Bioactive compounds extracted and investigated from *Momordica balsamina* L and their potential as therapeutics: An updated review

Iqra Aman, Tahir Mehmood, Aleena Sumrin, Sadaf Aman, Maryam Sehar, Aqsa Ashraf, Khushbakht Arshad, Sundas Ibrahim, Faiza Siddique

Abstract

Momordica balsamina belongs to family Cucurbitaceae and also commonly called as balsam apple or African pumpkin. This genus consists of approximately 60 species that are widely spread across the tropical regions of South Africa and Southeast Asia. This specie is famous due to its vast therapeutic applications including its leaves, stems and its fruit pulp. *Momordica balsamina* have a large number of bioactive compounds which are further be used for medicinal purposes. These bioactive compounds includes; alkaloids, tannins, saponins, proteins, flavonoids, phenolic compounds and Terpenoids. These phytochemicals that are naturally present in plants can be used for treatment of different ailments such as cancer, diabetes, malaria or bacterial infections. This review article highlights the different phytochemicals extracted and various therapeutic applications of *Momordica balsamina*. *Momordica balsamina* has a very promising potential as a medicinal resource but a clinical approach must be needed to fully harness its medicinal advantages.

Keywords

Momordica balsamina, therapeutic applications, phytochemicals, clinical approach.

1 Introduction

African pumpkin, scientifically known as *Momordica balsamina* L. and belonging to the Cucurbitaceae family, is a commonly found vegetable in tropical and subtropical regions.[1] It is highly regarded for its nutritional value and is a staple food source, particularly in sub-Saharan Africa. The 60 species were included in genus Momordica, such as *M. balsamina, M. foetida, M.charantia and M.cochinchinensis*. These species are among warm tropical regions of Southeast Asia and Africa. Originating from the Latin word "mordeo," meaning "to bite," the genus name may have been chosen to reflect the bitten look of the indented margins of the seeds and leaves, or the bitter taste of the ripe fruits of certain species. *M.balsamina* is also regarded as sacred plant in some areas because of its versatile medicinal potential. It has long history of use in African medicine for treating particular ailments like malaria and diabetes.[2]

The plant not only contains cucurbitane-type triterpenoids, with varying oxidation patterns, named cucurbitacins, but also secondary metabolites such as flavonoids, alkaloids, steroids, saponins, cardiac glycoside, tannins and terpenes.[3]

It possesses trumpet shaped flowers with a range of color shades including cream, yellow and white. Its ovoid-ellipsoid fruit measures about 2.5 to 5 cm ranging from vibrant orange to red.[4] Various parts of plants are reported to have medicinal and nutritional properties. These parts include leaves, roots, bark, fruit, seeds, flowers, and bulbs. [5] *M. balsamina* is considered a gifted plant by some rural populations due to its nutritional and medicinal properties.

This review article aims to summarize the current knowledge on *Momordica balsamina*, with a focus on the bioactive compounds extracted and their therapeutic uses.

Botanical Description of *Momordica balsamina*

An annual herbaceous monoecious climbing plant, *M. balsamina* can grow to a height of 4–5 m and has stems that are either glabrous or somewhat hairy and have tendrils that it uses to cling to other plants[6]. A range of 0 to 1,293 meters is where it thrives[7].

