nutraceuticals

Review

# *Momordica balsamina* L.: A Plant with Multiple Therapeutic and Nutritional Potential—A Review

**Marème Thiaw [1,2], Issa Samb [1,*], Manon Genva [2], Mohamed Lamine Gaye [3] and Marie-Laure Fauconnier [2,*]**

1 Department of Chemistry, Training and Research Unit for Applied Sciences and Information and Communication Technology, University Alioune Diop of Bambey (UADB), Bambey 30, Senegal; mareme.thiaw@doct.uliege.be
2 Laboratory of Chemistry of Natural Molecules, Gembloux Agro-Bio Tech, University of Liege, Passage des Deportes, 2-5030 Gembloux, Belgium; m.genva@uliege.be
3 Department of Chemistry, Faculty of Sciences and Technology (FST), University Cheikh Anta Diop Dakar (UCAD), Dakar 5005, Senegal; mlgayeastou@yahoo.fr
* Correspondence: issa.samb@uadb.edu.sn (I.S.); marie-laure.fauconnier@uliege.be (M.-L.F.); Tel.: +221-77-568-34-78 (I.S.); +32-81-62-22-89 (M.-L.F.)

**Abstract:** This review seeks to deepen our comprehension of the African plant *Momordica balsamina* L. by elucidating its therapeutically important molecules and nutrient composition. Commonly referred to as the balsam apple, this plant species is extensively harnessed for its diverse therapeutic potential across its various organs, including leaves, fruits, roots, and stems. Numerous bioactive molecules have been isolated or identified within this plant, notably encompassing polyphenols, flavonoids, terpenes, and carotenoids. These compounds exhibit a wide array of biological activities, ranging from antioxidative, anti-inflammatory, anti-diabetic and anti-carcinogenic to anti-malarial properties, among others. Furthermore, the leaves of *Momordica balsamina* L. stand out for their abundant micronutrients, proteins, and amino acids. This investigation aims to shed light not only on the botanical characteristics of the *Momordica balsamina* plant and its potential applications in traditional medicine but also on its chemical composition, biological functionalities, and physicochemical attributes, thus accentuating its nutritional advantages. Nonetheless, an intriguing avenue presents itself for the exploration of strategies to conserve this species, delve deeper into its potential within the cosmetics industry, and innovate methodologies for the synthesis or biosynthesis of these bioactive molecules.

**Keywords:** *Momordica balsamina* L.; phytotherapy; phytochemicals; biological properties; nutritional values; cosmetic uses

check for updates

**Citation:** Thiaw, M.; Samb, I.; Genva, M.; Gaye, M.L.; Fauconnier, M.-L. *Momordica balsamina* L.: A Plant with Multiple Therapeutic and Nutritional Potential—A Review. *Nutraceuticals* **2023**, *3*, 556–573. https://doi.org/10.3390/nutraceuticals3040040

Academic Editors: Ivan Cruz-Chamorro and Guillermo Santos Sánchez

Received: 15 September 2023
Revised: 9 November 2023
Accepted: 15 November 2023
Published: 17 November 2023

**Copyright:** © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

## 1. Introduction

For millennia, humanity has drawn upon environmental resources to ensure survival and well-being. Even in contemporary times, plants remain invaluable sources of sustenance and medicinal properties [1,2]. Nevertheless, a scarcity of ethnobotanical and chemical investigations has obscured the full extent of their pharmacopeia, nutritional value, and therapeutic potential.

In the present era, uncovering the botanical intricacies and therapeutic merits of plants presents a formidable challenge. Indeed, plants are fundamental and essential components in pharmaceutical research and production [1]. Consequently, delving into their chemical compositions and nutritional profiles emerges as a critical pursuit to enhance their application in medicine. Notably, plant-based derivatives constitute over 50% of the global medicinal repertoire [3]. These plants are frequently encountered in herbalists' domains, traditional healing practices, marketplaces, or their regions of origin. The leaves, barks, roots, and fruits of medicinal plants constitute the most utilized components for phytotherapeutic purposes, often administered via maceration, infusion, digestion, or decoction [4].

The Cucurbitaceae family, widely employed in traditional medicine, encompasses herbaceous vines with tendrils and, in some cases, shrubs. Certain of these species exhibit widespread distribution across tropical and subtropical regions [4,5]. Cucurbits notably hold a significant position in Africa, offering a range of edibles (such as squash, pumpkin, and melon) and utilitarian items (like gourds and sponges). The fruits of numerous cucurbit species, rich in micronutrients, constitute dietary staples in Africa, sometimes consumed as juices to alleviate micronutrient deficiencies. Plants within the *Momordica* genus are of notable importance for their remedial attributes [6].

*Momordica balsamina*, commonly known as balsam apple or referred to as Mburbuf or Mborbof in the Wolof language (native to Senegal), belongs to the *Momordica* genus. Flourishing in arid expanses of tropical and subtropical Africa, *M. balsamina* serves a dual role, being both a dietary staple and a fundamental element of traditional African medicine. It finds application in alleviating diverse symptomatic manifestations, including those associated with diabetes and malaria [7].

The primary objective of this article is to provide a comprehensive botanical delineation of *M. balsamina*, followed by an exhaustive exploration of its numerous applications. Subsequently, a detailed synthesis of its chemical composition, biological activities, and nutritional potential is presented. *M. balsamina*, with its numerous applications in the food sector, as a source of medicine, and potentially as a source for new cosmetic ingredients, is well worth this review paper. The uniqueness of this review lies in its extensive coverage, encompassing not only the phytochemical and pharmacological aspects of *M. balsamina* but also its nutritional potential, traditional uses, and cosmetic applications. The literature search was carried out using the following databases: Google Scholar, Science Direct, Pub Chem, ACS, and Scopus. The keywords mainly used were "*Momordica balsamina*", associated with thematic words such as botany, traditional use, biological properties, nutritional value, and cosmetic use.

## 2. Botanical Description and Geographical Distribution of *Momordica balsamina*

The genus *Momordica* comprises approximately fifty-nine herbaceous or perennial herbaceous species, occasionally manifesting as small shrub climbers. These plants belong to the cucurbit family and are indigenous to tropical and subtropical regions of Africa, Asia, and Australia [8].

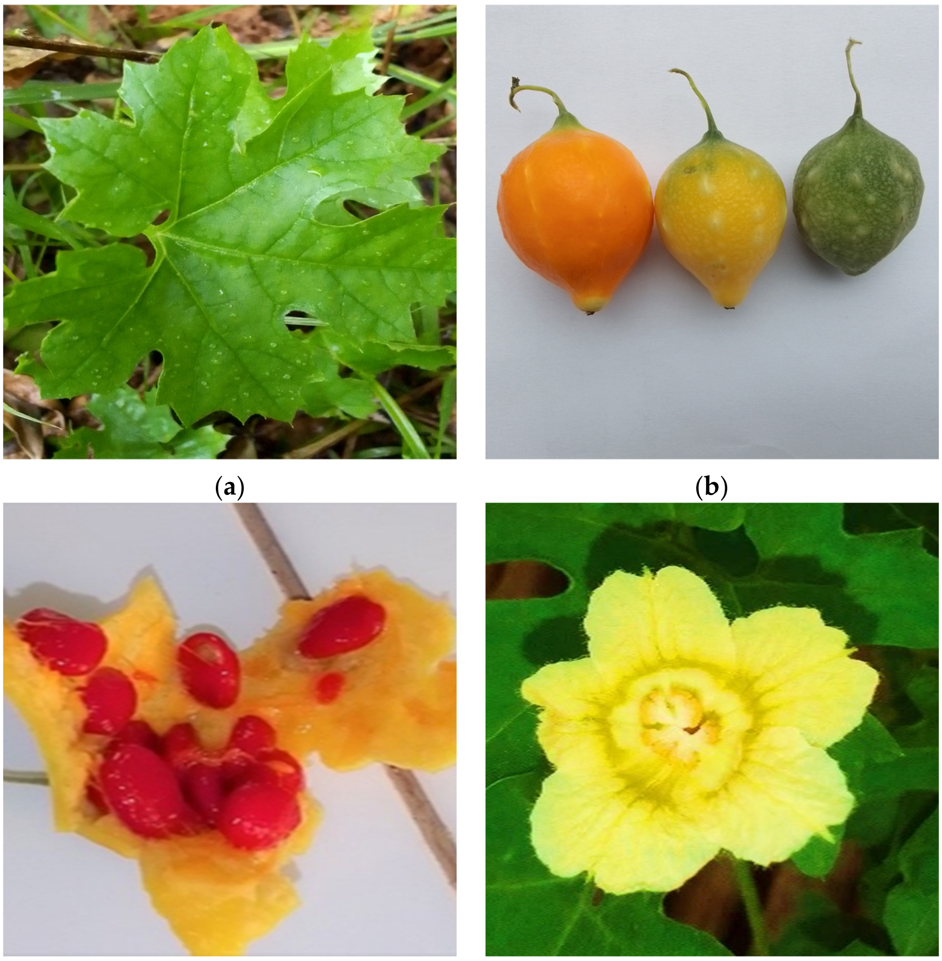
*M. balsamina* (Figure 1) is an annual herbaceous, monoecious, climbing plant with glabrous or lightly hairy stems up to 4 to 5 m long, equipped with tendrils for attachment to nearby vegetation. It grows at altitudes of 0 to 1293 m [3,4,9].

