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 anti diabetic, antiulcer, antioxidant, antimicrobial, antihelmintic, 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.

INTRODUCTION

Plants are a very rich source of new chemical entities, so much so that, to date, new prototypes with various therapeutic potentials are still being sought. 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, as well as in Brazil. M. Charantia is a plant belonging to the Cucurbitaceae family and is widely distributed in tropical and subtropical areas around the world. Studies have determined that this plant contains a great diversity of primary and secondary metabolites with therapeutic potential as antitumor properties, antioxidant, antimicrobial, antihelmintic, antidiabetic, anti-inflammatory, antihyperglycemic and anticancer, and nutritional as antilipolytic.

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. Currently there are bacteria that are resistant to almost all existing antibacterials. That is why the search for new entities with antibacterial potential is a worldwide research focus and M. Charantia is a species with great possibilities. Several studies have demonstrated antifungal and antibacterial activity in M. Charantia, as well as antimicrobial activity in leaves and fruit.

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.

Botanical description

Bitter melon, bitter cucumber or bitter gourd are some of the names given to M. charantia. It belongs to the Cucurbitaceae family. 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.
charantia is a slender and slightly hairy or hairless plant that can be grown at high altitude. A description of each part of the M. charantia is shown in Table 1.

**Chemical composition**

M. charantia contains triterpenoids, saponins, polypeptides, flavonoids, alkaloids, and sterols, 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 (c9, t11, r13) conjugated isomer of linolenic acid, known as α-essential acid (α-ESA). It is known that α-ESA has anti-cancer and anti-obesity properties.

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

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

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

**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. The bioactive components of M. charantia showed antimicrobial activity against Helicobacter pylori, Sindbis, Herpes simplex virus type 1 and anthelmintic activity against Caenorhabditis elegans.

The leaf and stem extracts of M. charantia in methanol have a remarkable activity against Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa, Bacillus subtilis and Klebsiella pneumonia, while leaf extracts in ethanol showed antimicrobial activity against Trypanosoma cruzi, in addition to enhancing the antifungal effect of metronidazole, E. coli, Salmonella paratyphi, Shigella dysenteriae.
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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 | ![Stem Image](image1.png) | 4,46       |
| Root     | It has a primary root that extends to the vertex where the stem is born      | ![Root Image](image2.png) | 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. | ![Leaves Image](image3.png) | 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. | ![Flowers Image](image4.png) | 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. | ![Fruit Image](image5.png) | 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. | ![Seed Image](image6.png) | 4,42,46    |

Figure 4. Amino acid sequence of MAP30 and α-momorcharin (FASTA sequence obtained from National Center for Biotechnology Information – NCBI).
and Colletotrichum musae. An extract of the whole plant has shown antiprotozoal activity against Entamoeba histolytica, Salmonella typhi, Staphylococcus aureus, Streptococcus pyogenes and Mycobacterium tuberculosis, and an extract of isolated proteins from leaves demonstrated an antifungal effect. 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. 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. This represents a new weapon against bacterial resistance to antibiotics. In addition, silver nanoparticles have been studied with antibiotics, as lower concentrations of antibiotics are required and are beneficial in terms of reducing the side effects.

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.

Fresh fruits extracts have exhibited similar antibacterial properties against strains of Bacillus subtilis, Pseudomonas aeruginosa andSaccharomyces cerevisiae, also have shown activity against E. coli, Staphylococcus, Pseudomonas, Salmonella and Streptococcus. Application of M. charantia fruit powder at wound sites is equally effective in stimulating tissue regeneration and wound healing in rats. Fruit extracts have shown a better activity compared to leaf extracts and seeds, with methanol extracts having the best antibacterial activity.

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 vivo. In addition to affecting macromolecular synthesis and organelles functions, RK29, the active lectin isolated from ripe fruit and seed, inhibits HIV-1 viral reverse transcriptase. Cucurbitane triterpenoids (kuguacins F-S), pentanocurbitacin, octanocurbitacin and trinocurbitacins exhibit weak anti-HIV-1 activities. The triterpene glycosides momordicines I and II are anthelmintic but not antiviral.

