistic effect has also been demonstrated between ethanolic extract and aminoglycosides, chlorpromazine, kanamycin and amikacin, indicating the participation of an efflux system in the resistance to these aminoglycosides.[90] This represents a new weapon against bacterial resistance to antibiotics. In addition, silver nanoparticles have been studied with *M. charantia*[52,91-93] although studies are still lacking to determine the real biochemical route by which it exerts its antimicrobial effects.

The leaf extract of *M. charantia* has a potent antimicrobial action against *S. typhi* with potential for hepato-inflammatory improvement by decreasing the concentrations of total and direct bilirubin, alanine aminotransferase, alkaline phosphatase, aspartate aminotransferase and gamma glutamyl transferase compared to the group control.[38] In addition, photosynthetic pigments and cinnamic acid showed a direct correlation with the antimicrobial potential against *Staphylococcus aureus* and *Pseudomonas aeruginosa*, sinaptic acid showed a positive correlation only with *Staphylococcus aureus*; likewise, cinnamic acid, coumaric acid, syringic acid and quercetin in direct correlation with *Pseudomonas aeruginosa*.[8] Plumericin (Figure 3), an iridoid lactone isolated from the stem of *M. charantia*, has shown antibacterial activity against *Enterococcus faecalis* and *Bacillus subtilis* with minimal inhibitory concentration values better than cloxacillin.[66]

The aqueous seed extract has shown greater antimicrobial capacity by inhibiting the growth of *Fusarium solani*[19] and *Pasteurella multocida*, compared to the extracts of methanolic, ethanolic, hexane and ethyl acetate that were effective against *S. aureus*, *Enterococcus* and fungi.[33,94-96] Seed oil, with *t*-nerolidol, *c*-dihydrocarveol and germacrene (Figure 3) as its main constituents, has shown antimicrobial activity towards *S. aureus*, *E. coli* and *C. albicans*[75,97], which makes the development of green antibacterial soaps, without chemical aggregates, feasible.[15]

The levels of flavonoids and phenols such as catechin, myricetin, quercetin, gallic acid, chlorogenic acid, gentisic acid and salicylic acid, increase considerably in hair roots *in vitro* growth compared to unprocessed roots, although metabolites such as ferulic acid, rutin, naringenin and naringin decreased significantly in the hair roots. Due to these metabolic variations, antimicrobial activity increases in hair roots *in vitro* growth compared to non-transformed roots.[51]

Fresh fruits extracts have exhibited similar antibacterial properties against strains of *Bacillus subtilis*, *Pseudomonas aeruginosa* and *Saccharomyces cerevisiae*[60], also have shown activity against *E. coli*, *Staphylococcus*, *Pseudomonas*, *Salmonella* and *Streptobacillus* very similar to the hydrophilic extracts of leaves[6] and *Aspergillus Niger*.[32] Application of *M. charantia* fruit powder at wound sites is equally effective in stimulating tissue regeneration and wound healing in rats.[98] Fruit extracts have shown a better activity compared to leaf extracts[41] and seeds[40], with methanol extracts having the best antibacterial activity.[37]

Recombinant α-momorcharin inhibits the growth of *F. solani*, causing deformation of cells with irregular outbreaks, integrity loss of the cell wall, rupture of the fungal cell membrane, DNA fragmentation, in addition to affecting macromolecular synthesis and organelles functions.[49] RK29, the active lectin isolated from ripe fruit and seed, inhibits HIV-1 viral reverse transcriptase.[6] Cucurbitane triterpenoids (kuguacins F-S), pentanorcucurbitacins, octanorcucurbitacin and trinorcucurbitacins exhibit weak *in vitro* anti-HIV-1 activities.[99] The triterpene glycosides momordicines I and II are anthelmintic but not antiviral (Table 2).[82]

Current and future challenges

There is a growing interest in investigating the antimicrobial activity of *M. charantia* (Figure 1) motivated by the search for new sources of chemical entities with therapeutic potential. Antimicrobial activity has been reported in isolation from fruits (Table 3)[100], so it is recommended to conduct studies of the efficacy of isolated cucurbitane, such as charantin found in almost all parts of the plant (Table 2), *in vivo*. In addition, cucurbitane are attributed antidiabetic activity[46], an effect that could enhance treatments against infections in diabetic foot.

Table 2. Bioactive chemical compounds reported in *M. charantia*.