The leaves of *M. balsamina* (see Figure 1a) exhibit a light green hue. They are alternate, waxy, simple, and lobed, featuring three to five distinct lobes reaching up to half of the leaf blade. These leaves can reach a length of 12 cm [4,9,10].

The flowers (see Figure 1d) are pale yellow, unisexual, and solitary. They take on a rounded, trumpet-like form, characterized by a pedicel measuring up to 0.5 cm in length. The receptacle spans 0.5–1 mm, while the sepals are narrow and can grow up to 0.5 cm. Petals range from 0.5 to 1.5 cm in length, surrounding a unicellular inferior ovary [3,4,10].

The fruits of *M. balsamina* (see Figure 1b) adopt a spindle-shaped appearance, with colors shifting from orange to vibrant red. These fruits exhibit about 19 rows of regular or irregular, short, blunt, non-prickly, creamy, or yellowish spines. Upon ripening (when orange), the fruits, which measure 25–60 mm, spontaneously split into three coiled valves, revealing numerous seeds enshrouded by a vivid (see Figure 1c), extremely adhesive scarlet aril. This aril is edible and possesses a sweetness akin to watermelon. The seeds are encased within a crimson pulp. Oval and compressed, the seeds span 9 to 12 mm in length [3,4,10].

*M. balsamina* is a prevalent vegetable within tropical and subtropical zones [6]. Originating from tropical Africa, it has proliferated across drier areas of South Africa and coastal regions of Australia. Its cultivation has extended to European gardens, as well as to Central American, Arabian, tropical Asian, and Indian regions. In India, it thrives naturally in forests during the rainy season. This species has been introduced to parts of the Neotropics, gaining naturalization in the United States and Pakistan [9,11]. It can be found growing in the wild across southern African regions, including Botswana, Swaziland, Namibia, and South Africa. Within South Africa, it flourishes in the Eastern and Northern Cape, Limbo, and Kwazulu-Natal provinces [3].



(**a**) (**b**) (**c**) (**d**)

**Figure 1.** Different parts of the *M. balsamina* plant: (**a**) leaves, (**b**) fruits, (**c**) seeds, and (**d**) flower (Mareme THIAW, Ngoundiane (Thies-Senegal) 2022).

## 3. Chemical Composition of *Momordica balsamina*

*M. balsamina* is revered in traditional medicine for its diverse chemical composition, contributing to its efficacy in treating a multitude of diseases. Each part of the plant is utilized in accordance with its distinct chemical composition and the specific ailment to be treated.

The plant's leaves, fruits, stems, seeds, and bark collectively contain a spectrum of compounds, including resins, alkaloids, flavonoids, glycosides, steroids, terpenes, cardiac glycosides, and saponins, among others [3,12–14].

Indeed, the aerial part of *M. balsamina* has been found to contain a variety of compounds, including terpenoids [12–14], alkaloids, saponins [13,14], tannins [12,13], flavonoids, anthocyanins, mucilages, and reducing compounds [12]. Additionally, the presence of glycosides and glycoside saponins has also been noted [14].

The fruit of *M. balsamina* notably contains a significant quantity of saponins, steroid rings, and carbohydrates. Alkaloids, tannins, flavonoids, glycosides, steroids, and terpenes are also present, albeit in smaller amounts [3].

Based on findings from ethnopharmacology surveys, phytochemical screenings, and extract fractionation via chromatography, a range of biological tests can be conducted. These include assessments in vitro and in vivo of antioxidant, antibacterial, anti-diabetic, anti-inflammatory, anti-malarial, antiviral, and anti-HIV properties, among others (Table 1) [15–18]. The observed biological activities can be attributed to the presence of identified or isolated metabolites within *M. balsamina* extracts, including flavonoids, terpenes, phenolic acids, carotenoids, and more (refer to Table 1).

Numerous phenolic acids, such as quinic acid and various chlorogenic acids, have been identified within the plant [16,17]. Unique compounds, including pseudolaroside A acid and isocitric feruloyl acid, have been reported for the first time in relation to *M. balsamina* [19]. Common flavonoids, including kaempferol, quercetin, and isorhamnetin, have been identified, each exhibiting distinct glycoside forms [16,17]. Notably, certain flavonoids demonstrate in vitro and in vivo an array of biological activities, such as anti-inflammatory, antioxidant, anti-diabetic, and anti-malarial effects [16,17,20].

Cucurbitane triterpenoids, the main constituents isolated from this species encompassing balsaminols, balsaminosides, balsaminagenins, karavilagenins, and cucurbalsaminols, have been extensively investigated by Ramalhete et al. (2010), (2011), and (2022) for their diverse bioactivities, including anti-diabetic, anti-malarial, antiplasmodial, anti-cancer, antibacterial, and P-glycoprotein (P-gp)-inhibitory effects [18,20,21]. Carotenoids, including zeaxanthin, lutein, and β-carotene, renowned for their antioxidative, anti-inflammatory, and anti-aging properties, have also been identified within the plant [17,20]. Biosynthetic pathways for cucurbitane have been established by Ramalhete et al. (2022) [18]. It proposed biosynthetic routes for the new cucurbalsaminane skeleton starting from a tetracyclic cucurbitane skeleton, with an α,β-unsaturated carbonyl at C-7.

Balsamin, a ribosome-inactivating protein (RIP), was isolated from the seeds of the plant *M. balsamina* [11]. It allows the in vitro inhibition of HIV-1 replication at the translation stage [11,22]. Ajji et al. (2018) [22] have shown that balsamin also possesses anti-tumor, antibacterial, and DNase-like activity. Moreover, a broad-spectrum antibacterial activity has been documented [18].

The chemical diversity of the plant has made it effective in treating various health problems, and its potential in traditional medicine has been substantiated by numerous biological tests, highlighting the significance of *M. balsamina* as a valuable resource in both traditional medicine and modern pharmacology for a wide range of health issues.

**Table 1.** Metabolites of *M. balsamina* and their biological activities.

| Class of Compounds | Compounds | Biological Activity | Essay/Conclusion | References |
|---|---|---|---|---|
| | Balsamin | Antiviral activity | In vitro. Inhibits HIV-1 replication in T-cell lines and human primary $CD4^+$ T cells during the translation of viral proteins with an $IC_{50}$ of approximately 10 nM after three days of treatment. | [23] |
| | | Antibacterial | In vitro Inhibition the growth in a dose-dependent manner of pathogens *Staphylococcus epidermidis* (MICs = 1.56 µg/mL) and *Staphylococcus aureus* (MICs = 6.25 µg/mL). | [24] |
| Flavonoids | Kaempferol | Depigmenting | In vitro. Tyrosine inhibition in B16 melanoma cells with $IC_{50}$ 171.40 µM. | [25] |