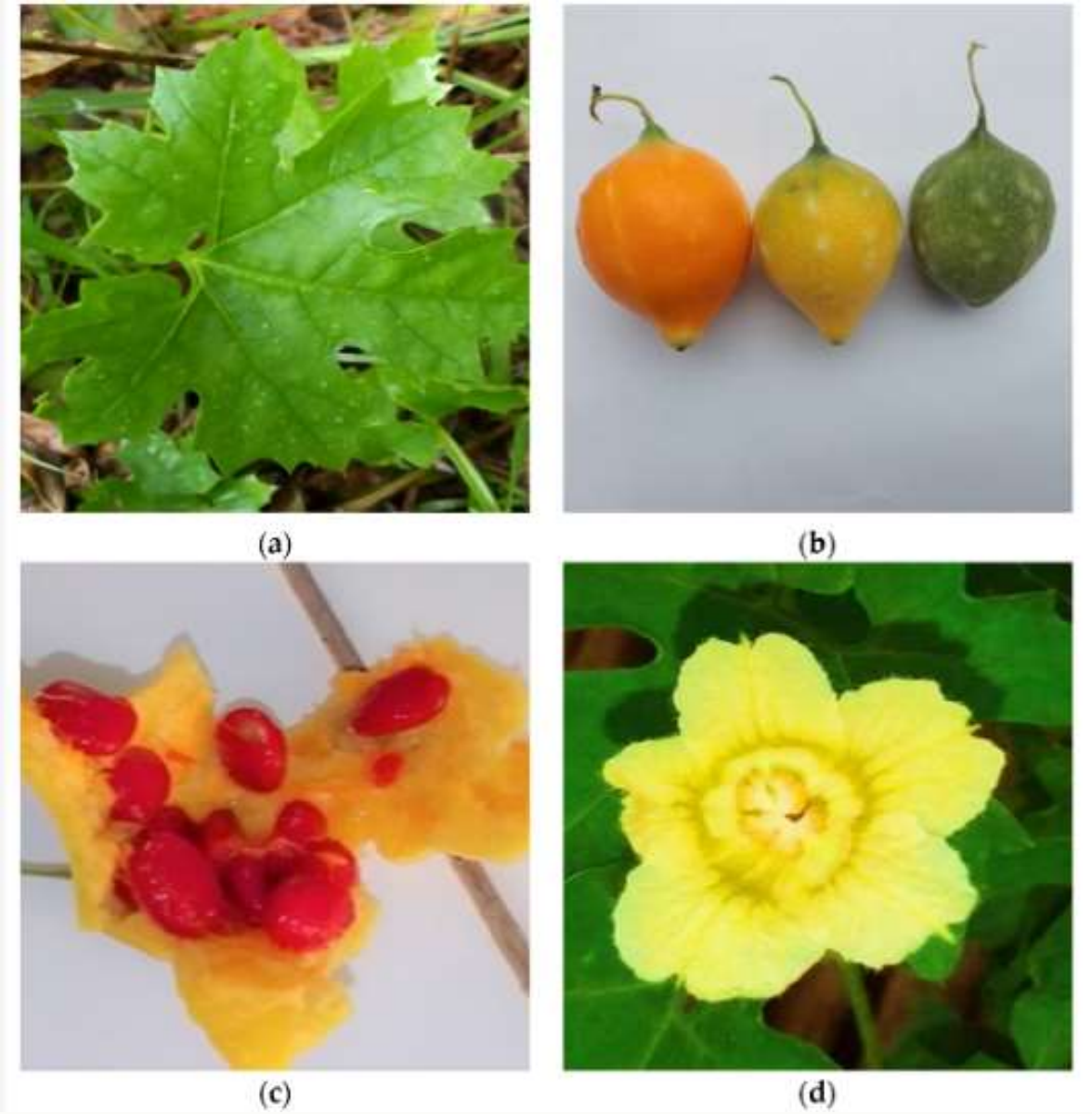


Figure 1: Momordica balsamina's different parts (a) leaves (b) fruit (c) seeds and (d) flower

Mild green is the color of *M. balsamina's* leaves[8]. The simple, alternating, waxy leaves have three or five lobes that extend up to half of the blade[9]. The maximum length of these leaves is 12 cm[7].

Unisexual and solitary, the flowers have a pale-yellow hue. With a pedicel that can reach a length of half a centimeter, they assume a trumpet-like shape[6]. There is a short receptacle that can reach a length of 0.5–1 mm and narrow sepals that can reach a maximum of 0.5 cm[7]. A unicellular inferior ovary is encircled by petals that are half a centimeter to one and a half centimeters long[9].

A spindle-shaped fruit ranging in color from bright orange to crimson is a hallmark of the *M. balsamina* tree[10]. Spines that are short, blunt, non-prickly, creamy, or yellowish and arranged in around 19 rows can be seen on these fruits[11]. When fruits are ripen, they spontaneously broke into the three coiled valves, exposing many seeds covered in a brilliant, very sticky crimson aril. You can eat this aril, and it tastes like watermelon. The seeds are covered with a red pulp. The seeds are compressed and oval in shape, measuring 9 to 12 mm in length[3].

Vegetables grown from M. balsamina are common in tropical and subtropical regions. Although it first appeared in tropical Africa, it has already spread over Australia's coastal regions and the drier parts of South Africa [12]. Gardens in Europe, Central America, Arabia, tropical Asia, and India now include it among their cultivars. During the wetter months of the year, it grows wild in India's jungles[13]. The United States and Pakistan are among the Neotropical countries where this species has become naturalized. Its native range extends into southern Africa, where it grows wild in countries including South Africa, Botswana, and Swaziland. The provinces of KwaZulu-Natal, Limbo, the Eastern and Northern Cape, and South Africa as a whole are ideal for its flourishing[14].

Bioactive Compounds extracted and chemical composition of *M. balsamina*

In traditional medicine, *M. balsamina* is highly esteemed for the wide range of ailments it effectively treats due to its complex chemical composition. The chemical makeup of the plant and the specific disease being treated determine which parts of the plant are used.

A wide number of substances are found in the different parts of the plant including; its leaves, fruits, stems, bark and seeds. These substances includes a large number of phytochemicals such as glycosides, flavonoids, terpenes, alkaloids and saponins[15].The balsamina's fruit is rich in steroid rings, saponins and carbs. Moreover, flavonoids, alkaloids, steroids, tannins, and terpenes are also present but in less amount[16]. Talking specifically about phenolic acids, Quinic acid and chlorogenic acids are those phenolic acids which are present in this plant [17]. According to the some reports, it was discovered that there are also some chemicals named as pseudolaroside A acid and isocitric feruloyl were also present in this plant [18]. Some of the flavonoids were also present named as quercetin, isorhamnetin and kaempferol [17]. Mostly flavonoids are included in various biological functions including; anti-cancerous, antiviral, anti-diabetic , and anti-bacterial both in vitro and in vivo[19].

A variety of bioactivities, such as anti-plasmodial , P-glycoprotein inhibitory effects, anti-malarial and anti-diabetic effects, have been thoroughly studied by Ramalhete et al. (2010, 2011), and 2022) in relation to the cucurbitane triterpenoids, which are the primary components identified from this species and include balsamina genins[18] , karavilagenins[20] , balsaminols, cucurbalsaminols and balsaminosides [21]. The plant has also been shown to contain carotenoids, such as lutein, beta-carotene and zeaxanthin, which are known for their anti-inflammatory, anti-oxidant and anti-aging characteristics [16]. Ramalhete et al. (2022) established cucurbitane biosynthetic routes. The article offered biosynthetic pathways for the novel cucurbalsaminane skeleton, which begins with a skeleton having tetracyclic cucurbitane pattern with an alpha and beta unsaturated carbonyl group at position number 7[20].