Part of Plant	Kind of Compound	Bioactive Compounds	References
Root	Flavonoids	Myricetin; Quercetin; Kaempferol; Catechin; Rutin	51
	Phenolic compounds	Caffeic acid; p-Coumaric acid; Ferulic acid; o-Coumaric acid; Chlorogenic acid; m-Coumaric acid; p-hydroxybenzoic acid; Gallic acid; Protocatechuic acid; β-Resorcylic acid; Vanillic acid; Syringic acid; Gentisic acid. Salicylic acid; Vanillin; Veratric acid; Hesperidin; Naringenin; Biochanin A; Homogentisic acid; *t*-cinnamic acid; Naringin	51
	Cucurbitane-type triterpenoids	Charantin*; kuguacins A; kuguacins B; kuguacins C; kuguacins D; kuguacins E; 3β,7β,25-trihydroxycucurbita-5,(23E)-diene-19-al; 3β,25-dihydroxy-5β,19-epoxycucurbita-6,(23E)-diene; Momordicine I	18,47
Leaf and Stem	Phenolic compounds	4-Hydroxybenzoic acid; 4-O-Caffeoylquinic acid derivative; 4-O-Feruloylquinic acid; 5-O-Feruoylquinic acid; Caffeic acid; Cinnamic acid; Ferulic acid; p-Coumaric acid; sinapinic acid; 2,4-bis (2-phenylpropan-2-yl) phenol	8,14,39,50
	Flavonoids	Isorhamnetin-3-O-glucoside; Isorhamnetin-O-acetylhexoside; Kaempferol-3-O-glucoside; Kaempferol-3-O-rutinoside; Kaempferol-O-acetylhexoside; Kaempferol-O-pentosylhexoside; Quercetin-3-O-glucoside; Quercetin-3-O-rutinoside; Quercetin-O-acetylhexoside; Quercetin-O-dihexoside; Quercetin-O-pentosylhexoside; Rutin	8,13,14,50,64
	Cucurbitane-type triterpenoids	Cucurbitane I; Cucurbitane II; Cucurbitane III; Karavilagenin F; Karaviloside XII; Karaviloside XIII; Kuguacin F-S; Momordicine I; Momordicine II; Momordicine VI; Momordicine VII; Momordicine VIII; Momordicosides; Charantal; Charantin*	11,18,39,64,65
	Iridoid lactone	Plumericin*	66
	Tannins	Not Identified	52
	Alkaloids	Not Identified	52
	Protein	α-momorcharin*	49