**Table 1.** *Cont.*

| Class of Compounds | Compounds | Biological Activity | Essay/Conclusion | References |
|---|---|---|---|---|
| Flavonoids | Kaempferol | Anti-inflammatory | In vitro. Potent inhibitory activity relative to Nitric Oxide (NO) production, induced by Lipopolysaccharides (LPS) in RAW 264.7 cells ($IC_{50}$ 15.40 μM) without cytotoxicity, and inhibited NF-κB-mediated luciferase activities ($IC_{50}$ 90.30 μM). | [25] |
| | | Managing cancer-associated ailments | In vitro. Effectively inhibit ($IC_{50}$ 43 μmol/L) multiple cancer-associated pathways in triple-negative breast cancer cells (TNBC cells) simultaneously. | [26] |
| | Quercetin | Anti-carcinogenic/ Antioxidant | In vitro. Scavenge oxygen-free radicals $H_2O_2$ ($IC_{50}$ 5 μM) and $O_2^-$ ($IC_{50}$ 9 μM); inhibit lipid peroxidation ($IC_{50}$ 60 μM); and quench 8 ohdg formation via UV light irradiation ($IC_{50}$ 0.8 μM) and Fenton reaction ($IC_{50}$ 80 μM). | [27] |
| | | Antioxidant/ Anti-inflammatory | In vivo Preserve the function of the liver in acute alcoholic injury by upregulating the expression of Interleukin 10 and Oxygenase-1 and thus inhibiting NLRP3 inflammasome activation and inflammatory factor secretion. | [28] |
| | Isorhamnétine | Anti-inflammatory | In vitro. At 30 and 60 mg/kg, inhibits the inflammatory response to lipopolysaccharides (LPS) in RAW 264.7 cells and in an acute lung injury (ALI) model. It significantly suppresses the overproduction of pro-inflammatory cytokines and neutrophil migration and reduces the histopathological changes and lung edema induced by LPS. | [29] |
| Phenolic Acids | Quinic acid | Anti-inflammatory | In vitro. At 0.10 μg/mL, inhibits vascular cell adhesion molecule-1 (VCAM-1) expression via the suppression of mitogen-activated Protein (MAP) kinase and NF-κb signaling pathways in TNF-α-stimulated vascular smooth muscle cells (VSMCs). | [30] |
| | | Antiviral | In vitro. Inhibits HBV (Hepatitis B Virus) DNA replication and Hepatitis B surface antigen (HBsAg) production in HepG2.2.15 cells infected with duck Hepatitis B virus. | [31] |
| Triterpenoids | Karavilagenin C | Anti-malarial | In vitro. Anti-malarial activity against the chloroquine-sensitive (3D7) ($IC_{50}$ 10.40 μM) and the chloroquine-resistant (Dd2) ($IC_{50}$ 11.20 μM) strains of Plasmodium *falciparum*. | [21] |
| | | Antibacterial | In vitro. At 3 μM inhibition, the activity of bacterial efflux pumps of methicillin-resistant *Staphylococcus aureus* (MRSA) $COL_{oxa}$ by increasing the intracellular accumulation of ethidium bromide. | [32] |

**Table 1.** *Cont.*

| Class of Compounds | Compounds | Biological Activity | Essay/Conclusion | References |
|---|---|---|---|---|
| Triterpenoids | Karavilagenin C | P-glycoprotein modulation activity | In vivo. Inhibition of P-glycoprotein in a mouse lymphoma cell transfected with the human ABCB1 gene. Fluorescence activity ratio (FAR) 42.10 at 2 μM. | [18] |
| | Balsaminagenin B | Antibacterial | In vitro. Inhibition of the activity of bacterial efflux pumps of *Enterococcus faecalis* by increasing the intracellular accumulation of ethidium bromide at 30 μM. | [18] |
| | Cucurbalsamin one B | P-glycoprotein modulation activity | In vivo. Inhibition of P-glycoprotein in a mouse lymphoma cell transfected with the human ABCB1 gene. Fluorescence activity ratio (FAR) 76.90 at 2 μM. | [18] |
| | Balsaminoside A | Anti-malarial | In vitro. Inhibition of *P. falciparum* 3D7 ($IC_{50}$ 4.60 μM) and Dd2 ($IC_{50}$ 4.00 μM stem cell growth. | [20] |
| | karavilagenin E | Anti-malarial | In vitro. Inhibition of *P. falciparum* 3D7 ($IC_{50}$ 4.70 μM) and Dd2 ($IC_{50}$ 8.20 μM) stem cell growth. | [20] |
| | Balsaminol groups, Balsaminoside and Balsamina-genine groups, Karavilagenin groups, Cucurbalsaminol groups | Anti-diabetic, Anti-malarial, Antiviral, Anticancer, antibacterial, P-glycoprotein (P-gp) inhibitors, and others. | | [18,20,21] |

## 4. Nutritional Value of *Momordica balsamina*

*M. balsamina* stands as a plant rich in vital nutrients and holds a significant place in African cuisine [33]. The leaves of *M. balsamina* deemed a significant green-leaf vegetable, possess multifaceted nutritional potential. It offers a source of nutrients (Figure 2) that complements major dietary components [9]. Table 2 highlights the nutritional composition, encompassing protein, fiber, fat, and caloric value of *M. balsamina* leaves. Notably, the protein content of this wild vegetable is remarkably high (287.70 ± 1.80 g/kg or 28.77%), surpassing that of numerous other vegetables [9]. This elevated protein content positions it as a promising protein supplement or meat substitute, especially for resource-scarce rural communities [9]. In line with recommended daily protein allowances, a mere 3 g of *M. balsamina* leaves could significantly contribute to daily protein requirements.

With its relatively low crude fiber content (37.20 ± 7.90 g/kg), *M. balsamina* leaves contribute substantially to dietary fiber intake, an essential component in human nutrition [9]. Characteristic of most green leafy vegetables, *M. balsamina* boasts a modest caloric value (1892.20 kcal/kg), making it a favorable dietary addition for those aiming to manage caloric intake [34].

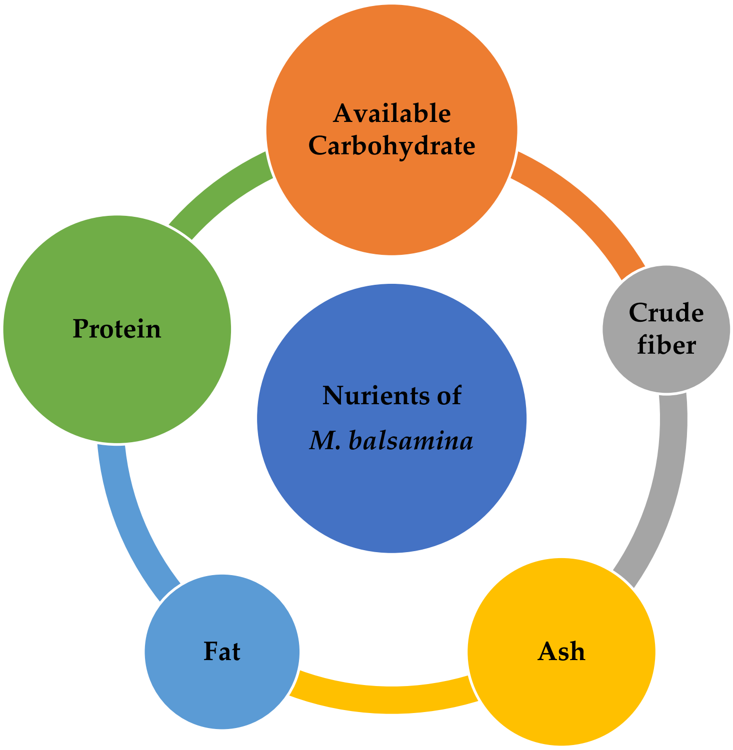



**Figure 2.** Nutrients of *M. balsamina* leaves.

Its impressively high ash content (127.00 ± 17.00 g/100 g) establishes *M. balsamina* as a dependable source of essential minerals (Table 3) [9]. Notably, potassium and calcium dominate the mineral composition (27.05 and 22.20 g/kg, respectively). Even a modest consumption of 4 g for children and 6 g for adults of *M. balsamina* can fulfill a part of daily calcium needs, along with potassium requirements ranging from 1.50 g to 17.00 g [9]. These results are not in agreement with studies by Karumi et al. (2004) [35] who report higher concentrations of Fe, Zn, and Mn at 28.00 ± 0.52 g/kg, 15.91 ± 0.13 g/kg, and 30.27 ± 0.32 g/kg, respectively (n = 5). In contrast, copper, potassium, and calcium show lower levels at 6.85 ± 0.22 g/kg, 0.98 ± 0.11 g/kg, and 2.45 ± 0.44 g/kg, respectively. The elevated potassium content suggests its potential as a dietary addition to mitigate hypertension, stroke, cardiac disorders, kidney damage, and osteoporosis, particularly in conjunction with low-sodium diets [9]. In contrast, the levels of sodium, magnesium, zinc, and iron remain relatively low, underscoring the need for alternative sources of these minerals. A high potassium content is a valuable source for managing hypertension and other cardiovascular conditions [2].