A ribosome-inactivated protein (RIPS) were isolated from the seeds of mentioned plant that is *M.balsamina* [22]. As a result, it is possible to block HIV-1 translation in vitro [19]. Balsamina has activity similar to DNase, antimicrobial, and anti-tumor, according to Ajji et al. (2018) [19]. Additionally, it has been shown to have antibacterial activity against a wide variety of microorganisms [20].

Numerous biological tests have confirmed the plant's potential in traditional medicine, and the plant's chemical diversity has made it worth effective in the treatment of various diseases. *M. balsamina* is significant because it is a most useful resource for the traditional medicine and as well in the field of pharmacology for many different types of issues related to health.

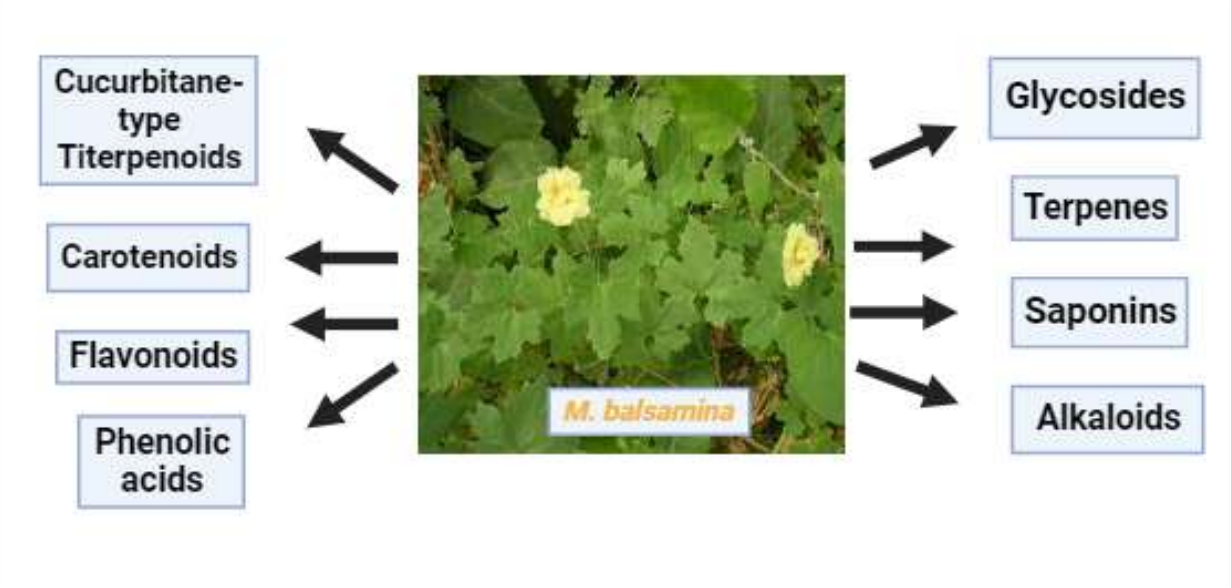
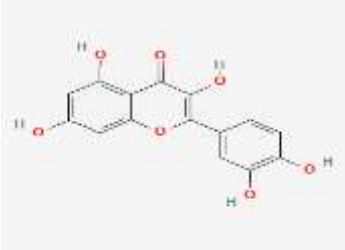
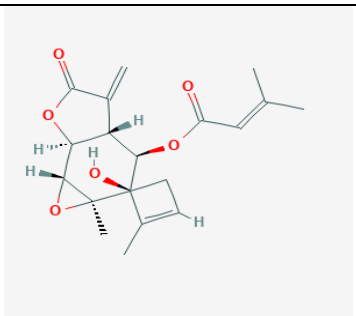
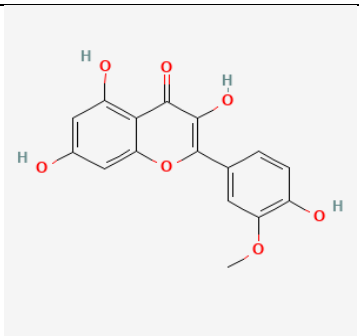
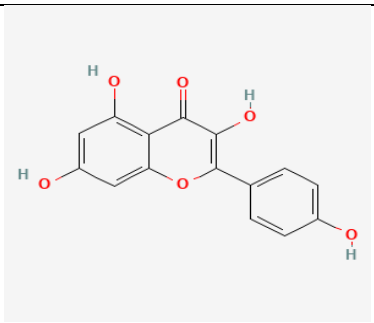
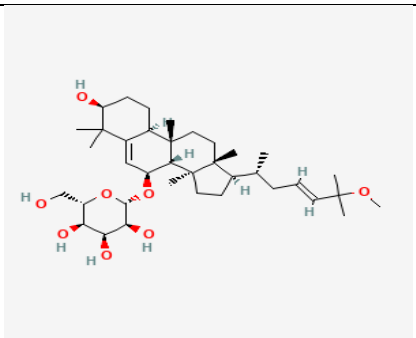
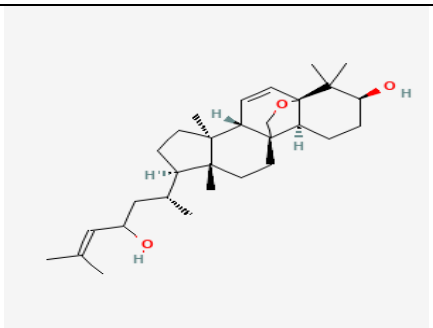
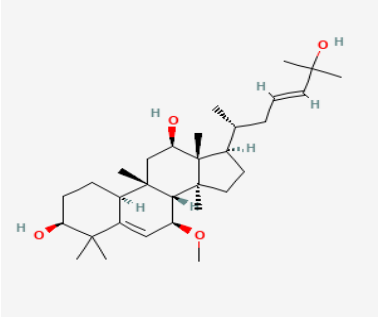
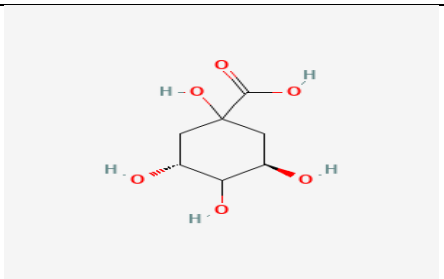
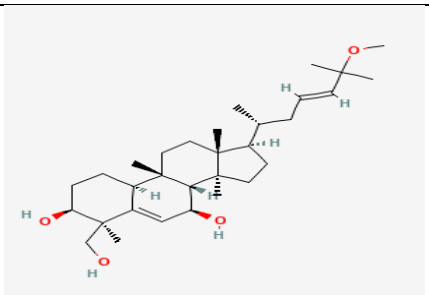