Flower	Phenolic compounds	4-Hydroxybenzoic acid; Caffeic acid; Catechin hydrate; Chlorogenic acid; Epicatechin; Ferulic acid; Gallic acid; p-Coumaric acid; *t*-Cinnamic acid	50
	Flavonoids	Kaempferol; Rutin	50
Fuit	Cucurbitane-type triterpenoids	(23E)-3β-Hydroxy-7β,25-dimethoxycucurbita-5,23-dien-19-al; (23E)-7β-methoxycucurbita-5,23,25-trien-3β-ol; (23E)-Cucurbita-5,23,23-triene-3α,7α-diol; 19-dimethoxycucurbita-5(10),6,22(E),24-tetraen-3β-ol 23E-3β-hydroxy-7β,25; 22-hydroxy-23,24,25,26,27- pentanorcucurbit-5-en-3-one; 25,26,27-trinorcucurbit-5-ene-3,7,23-trione; 25ξ-Isopropenylcholest-5(6)-ene 3-O-β-D-glucopyranoside; 3β,7β,23-trihydroxycucurbita-5,24-diene-7-O-β-D-glucoside; 3β,7β,25-Trihydroxycucurbita-5,23(E)-dien-19-al; 5β,19-epoxy-19,25-dimethoxy-cucurbita-6,23-diene-3β-ol; 7β-Ethoxy-3β-hydroxy-25-methoxy-cucurbita-5,23(E)-dien-19-al; Charantagenin D; Charantin*; Charantoside III; Charantoside IV; cucurbita-1(10)5,22,24-tetraen-3α-ol; Cucurbita-5,24-diene-3β,23(R)-diol 7-O-β-D-glucopyranoside; Goyaglycoside E; Karavilagenin B; Karavilagenin E; Karaviloside I; Karaviloside III; Kuguacin B; Kuguacin C; Kuguacin J; Kuguacin J; Kuguacin R; Kuguaglycoside A; Kuguaglycoside B; Kuguaglycoside F; Momordicin; Momordicinin; Momordicoside A; Momordicoside F1 aglycone; Momordicoside F2; Momordicoside G; Momordicoside I; Momordicoside K; Momordicoside L; Momordicoside Q; Momordinol; Octanorcucurbitacin A; Taiwacin A	45,46,53,60,67–69
	Carotenoids	5,6-Monoepoxy-β-Carotene; 9'-Z- neoxanthin; all-E-violaxanthin; Cryptoxanthin; Lutein; Lycopene; Mutatochrome; Phytofluene; Rubixanthin; Zeaxanthin; Zeinoxanthin; β-Carotene; α-Carotene; γ-Carotene; δ-Carotene; ζ-Carotene; α-tocopherol	56,70,71
	Carbohydrates	Arabinose; Galactose; Glucose; Mannose; Pectin; Rhamnose; Ribose; Xylose	56,72
	Protein	MAP30[b]*, Polypeptide-P, Lectins	6,46
	Phytosterols	Diosgenin; β-sitosterol; Stigmasterol; Campesterol; 3-O-[6'-O-stearyl-β-D-glucosyl]-stigmasta-5,25(27)-diene; 3-O-[6'-O-palmitoyl-β-D-glucosyl-stigmasta-5,25(27)-dien	13,54–56
	Phenolic compounds	Caffeic Acid; Chlorogenic acid; Ferulic acid; Gallic acid; Malic acid; Malonic Acid; Quinic acid; Salicylic acid; Shikimic acid; Tartaric acid; *t*-cinnamic acid; Vanyl acid; 2, 5-dihydroxybenzoic acid	45,73
	Alkaloids	Not Identified	53
Seed	Fatty acids	Gamolenic Acid; Linoleic acid; Oleic acid; Palmitic acid; Stearic acid; α-Eleostearic acid	15,57,74
	Essential oils	(E)-Anethole; 1,8-Cineole; Apiole; Carvone; Cedrol; *c*-Dihydrocarveol; Germacrene D; Limonene; Linalool; Methyl eugenol; Myristecin; Octanal; p-Cymene; Safrole; Spathulenol; *t*-Dihydrocarveol; *t*-Nerolidol; α-Pinene; α-Selinene; β-Bisabolol; β-Phellandrene; β-Pinene; β-Selinene; δ-Cadinene	75
	Carotenoids	Tocopherols	56
	Phenolic compounds	Caffeic acid; Catechin; Chlorogenic acid; Epicatechin; Gallic acid; Gentisic acid; o-Coumaric acid; p-Coumaric acid; Protocatechuic acid; Sinapic acid; Syringic acid; *t*-Cinnamic acid; *t*-Ferulic acid; Vanillic acid	50,76
	Cucurbitane-type triterpenoids	Goyaglycoside E; Goyaglycoside G; Momordicilin; Momordicoside A; Momordicoside B; Momordicoside C; Momordicoside D, Momordicoside E	46,48,77,78
	Saponins	Goyaglycoside A; Goyaglycoside B; Goyaglycoside C; Goyaglycoside D; momordicoside F2; momordicoside I; momordicoside K	48
	Alkaloids	Vicine	40,46
	Phytosterols	4-α- methylzymosterol; cycloeucalenol; desmethylsterols spinasterol; lophenol; obtusifoliol; β-sitosterol	11,79
	Protein	Cytostatic factor; MCL[a]; MAP30[b]; Momordin-I; Momordin-II; Napin-like protein; Napin-like RIP[c]; Polypeptide-P; Ribonuclease; Serpins; α-momorcharin*; β-momorcharin; γ-momorcharin; Polypeptide-P; Lectins	53,80,81

[a]MCL *M.* charantia lectin [b]MAP30 a 30 kDa *M. charantia* anti-HIV protein; [c]RIP ribosome inactivating protein; *relevant for antimicrobial activity.

Table 3. Antimicrobial activity of extracts or fractions of *M. charantia*.

Part	Extract or Fraction	Activity	MIC	Technique	Reference
leaf	Methanolic extract	*Escherichia coli*	10 mg/mL	Agar cup well technique	83
		Staphylococcus aureus			
		Escherichia coli	100 mg/mL	disc diffusion method	84
		Pseudomonas aeruginosa			
		Bacillus subtilis			
		Klebsiella pneumonia			
	Ethanolic extract	*Staphylococcus aureus*	125 µg/mL	microdilution	64
	Aqueous Extract	*Escherichia coli*	100 mg/mL	disc diffusion method	84
		Pseudomonas aeruginosa			
		Bacillus subtilis			
		Klebsiella pneumonia			
	Acetone Extract	*Pseudomonas aeruginosa*	2 µg/mL	microdilution	8
		Staphylococcus aureus	3 µg/mL		