While *M. balsamina* leaves are found to be low in vegetable lipids, aligning with the characteristic low-fat nature of leafy greens, the results substantiate its role in promoting health and preventing obesity [34].

Nutritional data on *M. balsamina* fruits reveal that they are among the most diverse and promising vegetable crops. They contain a range of essential minerals, with potassium (43.67 mg/100 g) and phosphorus (9.67 mg/100 g) being the most significant. Additionally, these fruits contain calcium (2.02 mg/100 g), sodium (0.53 mg/100 g), iron (1.24 mg/g), and zinc (0.38 mg/100 g). Consequently, incorporating *M. balsamina* fruits into the human diet is an intriguing possibility [36].

Table 4 delves into the amino acid composition of *M. balsamina* leaves, revealing a preponderance of non-essential amino acids, primarily glutamic acid and aspartic acid, comprising 12.38 and 8.21 mg/100 g of protein, respectively [34]. However, it is noteworthy that while these proteins, including balsamin, are rich in certain amino acids, their profile lacks balanced proportions of the eight essential amino acids, including isoleucine, leucine, lysine, methionine, phenylalanine, threonine, valine, and histidine.

In the final analysis, nutritional data reveal that *M. balsamina* offers a wealth of nutrients, making it an essential dietary component with the potential to enhance dietary diversity, support health management, and provide nutrient supplementation for diverse populations. However, it is important to note that its amino acid profile does not achieve an optimal balance of the eight essential amino acids. The nutritional composition of the *M. balsamina* may be variable, probably dependent on farming. This highlights the importance of incorporating this plant into a diet that includes other food sources to achieve a well-balanced nutritional intake.

**Table 2.** Nutritional composition of *M. balsamina* leaves.

| **Nutrients** | **Composition (g/kg) [9,34]** | **Recommended Daily Intake [37]** |
|---|---|---|
| Protein | 287.70 ± 1.80 | 1.05–0.85 g/kg body weight/day (Child)<br>0.80 g/kg body weight/day (Adult) |
| Fat | 53.70 ± 8.60 | |
| Crude fiber | 37.20 ± 7.90 | |
| Ash | 127.00 ± 17.00 | |
| Moisture | 710.00 ± 0.90 | |
| Available Carbohydrate | 390.50 ± 2.00 | |
| Calorific Value (Kcal/kg) | 1892.20 | |

Age range: children (1 to 18); adults (19 to 70); mean ± standard deviation of three replicates.

**Table 3.** Mineral composition of *M. balsamina* leaves and fruits.

| **Minerals** | **Leaves (g/kg) [9]** | **Fruits (mg/100 g) [36]** | **Recommended Daily Intake [37]** |
|---|---|---|---|
| Calcium | 22.20 ± 0.50 | 2.02 | 210–800 mg/day (Child); 1000–1300 mg/day (Adult) |
| Magnesium | 3.82 ± 0.06 | - | 80–410 mg/day (Child); 310–420 mg/day (Adult) |
| Phosphorus | 3.24 ± 0.01 | 9.67 | 460–1250 mg/day (Child); 700 mg/day (Adult) |
| Potassium | 27.05 ± 0.27 | 43.67 | 0.4–4.5 g/day (Child); 4.7 g/day (Adult) |
| Sodium | 0.06 ± 0.02 | 0.53 | 1.5–2.3 g/day (Child); 2.3 g/day (Adult) |
| Iron | 0.14 ± 0.01 | 1.24 | 7–15 mg/day (Child); 8–18 mg/day (Adult) |
| Manganese | 0.15 ± 0.00 | - | 0.6–2.2 mg/day (Child); 1.8–2.3 mg/day (Adult) |
| Zinc | 0.39 ± 0.01 | 0.38 | 3–8 mg/day (Child); 8–11 mg/day (Adult) |

Age range: children (1 to 18); adults (19 to 70); mean ± standard deviation of three replicates.

**Table 4.** Amino acid composition of *M. balsamina* leaves.

| **Amino Acid** | **Concentration (g/100 g Protein) [34]** | **Recommended Daily Intake in mg/day Body Weight for +12 Years [38]** |
|---|---|---|
| | Essential amino acids | |
| Isoleucine | 2.94 | 10 |
| Leucine | 8.38 | 14 |
| Lysine | 3.94 | 12 |
| Methionine | 0.90 | |
| Phenylalanine | 3.94 | |
| Threonine | 3.13 | 7 |
| Valine | 4.11 | 10 |
| Histidine | 2.50 | 8–12 |

**Table 4.** *Cont.*

| Amino Acid | Concentration (g/100 g Protein) [34] | Recommended Daily Intake in mg/day Body Weight for +12 Years [38] |
|---|---|---|
| | Non-essential Amino Acids | |
| Cysteine | 0.56 | |
| Total Sulfur | 1.46 | |
| Tyrosine | 2.62 | |
| Total aromatic | 6.46 | |
| Alanine | 4.16 | |
| Arginine | 4.87 | |
| Aspartic acid | 8.21 | |
| Glutamic acid | 12.38 | |
| Glycine | 4.66 | |
| Proline | 3.21 | |
| Serine | 4.00 | |

## 5. Biological Properties of *Momordica balsamina*

*M. balsamina* leaves have been employed as a vegetable, consumed as a decoction, or incorporated into various recipes in conjunction with other plants [39]. The leaves, fruits, seeds, and bark of this plant offer substantial medicinal benefits, including anti-HIV, anti-plasmodial, anti-diarrheal, antiseptic, antibacterial, antiviral, anti-inflammatory, antimicrobial, hypoglycemic, antioxidant, analgesic, hepato-protective properties, and so many others (Figure 3) [3,40,41].