Figure 2: Phytoconstituents of Momordica balsamina

In the table 1, a comprehensive overview of the diverse class of compounds extracted from *M.balsamina*, including compound names and their chemical structures is presented:

Table 1 Compounds present in M.balsamina

Class of compounds	Compounds	Structure	References
Flavonoids	Quercetin		[23]
Flavonoids	Balsamin		[24]
Flavonoids	Isorhamnetine		[25]
Flavonoids	Kaempferol		[26]

Triterpenoids	Balsaminoside A		[26]
Triterpenoids	Kravilagenin E		[21]
Triterpenoids	Cucurbalsaminone B		[27]
Phenolic Acids	Quinic Acid		[28]
Phenolic Acids	Balsaminagenin B		[29]

Biological activities or Potential therapeutic properties of M. balsamina

The leaves of M. balsamina can be used as a vegetable, or we can use them with combination of other plants and decoction can be used as medicine[30]. Figure 3 displays the many medicinal uses of this plant, which include anti-inflammatory, anti-diabetic, anti-cancerous, anti-microbial, anti-plasmodial , anti-oxidant and hypoglycemic activities[31] .

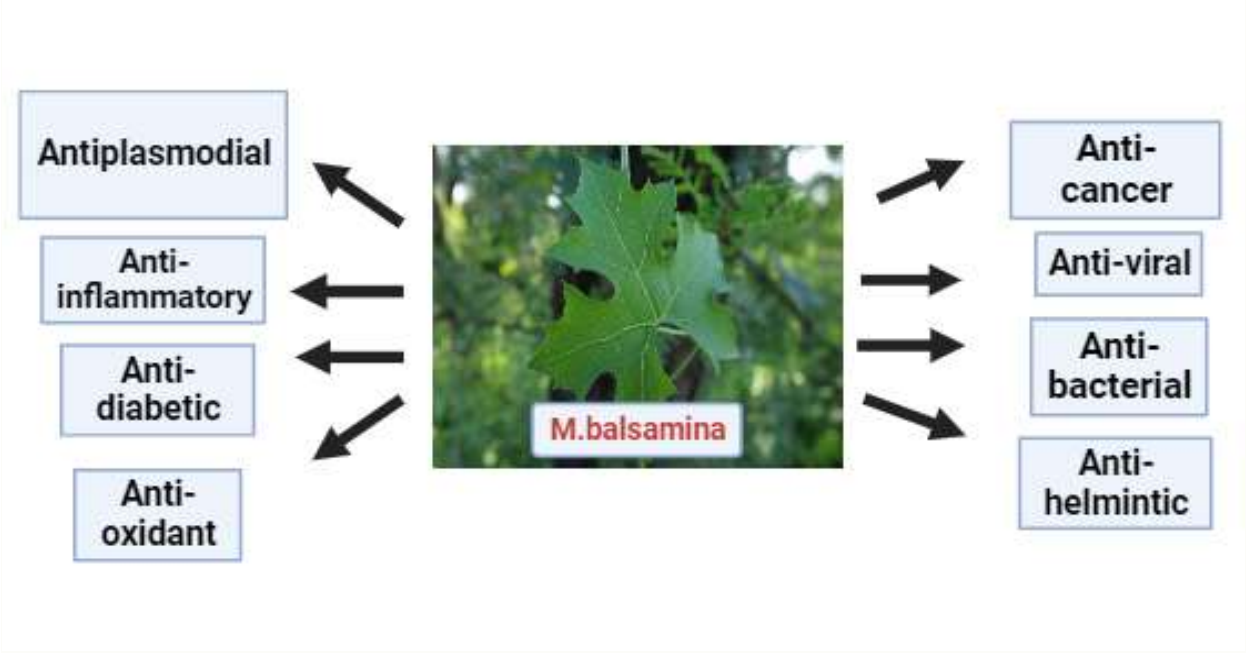


Figure 3: Biological activities of Momordica balsamina

Anti-plasmodial activity

It is worth noting that the methanolic extract of the aerial component of M. balsamina shows promising antiplasmodial properties with minimal toxicity. The one strain was used named as Plasmodium vinckei with which the mice was infected for four days as a part for suppression test, and the results showed that it demonstrated the action against 3 stains of Plasmodium falciparum(cB1-Colombia, F32-Tanzania and FcM29-Cameroon) in vitro. For this reason, it may have a long history of usage in Niger's traditional medicine for treating malaria [32]. Novel triterpenoids derived from Melanochrysum balsamina showed anti-malarial action in a research by Ramalhete et al. (2010) [21]. The anti-malarial activity was demonstrated from the new triterpenes which were isolated from *Momordica balsamina* . The certain derivatives of karavilagenin showed substantial in vitro activity against the strains of P.falciparum. By using the aqueous extracts of leaves and the stems of *Momordica balsamina* in vitro showed the effectiveness against P. falciparum [31].

Anti-bacterial activity

The anti-bacterial activity of *Momordica balsamina* was also investigated [33]. For studying the effect against Staphylococcus aureus and E.coli the methanol leaf extract was used. Using the zone of inhibition as a metric, they revealed

that the methanol extracts were sensitive to the bacteria to be tested. From this, it was concluded that the leaves of balsamina can be a very good alternative to antibiotics for any illness that could be caused by these bacteria [34]. With the help of balsamina extracts a large number of in-vitro antibacterial activities were investigated having action against a wide range of bacteria which includes: Proteus mirabilis, Bacillus subtilis, Klebsiella pneumonia, Salmonella typhi and Pseudomonas aeruginos [35]. It was also investigated that a protein named as balsamin extracted from balsamina has nutraceutical potential due to its anti-bacterial activity against a wide range of bacteria including Salmonella enterica, E.coli, Staphylococus epidermidis and Staphylococcus aureus[36]. Furthermore, the ethyl acetate extract of balsamina showed antibacterial activity against E.faecalis in vitro[37]. So, it was concluded that crude extracts of balsamina have antibacterial activities which ultimately can be used for the treatment of diabetic wounds [34]. Whenever the infection caused by certain bacteria the leaves of balsamina had a potential to be effective against it.