Stem	Plumericin Isolated using the supercritical fluid extraction	*Enterococcus faecalis*	250 µg/mL	disc diffusion method	66
		Bacillus suptilis	125 µg/mL		
Fruit	Charantin	*Bacillus suptilis*	200 µg/mL	disc diffusion method	60
		Pseudomonas aeruginosa			
		Saccharomyces cerevisiae			
	Ethanolic extract	*Aspergillus niger*	Not determined	disc diffusion method	32
		Staphylococcus aureus			
		Salmonella typhi			
	Chloroform extract	*Escherichia coli*	200 µg/mL	microdilution	100
		Bacillus suptilis	200 µg/mL		
		Aspergillus niger	100 µg/mL		
	Hexane extract	*Aspergillus niger*	100 µg/mL		
	Ethyl acetate extract				
Seed	Extraction with buffer	*Fusarium solani*	108.9 µg/mL	well diffusion and broth	19
	Methanolic extraction by soxhlet	*Enterococcus faecium*	20 mm	disc diffusion method	96
	Ethanolic extract	*Proteus mirabilis*	3 µg/mL	microdilution	33
		Providencia rettgeri	7 µg/mL		
		Staphylococcus aureus	31 µg/mL		
		Escherichia coli	31 µg/mL		
		Pseudomonas aeruginosa	62 µg/mL		
		Candida parapsilosis	15 µg/mL		
		Candida guillermond	31 µg/mL		
		Candida glabata	31 µg/mL		
		Candida tropicallis	62 µg/mL		
		Candida albicans	62 µg/mL		
		Candida krusei	125 µg/mL		
	Hydrodistillation	*Sthaphylococcus aureus*	125 µg/mL	microdilution	75
		Escherichia coli	>500 µg/mL		
		Candida albicans	>500 µg/mL		
Whole plant	Fraction 1	*Salmonella typhi*	40 µg/mL	Agar cup well technique	16
	Fraction 2	*Staphylococcus aureus* *Streptococcus pyogenes*	60 µg/mL		
	Fraction 3	*Streptococcus pyogenes*	40 µg/mL		

On the other hand, studies of its safety and efficacy have been carried out in combination with antimicrobials such as aminoglycosides[90], with the intention of being able to cope with bacterial resistance as well as a decrease in side effects; Therefore, it is recommended to continue studies on proteins such as α-momorcharin and MAP30 which is located in leaves, stems, fruits and seeds (Table 2), which have demonstrated very good antimicrobial metabolites[49,63] as well as some protein fractions[89]. Although there are a large number of articles that corroborate the antimicrobial activity, the mechanism of this therapeutic activity is not yet known.

CONCLUSIONS

Although a large number of medicinal plants have been reported with antimicrobial activity, studies that corroborate their efficacy and safety are still needed. The phytochemical analysis and demonstration of the *in vivo* and *in vitro* antimicrobial activity of *M. charantia*, promotes the need to study the probable mechanisms by which bioactive compounds such as charantin, α-momorcharin and MAP30 act.

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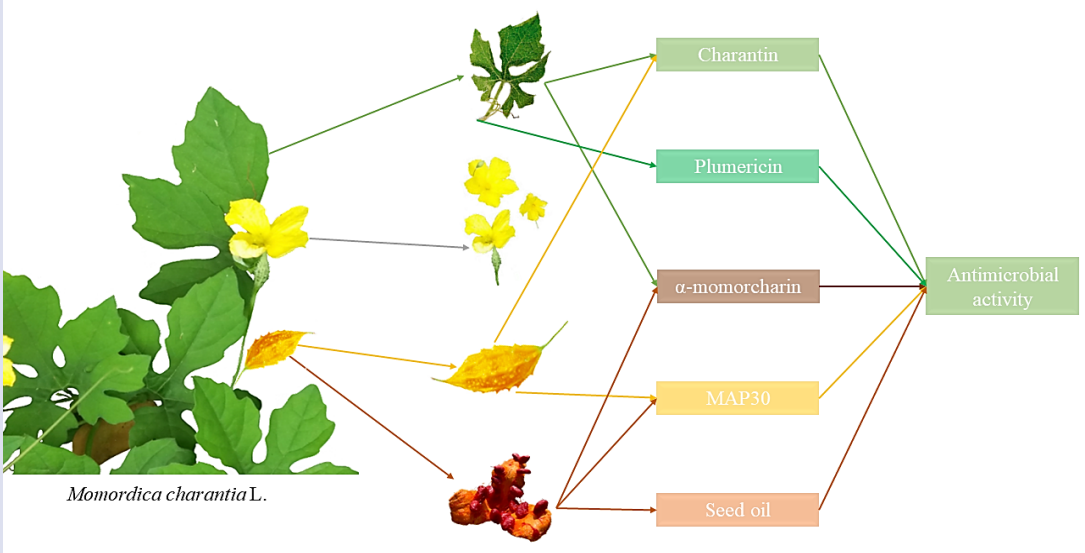
GRAPHICAL ABSTRACT



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