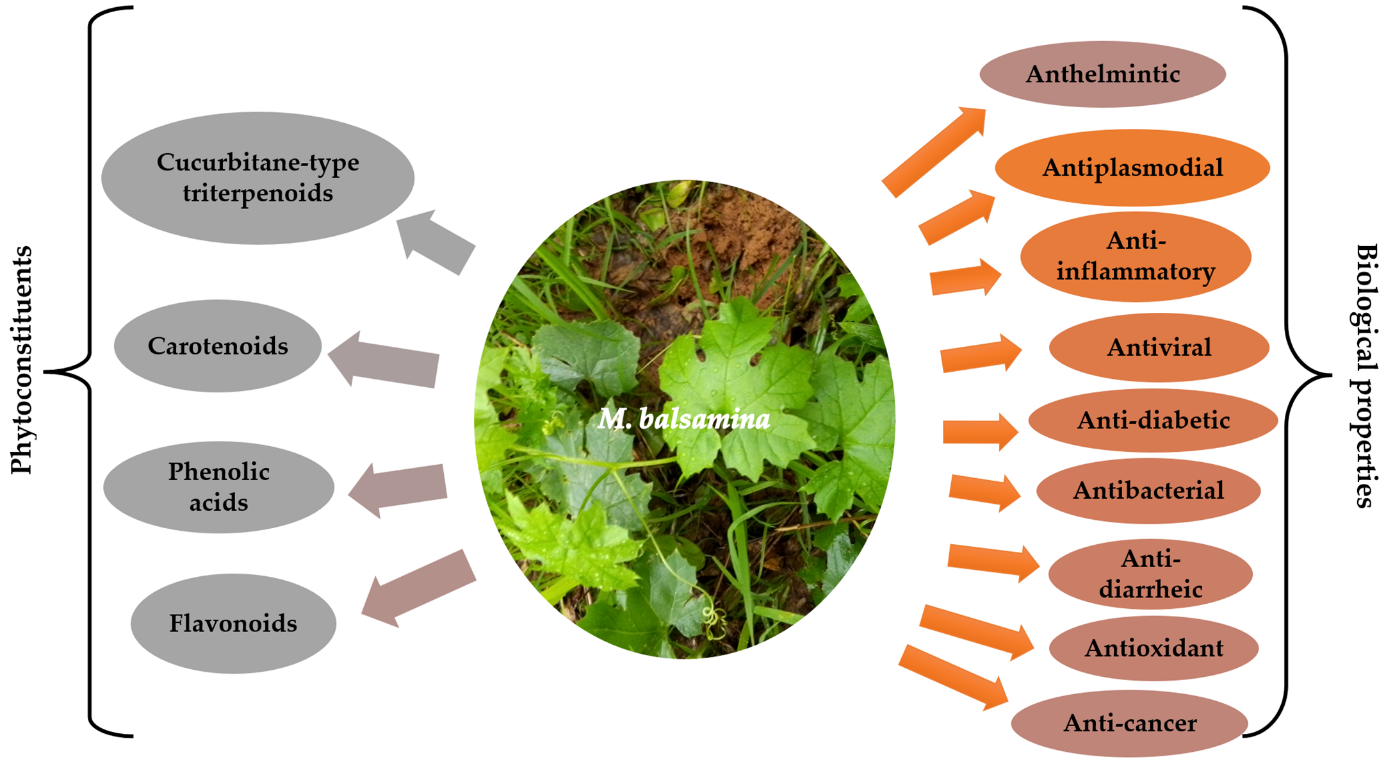



**Figure 3.** Biological properties and phytoconstituents of *Momordica balsamina*.

Indeed, the methanolic extract of the *M. balsamina* aerial part exhibits antiplasmodial activities that are highly promising with very low toxicity. This extract showed in vitro activity on three strains of *Plasmodium falciparum* (*P. falciparum*) (F32-Tanzania, FcB1-Colombia, and FcM29-Cameroon) and in vivo activity on mice infected with *Plasmodium vinckei*, which were treated either intraperitoneally or orally in a 4-day suppression test. This could potentially explain its widespread use in traditional malaria treatment in Niger [42]. In a study by Ramalhete et al. (2010) [20], the anti-malarial activity of new triterpenoids isolated from *M. balsamina* was demonstrated. These triterpenes and, notably, certain derivatives of karavilagenin exhibited substantial in vitro activity against *P. falciparum* strains 3D7 and Dd2, with low cytotoxicity. Furthermore, Clarkson et al. (2004) [43] demonstrated the in vitro activity of the aqueous extract of leaves and stems of *M. balsamina* against *P. falciparum D10*.

The antibacterial activity of *M. balsamina* was studied in vitro by Abdulhamid et al. (2023) [44], using methanol leaf extracts against *Staphylococcus aureus* and *Escherichia coli* over a 24 h period. They reported that methanol extracts from *M. balsamina* exhibited sensitivity (measured by the zone of inhibition) against the tested bacteria, suggesting that *M. balsamina* leaves could serve as a natural antibacterial alternative for infections caused by these bacteria. This discovery aligns with previous research by Otimenyin et al. (2008) [45] and Jigam et al. (2004) [46], who also demonstrated in vitro antibacterial activity against various bacteria, including *Pseudomonas aeruginosa*, *Salmonella typhi*, *Bacillus subtilis*, *Proteus mirabilis*, and *Klebsiella pneumoniae*, using extracts from *M. balsamina*. Additionally, a protein isolated from *M. balsamina* known as balsamin has shown in vitro antibacterial properties against bacteria such as *Staphylococcus aureus*, *Salmonella enterica*, *Staphylococcus epidermidis*, and *Escherichia coli*, suggesting its potential as a nutraceutical [24]. The ethyl acetate extract of the aerial parts of the *M. balsamina* plant also exhibited remarkable antibacterial activity in vitro against the *E. faecalis* strain [47]. Thus, crude extracts of *M. balsamina* possess significant potential as antimicrobial agents, potentially explaining their traditional use in treating diabetic wounds [45]. *M. balsamina* leaves could serve as a natural antibacterial alternative for infections caused by these bacteria and can be utilized in the treatment of infectious diseases.

The *M. balsamina* plant exhibits remarkable anti-HIV potential. In fact, the plant protein MoMo30 (30 kDa protein), isolated from *M. balsamina*, effectively inhibits HIV-1 in vitro at nanomolar levels while exhibiting minimal cellular toxicity at inhibitory concentrations [48]. This finding is in line with the work of Coleman et al. (2022) [49]. They found that the aqueous extract of *M. balsamina* leaves inhibits HeLa-CD4+-LTR-βgal cells with HIV-$1_{NL4-3}$ by more than 50% at concentrations of 0.02 mg/mL and above, with no toxicity in the 0–0.5 mg/mL range [49]. Other antiviral properties of the plant have been demonstrated. For instance, in vitro tests against the growth of Newcastle disease virus on a cell line of chicken embryo fibroblast (CEF) using aqueous extracts of fruit pulp and leaves have shown promising potential in the management of Newcastle disease [50]. Ampitan et al. (2023) [51] demonstrated the in vivo efficacy of *M. balsamina* extract against avian paramyxovirus-1 infection in broilers. These results indicate that the plant can prevent the virus from attaching to host cells, thus confirming its antiviral potential against this virus [50].

Khumalo et al. (2023) [52] conducted a study demonstrating that oral administration of methanolic leaf extracts of *M. balsamina* to pre-diabetic rats, induced by an experimental high-fat, high-carbohydrate diet, attenuated diabetes-associated renal function abnormalities. This treatment reduced damage and restored renal function. Similar research by Siboto et al. (2018) [53], using diabetic rats induced by streptozotocin (STZ), suggests that *M. balsamina* may have beneficial effects on processes associated with renal disorders in STZ-induced diabetic rats [52,53]. The in vivo study conducted by Sani et al. (2019) [54] on diabetic rats, induced by an injection of alloxan monohydrate, further confirms this property of the plant. Kgopa et al. (2020) [55] revealed that relatively non-polar extracts from *M. balsamina* fruits, such as hexane and ethyl acetate extracts, can increase glucose uptake by RIN-m5F β-cells In vitro. They argued that *M. balsamina* fruit extracts may exert their anti-diabetic effects not only via increased insulin sensitivity and inhibition of intestinal glucose absorption but also via the stimulation of insulin synthesis and secretion [55].

The results of research by A.T. Samaila's [56] revealed that *M. balsamina* leaf and root extracts have the potential to generate drugs and compounds with antifungal properties, effectively targeting pathogenic fungi.

Mabasa et al. (2012) [16] demonstrated in vitro anti-inflammatory activity in *M. balsamina* leaves on RAW 264.7 cell lines. They confirmed that *M. balsamina* leaves contain nontoxic secondary metabolites that may play a pivotal role in human health as anti-inflammatory agents [16]. Ndhlala et al. (2011) [57] showed the in vitro anti-inflammatory capacity of the aqueous extract of *M. balsamina* via the inhibition of cyclo-oxygenase 1 and cyclo-oxygenase 2.

Biological studies have indicated that *M. balsamina* possesses anticancer properties. In fact, a significant number of triterpenoids tested in vitro by Silva (2017) [58] demonstrated robust P-glycoprotein (P-gp) modulation activity with a Fluorescence Activity Report (FAR) > 10 and synergistic interactions with the antitumor drug doxorubicin. These findings support their potential as multidrug resistance (MDR) reversers.

This plant possesses significant antioxidant potential. The in vitro antiradical capacity, as demonstrated by Odhav et al. (2007) [59] on methanol extracts of its leaves, exhibits strong inhibition of free radicals.

Studies in vitro conducted by Okpara et al. (2017) [60] on the methanolic extract of *M. balsamina* fruit also demonstrated its potential effectiveness in managing diarrhea. The methanolic extract, when administered at moderate doses (400 mg/kg and 800 mg/kg), significantly reduced the gastrointestinal transit of activated charcoal in mice. Furthermore, oral administration of the extract (at doses of 200 mg/kg, 400 mg/kg, and 800 mg/kg) provided dose-dependent protection to Wistar rats against castor oil-induced diarrhea (2 mL/rat) and significantly reduced castor oil-induced enteropooling in Wistar rats.

The aqueous leaf extract of *M. balsamina* demonstrated a promising effect on acetic acid-induced twisting/stretching in Wistar rats in a dose-dependent manner. This extract was found to have significant antinociceptive (analgesic) effects, with a reduction of up to 71.3% observed at a dose of 400 mg/kg body weight [61].

*M. balsamina* is a plant with significant anti-malarial potential. Triterpenoids, isolated from *M. balsamina*, possess a broad range of potent biological activities, including hepatoprotective, anti-malarial, anti-inflammatory, cardiovascular, anti-diabetic, and antiparasitic effects [20].

Continued investigations and exploration of the bioactive compounds within *M. balsamina* hold immense potential for the development of novel drugs and therapeutic approaches across various medical disciplines. The identification and isolation of its bioactive compounds have opened new avenues for drug development and therapeutic interventions spanning diverse medical fields. The wide-ranging pharmacological properties of *M. balsamina*, substantiated by scientific research, not only underscore its significance in traditional medicine but also illuminate its potential in modern pharmaceutical research. This plant's diverse bioactive compounds have demonstrated their ability to address various health conditions, making it a valuable resource for both traditional and modern medicine. However, it should be noted that some biological studies have limitations either due to the high concentrations required to produce a biological effect or the low content of specific active ingredients in the plant. This is the case with balsamin, a bioactive protein found in the seeds of the plant but in low concentrations.