Anti-HIV potential of *Momordica balsamina*

The anti-HIV potential of the M. balsamina plant is quite outstanding. Isolated from the plant M. balsamina, the 30 kDa protein MoMo30 suppresses HIV-1 in vitro at nanomolar concentrations with negligible cellular damage at inhibitory doses [38]. As stated in reference it was discovered that at the concentration of 0.02 mg and higher, the extracts of balsamina leaves showed inhibitory effect for LTR-betagal cells+HeLa-CD4 with HIV-1NL4-3 by over 50%, whereas concentrations ranging from 0 to 0.5 mg/ did not cause any harm[39]. There is evidence that the plant has additional antiviral effects. For example, there has been encouraging evidence in vitro that aqueous extracts of fruit pulp and leaves can inhibit the growth of the Newcastle disease virus on a chicken embryo fibroblast (CEF) cell line, suggesting that these compounds may have therapeutic utility in the treatment of this illness [40]. The in vivo effectiveness of M. balsamina extract against avian paramyxovirus-1 infection in broilers was shown by Ampitan et al. (2023) [41]. This literature confirms the plants anti-viral potential against this virus by inhibiting the virus ability to bind with the host cells [40].

Anti-diabetic activity

An experiment was conducted which confirms that by giving methanolic leaf extract of balsamina to that pre-diabetic rats which were given a high fat, high carbohydrate diet to produce diabetes, ultimately reduced the diabetes-related kidney function abnormalities[42]. By using this treatment renal function was recovered and damage was decreased. One more study in stretozotocin (STZ)-induced diabetic rats confirms that *M.balsamina* helps in processes related to renal diseases in rats [43]. One more in-vivo study was performed in which the rats were given alloxan monohydrate injections to induce diabetes and confirms this plant characteristic in diabetes[44]. RIN-m5F β-cells can be used to increase the glucose absorption when exposed to the non-polar extracts of balsamina such as hexane and ethyl acetate[45].Moreover, to increasing insulin sensitivity and inhibiting intestinal glucose absorption the balsamina's fruit extract was helpful to stimulate insulin production and secretion, which confirms their anti-diabetic activity[45].

Anti-inflammatory activity

The efficacy of anti-inflammatory activity of balsamina leaves was investigated on RAW 264.7 cell lines in-vitro[14]. Their experiment confirms that there is no any harmful secondary metabolites in leaves so it could have significant anti-

inflammatory effects on the health of humans[14]. By inhibiting cyclo-oxygenase 1 and 2, Ndhlala et al. (2011) demonstrated that the aqueous extract of M. balsamina had the ability to reduce inflammation in vitro[46].