### 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) so it is recommended to conduct studies of the efficacy of isolated cucurbite, such as charantin found in almost all parts of the plant (Table 2), in vivo. In addition, cucurbitane are attributed antidiabetic activity, an effect that could enhance treatments against infections in diabetic foot.

### Table 2. Bioactive 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; Chlrogeric acid; m-Coumaric acid; p-hydroxybenzoic acid; Gallic acid; Protocatechuic acid; β-Resorcylic acid; Vanillic acid; Sringic 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-trihydroxycurcurbita-5(23E)-diene-19-αl; 3β,25-dihydroxy-5β,19-epoxy-cucurbita-6,23(25)-diene; Momordicine I | 18,47 |
| Leaf and Stem Phenolic compounds | 4-Hydroxybenzoic acid; 4-O-Caffeoylquinic acid derivative; 4-O-Feruloylquinic acid; 5-O-Feruloylquinic acid; Caffeic acid; Chlrogeric acid; Ferulic acid; p-Coumaric acid; sinapinic acid; 2,4-bis (2-phenylpropan-2-yl) phenol | 8,14,39,50 |
| Flavonoids | Isotherhamnetin-3-O-glucoside; Isotherhamnetin-3-O-acetylguloside; Kaempferol-3-O-glucoside; Kaempferol-3-O-rutinoside; Kaempferol-3,5-O-diacetyletheroside; Kaempferol-O-pentosyletheroside; Quercetin-3-O-glucoside; Quercetin-3-O-rutinoside; Quercetin-3-O-acetylguloside; Quercetin-O-dihexoside; Quercetin-O-pentosyletheroside; Rutin | 8,13,14,50,64 |
| Cucurbitane-type triterpenoids | Cucurbitane I; Cucurbitane II; Cucurbitane III; Karavilagenin F; Karavilose II; Karavilose XII; Kugucin F-S; Momordicine I; Momordicine II; Momordicine VI; Momordicine VII; Momordicine VIII; Momordicidoses; 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

Flavonoids

- Kaempferol; Rutin

Cucurbitane-type triterpenoids

- (23E)-3β-Hydroxy-7β,25-dimethoxycucurbita-5,23-dien-19-β-al; (23E)-7β-methoxycucurbita-5,23,25-trien-3β-ol; (23E)-Cucurbita-5,23,25-triene-3a,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- pentanocurbit-5-en-3-one; 25,26,27-trinocurbit-5-en-3,7,23-triene; 25α-Isoprenylcucurbita-5(6)-ene 3α,β-D-glucopyranoside; 3β,7β,23-trihydroxycurbita-5,24-diene-7β-β-D-glucoside; 3β,7β,25-22-hydroxycurbita-5,23(E)-diene-19-αL; 5β,19-epoxy-19,25-dimethoxy-curbita-6,24-diene-3β-ol; 5β,19-epoxy-25-methoxy-curbita-6,23-diene-3β-ol; 5β-23-(4-hydroxyphenyl)curbita-5,24-diene-3β-ol; 5β-23-epoxycurbita-5,24-diene-3β-ol

Fruit Phenolic compounds

- Caffeic Acid; Chlorogenic acid; Ferulic acid; Gallic acid; p-Coumaric acid; t-Cinnamic acid; Vanyl acid; 2,5-dihydroxybenzoic acid

Flavonoids

- Kaempferol; Rutin

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

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

Carbohydrates

- Arabinose; Galactose; Glucose; Mannose; Pectin; Rhamnose; Ribose; Xylose

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* | 100 mg/mL | disc diffusion method | 84 |
|      |                     | *Escherichia coli* | 100 mg/mL | microdilution | 64 |
|      | Ethanol extract     | *Escherichia coli* | 125 µg/mL | microdilution | 64 |
|      | Aqueous Extract     | *Escherichia coli* | 100 mg/mL | microdilution | 64 |
|      | Acetone Extract     | *Escherichia coli* | 2 µg/mL | microdilution | 64 |

*MCL M. charantia lectin  
*MAP30 a 30 kDa M. charantia anti-HIV protein;  
*RIP ribosome inactivating protein;  
*relevant for antimicrobial activity.
On the other hand, studies of its safety and efficacy have been carried out in combination with antimicrobials such as aminoglycosides, 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 as well as some protein fractions. 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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