## 6. Traditional Uses of *Momordica balsamina*

*M. balsamina* is an intriguing plant renowned for its potent medicinal properties. It finds application in treating a variety of conditions, such as hypertension, digestive disorders, malaria, diabetes, and measles prevention [4].

Furthermore, *M. balsamina* is recommended for addressing dermatological ailments like pimples, skin spots, and edema. It serves as a remedy for wounds, eczema, allergies, and skin infections while also functioning as a skin moisturizer. Its effectiveness in addressing dermatological issues may be associated with its scientifically proven anti-inflammatory and antibacterial properties.

The plant assumes the role of an anthelmintic when employing its fruits, seeds, and leaves. Leaves are used to combat fever and excessive uterine bleeding, while the whole plant is utilized to manage syphilis, rheumatism, hepatitis, and diverse skin conditions. It has applications as an abortifacient, aphrodisiac, galactogen, and diabetic treatment [4,62]. *M. balsamina* is used for its anti-diabetic properties. Indeed, diabetic patients consume leaf decoctions orally to regulate blood sugar levels. The plant is employed in various forms, such as infusions, poultices, and herbal teas, to address issues like liver problems, stomach cramps, and ulcers [4].

The utilization of *M. balsamina* in traditional medicine is both diverse and extensive, spanning various countries and cultures. This plant has found its way into the pharmacopeias of different regions, where its different parts are harnessed to address a multitude of health concerns. Below is an overview of its traditional medicinal applications (refer to Figure 4).

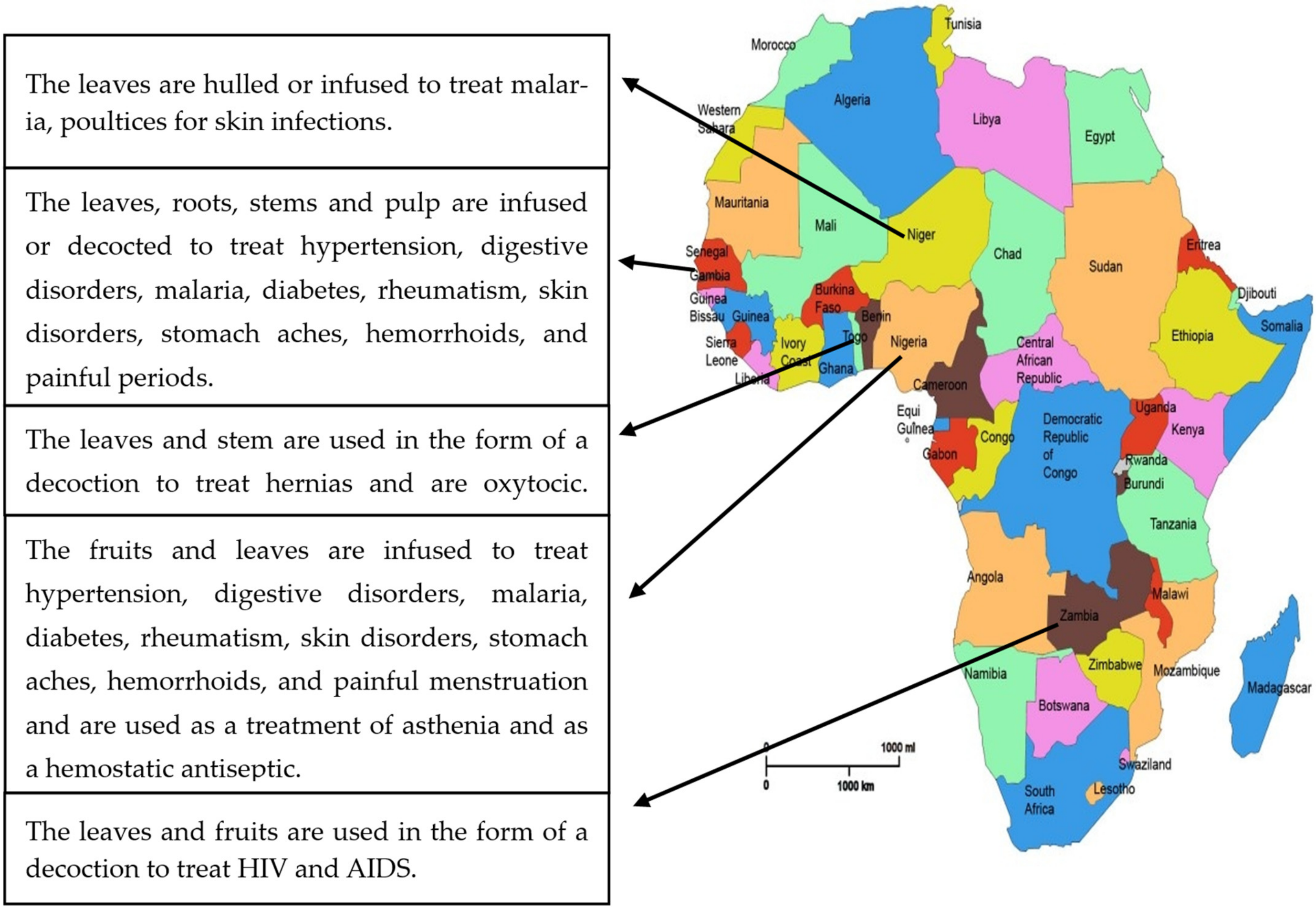



**Figure 4.** The utilization of *M. balsamina* in traditional medicine in Africa [2,3,42,63]. Data presented in the figure refer to traditional uses of the plants based on ethnobotanical studies.

In Senegal, it is employed for its anti-inflammatory, anthelminthic, and antibacterial properties for treating dermatosis, stomachaches, rheumatism, hemorrhoids, painful menstruation, and other ailments. An aqueous extract of its leaves alleviates menstrual discomfort in young girls. It also finds anti-malarial and anti-diabetic properties, often in the forms of decoction or infusion. The Wolof people (Senegal) utilize the fruits for purgative and deworming purposes [2,3]. This use highlights its anthelmintic properties.

In Nigeria, *M. balsamina* addresses asthenia and digestive issues, while the Fulani people use it as a deworming agent and tranquilizer [63]. It is even integrated into prescriptions for mental health concerns. Additionally, the maceration of the entire plant acts as a galactagogue and is employed for chest massages to alleviate intercostal pain [3].

In Togo, a decoction of *M. balsamina*'s aerial parts, along with honey and *Zanthoxyloides fagara* root bark, functions as an oxytocic agent. Togolese people frequently utilize the leaves and stems. Oral administration of calcined aerial parts powder is employed to treat hernias [63].

In different regions, the plant's fruits and leaves are used as hemostatic antiseptics for wound treatment. In Zambia, the use of *M. balsamina* is associated with its antiviral potential. Indeed, a decoction of the entire plant is used to treat conditions like syphilis, human immunodeficiency virus (HIV), and acquired immunodeficiency syndrome (AIDS) [3].

In Niger, crushed *M. balsamina* leaves are used as poultices for skin infections. Pounded leaves are recommended for hemorrhoids, diabetes, and fever. In combination with *Combretum micranthum*, it is utilized to treat malaria. Some women mix it with henna for abortion [63].

The Hausa people (Mali) use the whole plant for embalming, drinking, and bathing to ward off malevolent spirits [63].

In Syria, an infusion of fruit or leaf powder is used as an antiseptic and for treating asthenia and hemostasis [3].

In Indonesia, bitter melon is not only known as a vegetable but also traditionally used as a laxative, a fever remedy, and an appetite stimulant. Additionally, bitter melon leaves are used to alleviate menstrual discomfort, heal burns, treat skin diseases, and act as a vermifuge [64].

The traditional medicinal applications of *M. balsamina* are both diverse and extensive, reflecting its adaptability and effectiveness in addressing a multitude of health concerns. These uses have been passed down through generations and are integrated into the traditional healing practices of various countries and cultures. *M. balsamina* has found a place in the pharmacopeias of different regions, where its different parts are harnessed to improve the well-being of individuals and communities. Its role as a natural remedy for a wide range of ailments highlights its importance in traditional medicine.