Anticancerous activity

There is evidence from biological investigations that *M. balsamina* has anticancer effects. Many triterpenoids studied in vitro by Silva (2017) showed strong P-glycoprotein (P-gp) modulation activity (FAR > 10) and interacted synergistically with the anticancer medicine doxorubicin. These results provide credence to their promise as MDR reversers[47]. Cucurbitacin, a well known kind of famous triterperne present in *Cucurbitaceae family, has been found to promote apoptosis, block cell cycle by inhibition of cyclins and and accelerate autophagy* [48]. A study reported by Karabo et al, (2024) reveals that the extracts of *M.balsamina* show induction of apoptosis and inhibition of metastasis of MCF-7 cells. Moreover, the extract shows ability to modulate the expression of proteins taking part in apoptotic pathways and in the regulation of cell migration and invasion [49].

Anti-malarial activity

One plant that has promising anti-malarial properties is *M. balsamina*. Isolated triterpenoids from *M. balsamina* have a wide variety of powerful pharmacological actions, including as hepatoprotective, anti-inflammatory, anti-diabetic, anti-malarial, and antiparasitic properties [21].

Anti-oxidant activity

The antioxidant potential of this plant is substantial. Odhav et al. showed that methanol extracts of its leaves have a significant antiradical ability in vitro, meaning they inhibited free radicals[50]. Flavonoids and tannins are found to possess natural anti-oxidant potential. The presence of these polyphenols repoted by Samriti et al, (2013) have revealed the anti-oxidant potential of various extracts of *M.balsamina* [51].

Table 2 shows names of bioactive compounds present in *M. balsamina* and their biological activity:

Table 2: Therapeutic activities of different bioactive compounds

Compounds	**Biological Activity**	**References**
Kaempferol	Anti-inflammatory	[25]
Kaempferol	Depigmenting	[52]
Kaempferol	Manages cancer related ailments	[53]
Isorhamnetine	Anti-inflammatory	[54]
Quinic Acid	Antiviral	[35]
Quinic Acid	Anti-inflammatory	[55]
Quercetin	Anti-oxidant	[28]

Conclusion and future directions

In conclusion, this analysis highlights the widespread use of M. balsamina in traditional African medicine. The wide range of biological characteristics and complex chemical compositions of this substance provide credence to its extensive history of use. Therefore, we support the use of M. balsamina in phototherapy regimes. Attention must be paid with great care to guarantee correct use, adherence to recommended dosages, and mitigation of possible adverse effects because many plants used in traditional medicine can be hazardous. At the same time, protecting a plentiful and sustainable supply of active chemicals is critical to preventing the loss of irreplaceable natural resources. Here, in-depth studies of novel approaches to biosynthesis or synthesis of these bioactive components found in nature are required. The discovery of novel medications is a complex and protracted process, regardless of whether they are sourced from natural sources like M. balsamina or synthetic molecules. One of the most important parts of developing a medicine is moving from laboratory and preclinical investigations to clinical trials. To determine if medicines derived from M. balsamina are safe and effective for human use, clinical trials are required. Given that the majority of biological testing include using crude extracts of M. balsamina or even individual chemicals in laboratory investigations, it is of utmost importance to move forward with clinical trials in order to discover novel medications.

References

1. van de Venter, M., et al., *Antidiabetic screening and scoring of 11 plants traditionally used in South Africa.* Journal of ethnopharmacology, 2008. **119**(1): p. 81-86.
2. Bandeira, S.O., F. Gaspar, and F.P. Pagula, *African ethnobotany and healthcare: emphasis on Mozambique.* Pharmaceutical Biology, 2001. **39**(sup1): p. 70-73.
3. Ramalhete, C., et al., *Cucurbitane-type triterpenoids from the African plant Momordica balsamina.* Journal of natural products, 2009. **72**(11): p. 2009-2013.
4. Deutschländer, M., N. Lall, and M. Van De Venter, *Plant species used in the treatment of diabetes by South African traditional healers: An inventory.* Pharmaceutical Biology, 2009. **47**(4): p. 348-365.
5. Karumi, Y., *Anti-inflammatory and antinociceptive (analgesic) properties of Momordical balsamina Linn.(Balsam apple) leaves in rats.* Pak J Biol Sci, 2003. **6**(17): p. 1515-1518.
6. Thakur, G.S., et al., *Momordica balsamina: a medicinal and neutraceutical plant for health care management.* Current pharmaceutical biotechnology, 2009. **10**(7): p. 667-682.
7. Omokhua-Uyi, A.G. and J. Van Staden, *Phytomedicinal relevance of South African Cucurbitaceae species and their safety assessment: A review.* Journal of ethnopharmacology, 2020. **259**: p. 112967.
8. Flyman, M.V. and A.J. Afolayan, *Proximate and mineral composition of the leaves of Momordica balsamina L.: an under-utilized wild vegetable in Botswana.* International journal of food sciences and nutrition, 2007. **58**(6): p. 419-423.
9. Duenas-Lopez, M., *Momordica balsamina (common balsam apple).* Invasive Species Compendium, 2019(34677).
10. Thomas, B., *Encyclopedia of applied plant sciences*. 2016: Academic Press.
11. Bouquet, A., *Plantes médicinales de la Côte d'Ivoire.* Office de la Recherche Scientifique et Technique d'Outre Mer (ORSTOM), Paris, 1974. **165**: p. 38-39.
12. Thiaw, M., et al., *Momordica balsamina L.: A Plant with Multiple Therapeutic and Nutritional Potential—A Review.* Nutraceuticals, 2023. **3**(4): p. 556-573.
13. Mu'azu, A. and M. Bello, *Reproductive performance of rabbit feed with graded of balsam apple (Momordica balsamina).* J. Agric. Sci. Technol, 2022. **9**: p. 17-26.

14. Mabasa, X., et al., *Molecular spectroscopic (FTIR and UV-Vis) and hyphenated chromatographic (UHPLC-qTOF-MS) analysis and in vitro bioactivities of the Momordica balsamina leaf extract.* Biochemistry Research International, 2021. **2021**.
15. Avato, P. and M.P. Argentieri, *Editorial to the special issue:"Phytochemicals in nutrition and health: advances and challenges".* Phytochemistry Reviews, 2022. **21**(2): p. 313-316.
16. Mashiane, P., et al., *A Comparison of bioactive metabolites, antinutrients, and bioactivities of african pumpkin leaves (Momordica balsamina L.) cooked by different culinary techniques.* Molecules, 2022. **27**(6): p. 1901.
17. Maibulangu, B., M. Ibrahim, and L. Akinola, *Inhibitory effect of African Pumpkin (Momordica balsamina Linn.) leaf extract on copper corrosion in acidic media.* Journal of Applied Sciences and Environmental Management, 2017. **21**(6): p. 1067-1071.
18. Ramalhete, C., et al., *Karavilagenin C derivatives as antimalarials.* Bioorganic & medicinal chemistry, 2011. **19**(1): p. 330-338.
19. Ajji, P.K., et al., *Purification and functional characterization of recombinant balsamin, a ribosome-inactivating protein from Momordica balsamina.* International journal of biological macromolecules, 2018. **114**: p. 226-234.
20. Ramalhete, C., et al., *Momordica balsamina: phytochemistry and pharmacological potential of a gifted species.* Phytochemistry Reviews, 2022. **21**(2): p. 617-646.
21. Ramalhete, C., et al., *New antimalarials with a triterpenic scaffold from Momordica balsamina.* Bioorganic & medicinal chemistry, 2010. **18**(14): p. 5254-5260.
22. Kaur, I., et al., *Balsamin, a novel ribosome-inactivating protein from the seeds of Balsam apple Momordica balsamina.* Amino acids, 2012. **43**: p. 973-981.
23. Law, S.K.-Y., et al., *A switch-on mechanism to activate maize ribosome-inactivating protein for targeting HIV-infected cells.* Nucleic acids research, 2010. **38**(19): p. 6803-6812.
24. Fu, Y., et al., *Magnolol inhibits lipopolysaccharide-induced inflammatory response by interfering with TLR4 mediated NF-κB and MAPKs signaling pathways.* Journal of ethnopharmacology, 2013. **145**(1): p. 193-199.
25. Rho, H.S., et al., *Changes in flavonoid content and tyrosinase inhibitory activity in kenaf leaf extract after far-infrared treatment.* Bioorganic & medicinal chemistry letters, 2010. **20**(24): p. 7534-7536.
26. Chen, A.Y. and Y.C. Chen, *A review of the dietary flavonoid, kaempferol on human health and cancer chemoprevention.* Food chemistry, 2013. **138**(4): p. 2099-2107.
27. Abu-Odeh, A.M. and W.H. Talib, *Middle East medicinal plants in the treatment of diabetes: a review.* Molecules, 2021. **26**(3): p. 742.
28. Wang, G.-F., et al., *Anti-hepatitis B virus activity of chlorogenic acid, quinic acid and caffeic acid in vivo and in vitro.* Antiviral research, 2009. **83**(2): p. 186-190.
29. Ajji, P.K., et al., *Recombinant Balsamin induces apoptosis in liver and breast cancer cells via cell cycle arrest and regulation of apoptotic pathways.* Process Biochemistry, 2020. **96**: p. 146-156.
30. De Wet, H., M. Ramulondi, and Z. Ngcobo, *The use of indigenous medicine for the treatment of hypertension by a rural community in northern Maputaland, South Africa.* South African Journal of Botany, 2016. **103**: p. 78-88.
31. Clarkson, C., et al., *In vitro antiplasmodial activity of medicinal plants native to or naturalised in South Africa.* Journal of ethnopharmacology, 2004. **92**(2-3): p. 177-191.
32. Benoit-Vical, F., et al., *In vitro and in vivo antiplasmodial activity of Momordica balsamina alone or in a traditional mixture.* Chemotherapy, 2006. **52**(6): p. 288-292.
33. Abdulhamid, A., et al., *Phytochemical and antibacterial activity of Momordica balsamina leaves crude extract and fractions.* Drug Discov, 2023. **17**: p. e11dd1012.
34. Otimenyin, S.O., M. Uguru, and A. Ogbonna, *Antimicrobial and hypoglycemic effects of Momordica balsamina. Linn.* 2008.
35. Jigam, A., H. Akanya, and D. Adeyemi, *Antimicrobial and antiplasmodial effects of Momordica balsamina.* Nigerian Journal of Natural Products and Medicine, 2004. **8**: p. 11-12.
36. Ajji, P.K., K. Walder, and M. Puri, *Functional analysis of a type-I ribosome inactivating protein balsamin from Momordica balsamina with anti-microbial and DNase activity.* Plant foods for human nutrition, 2016. **71**: p. 265-271.