In the realm of traditional medicine, *M. balsamina* has long held a revered position for its therapeutic effects on a multitude of ailments. Scientific studies have now provided empirical evidence to validate these traditional uses, further emphasizing their importance in preserving and promoting traditional healing practices. Moreover, in the context of modern pharmaceutical research, *M. balsamina* emerges as a promising candidate. Its potential as an anti-diabetic agent, as well as its antimicrobial, anticancer, HIV-inhibiting, anti-inflammatory, anti-malarial properties, and many others, showcase the plant's phytoconstituents offering a wealth of opportunities for drug discovery and innovation. This interdisciplinary approach, bridging the wisdom of traditional medicine with the rigor of scientific research, paves the way for the advancement of healthcare and the enhancement of global well-being. It is essential to recognize that many traditional uses of *M. balsamina* rely on its biological or pharmacological properties. Nevertheless, it should be noted that the effectiveness of *M. balsamina* for certain health issues in traditional uses still requires further investigation regarding its biological or pharmacological properties.

## 7. Cosmetic Use of *Momordica balsamina*

In the realm of cosmetics, *M. balsamina* finds extensive application in addressing dermatological concerns. Notably, the juice extracted from the leaves of *M. balsamina* has been employed as a natural soap [62]. This unique formulation, often referred to as "pimples natural soap," harnesses the properties of *M. balsamina* to combat pimples, skin spots, and edema. When mixed with water, it produces a mildly soapy solution. The plant's soothing attributes extend to the treatment of wounds, eczema, pimples, allergies, and skin infections. Additionally, *M. balsamina* serves as a highly effective skin moisturizer [10,62].

The utilization of *M. balsamina* for dermatological issues can indeed be linked to its demonstrated anti-inflammatory [16] and antibacterial [44–46] properties, as supported by biological studies. These properties make the plant a valuable natural remedy for skin-related problems. Incorporating *M. balsamina* into dermatological treatments or skincare routines holds promise as a natural and holistic approach to addressing skin issues.

The use of *M. balsamina* in natural soap formulations reflects its role in promoting skin health and well-being. However, there have been limited studies conducted on its cosmetic applications. Therefore, it would be intriguing to conduct further research into the cosmetic uses of *M. balsamina*. Indeed, the cosmetic potential of *M. balsamina* is an intriguing area that warrants further exploration via research. While some traditional uses of *M. balsamina* in skincare and cosmetics have been documented, there is still much to discover about its specific cosmetic applications and the potential benefits it can offer in modern skincare and beauty products.

## 8. Other Uses of *Momordica balsamina*

The versatility of the *M. balsamina* plant transcends beyond therapy and encompasses various other domains. The whole plant extract demonstrates insecticidal properties, making it a valuable tool in pest control. The seeds of the plant are often utilized as arrow poison. The plant contributes to mitigating micronutrient deficiencies within the soil, aiding in soil health and fertility enhancement [3]. Extracts from the leaves of *M. balsamina* serve as effective metal cleaners [62]. Additionally, the ethanolic extract of *M. balsamina* leaves has been studied for its potential to safeguard copper from corrosion within acidic environments [19]. In the Hausa regions of Nigeria and the Niger Republic, the leaves are incorporated into green vegetable soups consumed by nursing mothers. It is believed that these soups aid in post-labor blood regeneration and the purification of breast milk [34]. Among farmers, the plant is harnessed to augment milk production in cows [63]. The multifaceted applications of *M. balsamina* highlight its valuable contributions across diverse sectors, ranging from cosmetics and therapy to agriculture and beyond.

Its anthelmintic properties enable it to combat gastrointestinal disorders (diarrhea) in animals [65]. Breeders in Benin use *M. balsamina* leaves and stems in combination with potash in the form of maceration to combat diarrhea in animals [66].

The multifaceted applications of *M. balsamina* highlight its valuable contributions across diverse sectors beyond traditional medicine. They underscore the importance of understanding and preserving traditional knowledge of the plant's uses in various communities.

## 9. Adverse Effects of *Momordica balsamina*

Toxicity and cytotoxicity studies were conducted on crude extracts of *M. balsamina*. Oral administration of the methanolic extract of *M. balsamina* to albino mice for one week revealed that doses of 30 and 40 mg/kg do not induce any toxicity. However, when the dosage ranges from 50 mg/kg to 150 mg/kg, instances of mouse fatalities are observed due to the toxicity of the methanolic extract, with an average death rate of 20% in most cases. An intoxication syndrome becomes evident in mice starting from 50 mg/kg, followed by occasional cases of death, with the highest average death rate reaching 40% [63]. In contrast, the larval cytotoxicity test conducted by Dehou et al. [16] using the *Artemia salina* model indicates that the hydro-ethanoic and dichlomethanic extracts do not exhibit toxicity, with $LC_{50}$ values of 2.25 mg/mL and 5.20 g/mL, respectively.

Mabasa et al. (2021) [16] have demonstrated that *M. balsamina* leaves have no cytotoxic activity against human colorectal adenocarcinoma cell lines HT29 and Caco2.

These findings suggest that while certain extracts of *M. balsamina* may exhibit toxicity at high doses, others, such as the hydro-ethanoic and dichlomethanic extracts, appear to be safer. The specific components and concentrations of the extracts play a crucial role in determining their toxicity levels. The toxicity and cytotoxicity studies on crude extracts of

*M. balsamina* provide important insights into the safety and potential risks associated with the use of these extracts.

Furthermore, some compounds isolated from *M. balsamina*, including balsaminaepoxide, balsaminatriol, balsaminal, balsaminol G, karavilagenin A, karavilagenin B, karavilagenin C, and kuguacin B, have demonstrated interactions with the anti-cancer drug doxorubicin, as reported by Ramalhete et al., (2016) [67]. In fact, the interaction of these non-cytotoxic compounds with doxorubicin was assessed in vitro in a combination chemotherapy model using ABCB1-transfected mouse T lymphoma cells (L5178Y-MDR). These compounds displayed a synergistic interaction with the anti-cancer drug doxorubicin [58,67].

These findings highlight the complexity of *M. balsamina*'s effects on different models and cell lines. While some extracts and compounds may exhibit toxicity at high doses, others appear to be safe. The specific components and concentrations of the extracts play a significant role in determining their toxicity levels. Additionally, the interactions with anti-cancer drugs suggest potential applications in combination chemotherapy. These studies emphasize the importance of careful dosage and safety assessments when using *M. balsamina* for various purposes.

## 10. Conclusions and Future Directions

In summary, this review underscores the extensive utilization of *M. balsamina* within traditional African medicine. The breadth of its traditional applications finds validation in its diverse array of biological properties and intricate chemical compositions. Consequently, we advocate for the incorporation of *M. balsamina* in phytotherapeutic practices. It is imperative, however, to acknowledge the potential toxicity associated with many plants employed in traditional medicine, and therefore, meticulous attention must be dedicated to ensuring proper usage, adherence to prescribed doses, and mitigation of potential toxic effects. Simultaneously, it becomes essential to safeguard a sustainable and ample reservoir of active compounds, thereby averting the depletion of vital natural resources. In this context, comprehensive investigations into the innovative methodologies and strategies for the synthesis or biosynthesis of these naturally occurring bioactive constituents. However, it is important to acknowledge that the development of new drugs, whether derived from natural sources like *M. balsamina* or synthetic compounds, is a complex and lengthy process. The transition from laboratory and preclinical studies to clinical trials is a critical step in drug development. Clinical studies are necessary to evaluate the safety and efficacy of *M. balsamina*-based treatments in humans. Considering that most biological tests are conducted on crude extracts of *M. balsamina* or even on isolated compounds in experimental studies, it is now crucial to progress toward clinical studies for the development of new drugs.

Overall, *M. balsamina*'s nutritional richness suggests a pivotal role in enhancing dietary diversity, managing health, and supplementing nutrients across populations. *M. balsamina*, rich in vital micronutrients and macronutrients, holds significance in African cuisine as a versatile plant. Its leaves, a valuable green vegetable, offer high protein content, making it a potential protein supplement, particularly for resource-scarce communities. With considerable dietary fiber and modest caloric value, it aids nutritional intake and suits calorie management.

Furthermore, given its prevalent application in addressing dermatological concerns, particularly in Senegal, there exists a compelling rationale to embark on comprehensive studies exploring its potential within the cosmetic sphere. As the intricate interplay between tradition, science, and sustainability unfolds, embracing the multifaceted potentials of *M. balsamina* beckons us toward a realm of holistic health and well-being.