37. Madureira, A.M., et al., *Antibacterial activity of some African medicinal plants used traditionally against infectious diseases.* Pharmaceutical Biology, 2012. **50**(4): p. 481-489.
38. Khan, M., et al., *Anti-human immunodeficiency virus-1 activity of MoMo30 protein isolated from the traditional African medicinal plant Momordica balsamina.* Virology Journal, 2023. **20**(1): p. 50.
39. Coleman, M.I., et al., *Identification of a novel anti-HIV-1 protein from Momordica balsamina leaf extract.* International Journal of Environmental Research and Public Health, 2022. **19**(22): p. 15227.
40. Chollom, S., et al., *Antiviral potential of aqueous extracts of some parts of Momordica balsamina plant against newcastle disease virus.* Journal of Advanced Pharmacy Education & Research, 2012. **2**(3): p. 82-92.
41. Ampitan, T., et al., *PROPHYLACTIC POTENCY OF METHANOLIC EXTRACT OF Momordica balsamina L. AGAINST AVIAN PARAMYXOVIRUS-1 INFECTION IN BROILER CHICKENS.* Egyptian Journal of Animal Production, 2023. **60**(1): p. 25-32.
42. Khumalo, B., et al., *Effects of Momordica balsamina on markers associated with renal dysfunction in a diet-induced prediabetic rat model.* 2023.
43. Siboto, A., et al., *The effects of Momordica balsamina methanolic extract on kidney function in STZ-induced diabetic rats: effects on selected metabolic markers.* Journal of diabetes research, 2018. **2018**.
44. Sani, A.A., S.B. Idris, and S. Yakubu, *Anti-diabetic activity of methanolic extract of Momordica balsamina in rabbits.* Sci Res J, 2019. **7**: p. 1-6.
45. Kgopa, A.H., L.J. Shai, and M.A. Mogale, *fruit extracts enhances selected aspects of the insulin synthesis/secretion pathway.* American Journal of Biochemistry and Biotechnology, 2020. **16**(4): p. 549-560.
46. Ndhlala, A., J. Finnie, and J. Van Staden, *Plant composition, pharmacological properties and mutagenic evaluation of a commercial Zulu herbal mixture: Imbiza ephuzwato.* Journal of Ethnopharmacology, 2011. **133**(2): p. 663-674.
47. Silva, C.D., et al., *Triterpenes from Momordica balsamina (African pumpkin): ABCB1 inhibition and synergistic interaction with doxorubicin in resistant cancer cells.* Phytochemistry, 2022. **203**: p. 113354.
48. Jing, S., et al., *Cucurbitacins: Bioactivities and synergistic effect with small-molecule drugs.* Journal of Functional Foods, 2020. **72**: p. 104042.
49. Serala, K., et al., *Momordica balsamina acetone leaf extract induces apoptosis and inhibits the invasiveness and migration of MCF-7 breast cancer cells.* South African Journal of Botany, 2024. **165**: p. 257-263.
50. Odhav, B., et al., *Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal, South Africa.* Journal of Food Composition and Analysis, 2007. **20**(5): p. 430-435.
51. Faujdar, S., S. Nain, and A. Kalia, *Antioxidant activity and estimation of total phenolic content of Momordica balsamina.* Int J Adv Res, 2013. **2**(2): p. 233-238.
52. De Melo, G.O., et al., *Antinociceptive and anti-inflammatory kaempferol glycosides from Sedum dendroideum.* Journal of Ethnopharmacology, 2009. **124**(2): p. 228-232.
53. Yen, C.-T., et al., *Flavonol glycosides from Muehlenbeckia platyclada and their anti-inflammatory activity.* Chemical and Pharmaceutical Bulletin, 2009. **57**(3): p. 280-282.
54. Agbor, G.A., et al., *Hepatoprotective activity of Hibiscus cannabinus (Linn.) against carbon tetrachloride and paracetamol induced liver damage in rats.* Pak. J. Biol. Sci, 2005. **8**(10): p. 1397-1401.
55. Ahn, S.-M., et al., *Antibacterial, antioxidative and anti-proliferative activity against human colorectal cell of pimpinella brachycarpa.* Korean Journal of Food Preservation, 2011. **18**(4): p. 590-596.

Iqra Aman is currently pursuing masters degree program in Molecular Biology and Forensic Science in Centre for Applied Molecular Biology, University of the Punjab, Lahore, Pakistan,

Tahir Mehmood is currently serving as Professor of Microbiology and Molecular Genetics in University of the Punjab, Lahiore, Pakistan,

Aleena Sumrin is currently serving as associate professor in Centre for Applied Molecular Biology, University of the Punjab, Lahore, Pakistan,

Sadaf Aman is currently serving as associate professor in Minhaj University, Lahoe, Pakistan,

Maryam sehar currently pursuing masters degree program in Molecular Biology and Forensic Science in Centre for Applied Molecular Biology, University of the Punjab, Lahore, Pakistan,

Aqsa ashraf currently pursuing masters degree program in Molecular Biology and Forensic Science in Centre for Applied Molecular Biology, University of the Punjab, Lahore, Pakistan

Khushbakht Arshad currently pursuing masters degree program in Molecular Biology and Forensic Science in Centre for Excellence in Molecular Biology, University of the Punjab, Lahore, Pakistan,

Sundas Ibrahim currently pursuing PhD degree program in Molecular Biology and Forensic Science in Centre for Applied Molecular Biology, University of the Punjab, Lahore, Pakistan

Faiza Siddique currently pursuing PhD degree program in biochemistry from Institute of chemistry, University of Sargodha, Pakistan,