**Author Contributions:** Conceptualization, M.T., I.S. and M.-L.F.; Methodology, M.T.; Investigation, I.S. and M.-L.F.; Writing and original draft preparation, M.T.; Writing, Review and Editing, I.S., M.-L.F., M.L.G. and M.G.; Project Administration, I.S. and M.-L.F. All authors have read and agreed to the published version of the manuscript.

**Funding:** Marème Thiaw thanks the Academy of Research and Higher Education (ARES) for the B-MOB mobility grant as part of the 2022–2027 five-year development cooperation program 2022-MAA-522; and the University of Liege for the impulse grant.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** We would like to thank the Center for Partnership and Development Cooperation (PACODEL), the Academy of Research and Higher Education (ARES), and the University of Liege (ULiege).

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Rikisahedew, J.J.; Naidoo, Y. Phyto-histochemical evaluation and characterization of the foliar structures of *Tagetes minuta* L. (Asteraceae). *S. Afr. J. Bot.* **2018**, *115*, 328–329. [CrossRef]
2. Balde, S.; Ayessou, N.C.; Gueye, M.; Ndiaye, B.; Sow, A.; Cissé, O.I.K.; Cissé, M.; Diop, C.G. Ethnobotanical investigations of *Momordica charantia* Linn (Cucurbitaceae) in Senegal. *Int. J. Biol. Chem. Sci.* **2019**, *13*, 466–474. [CrossRef]
3. Thakur, G.; Bag, M.; Sanodiya, B.S.; Bhadauriya, P.; Debnath, M.; Prasad, G.B.; Bisen, P.S. *Momordica balsamina*: A medicinal and neutraceutical plant for health care management. *Curr. Pharm. Biotechnol.* **2009**, *10*, 667–682. [CrossRef]
4. Omokhua-Uyi, A.G.; Staden, J.V. Phytomedicinal relevance of South African Cucurbitaceae species and their safety assessment: A review. *J. Ethnopharmacol.* **2020**, *259*, 112967. [CrossRef]
5. Paris, H.S.; Tadmor, Y.; Schaffer, A.A. Cucurbitaceae, melons, squash, cucumber. In *Encyclopedia of Applied Plant Sciences*, 2nd ed.; Thomas, B., Murray, B.G., Murphy, D.J., Eds.; Academic Press: Oxford, UK, 2017; Volume 3, pp. 209–217. [CrossRef]
6. Bouquet, A. Plantes médicinales de la côte d'ivoire. *Off. De La Rech. Sci. Et Tech. D'outre-Mer (ORSTOM) Paris* **1974**, *165*, 38–39. Available online: https://cir.nii.ac.jp/crid/1571135650006923392 (accessed on 1 September 2023).
7. Ramalhete, C.; Mansoor, T.A.; Mulhovo, S.; Molnár, J.; Ferreira, M.J. Cucurbitane-type triterpenoids from the African plant *Momordica balsamina*. *J. Nat. Prod.* **2009**, *72*, 2009–2013. [CrossRef] [PubMed]
8. Schaefer, H.; Renner, S.S. A three-genome phylogeny of *Momordica* (Cucurbitaceae) suggests seven returns from dioecy to monoecy and recent long-distance dispersal to Asia. *Mol. Phylogenet. Evol.* **2010**, *54*, 553–560. [CrossRef]
9. Flyman, M.V.; Afolayan, A.J. Proximate and mineral composition of the leaves of *Momordica balsamina* L.: An under-utilized wild vegetable in Botswana. *Int. J. Food Sci. Nutr.* **2007**, *58*, 419–423. [CrossRef]
10. Duenas-Lopez, M.A. *Momordica balsamina (Common Balsam Apple)*; Invasive Species Compendium (CABI Compendium): Wallingford, UK, 2019; p. 34677. [CrossRef]
11. Kaur, I.; Yadav, S.K.; Hariprasad, G.; Gupta, R.C.; Srinivasan, A.; Batra, J.K.; Puri, M. Balsamin, a novel ribosome-inactivating protein from the seeds of Balsam apple *Momordica balsamina*. *Amino Acids* **2012**, *43*, 973–981. [CrossRef] [PubMed]
12. Dehou, R.; Dougnon, V.; Atchade, p.; Attakpa, C.; Legba, B.; Baba-Moussa, L.; Gbaguidi, F. Phytochemical and toxicological study of *Cassia italica*, *Momordica balsamina* and *Ocimum gratissimum*, three plants used against scabies in southern Benin. *Rev. Ivoir. Sci. Technol.* **2018**, *32*, 286–297.
13. Yolidjé, I.; Keita, D.A.; Moussa, I.; Toumane, A.; Maarouhi, I.M.; Saley, K.; Jean-Luc, P.; Much, O.J.T. Phytochemical Characterization and Larvicidal Activity of Crude Plant Extracts from the Traditional Pharmacopoeia of Niger on Larvae of *Anopheles gambiae*. *Eur. Sci. J.* **2019**, *15*, 30–51. [CrossRef]
14. Mu'azu, A.; Bello, M. Reproductive performance of rabbit feed with graded of balsam apple (*Momordica balsamina*). *J. Agric. Sci. Technol.* **2022**, *9*, 17–26.
15. Bot, Y.S.; Mgbojikwe, L.O.; Nwosu, C.; Abimiku, A.; Dadik, J.; Damshak, D. Screening of the fruit pulp extract of *Momordica balsamina* for anti-HIV property. *Afr. J. Biotechnol.* **2007**, *6*, 047–052.
16. Mabasa, X.E.; Mathomu, L.M.; Madala, N.E.; Musie, E.M.; Sigidi, M.T. Molecular spectroscopic (FTIR and UV-Vis) and hyphenated chromatographic (UHPLC-qTOF-MS) analysis and in vitro bioactivities of the *Momordica balsamina* leaf extract. *Biochem. Res. Int.* **2021**, *2021*, 2854217. [CrossRef]
17. Mashiane, P.; Shoko, T.; Manhivi, V.; Slabbert, R.; Sultanbawa, Y.; Sivakumar, D. A Comparison of Bioactive Metabolites, Antinutrients, and Bioactivities of African Pumpkin Leaves (*Momordica balsamina* L.) Cooked by Different Culinary Techniques. *Molecules* **2022**, *27*, 1901. [CrossRef]
18. Ramalhete, C.; Gonçalves, B.M.; Barbosa, F.; Duarte, N.; Ferreira, M.J. *Momordica balsamina*: Phytochemistry and pharmacological potential of a gifted species. *Phytochem. Rev.* **2022**, *21*, 617–646. [CrossRef]
19. Maibulangu, B.M.; Ibrahim, M.B.; Akinola, L.K. Inhibitory effect of African Pumpkin (*Momordica balsamina* Linn.) leaf extract on copper corrosion in acidic media. *J. Appl. Sci. Environ. Manag.* **2017**, *21*, 1067–1071. [CrossRef]
20. Ramalhete, C.; Lopes, D.; Mulhovo, S.; Molnár, J.; Rosário, V.E.; Ferreira, M.U. New antimalarials with a triterpenic scaffold from *Momordica balsamina*. *Bioorg. Med. Chem.* **2010**, *18*, 5254–5260. [CrossRef] [PubMed]

21. Ramalhete, C.; Lopes, D.; Molnár, J.; Mulhovo, S.; Rosário, V.E.; Ferreira, M.U. Karavilagenin C derivatives as antimalarials. *Bioorg. Med. Chem.* **2011**, *19*, 330–338. [CrossRef]
22. Ajji, P.K.; Sonkar, S.P.; Walder, K.; Puri, M. Purification, and functional characterization of recombinant balsamin, a ribosome-inactivating protein from *Momordica balsamina*. *Int. J. Biol. Macromol.* **2018**, *114*, 226–234. [CrossRef] [PubMed]
23. Kaur, I.; Puri, M.; Ahmed, Z.; Blanchet, F.P.; Mangeat, B.; Piguet, V. Inhibition of HIV-1 Replication by Balsamin, a Ribosome Inactivating Protein of *Momordica balsamina*. *PLoS ONE* **2013**, *8*, e73780. [CrossRef] [PubMed]
24. Ajji, P.K.; Walder, K.; Puri, M. Functional Analysis of a Type-I Ribosome Inactivating Protein Balsamin from *Momordica balsamina* with Anti-Microbial and DNase Activity. *Plant Foods Hum. Nutr.* **2016**, *71*, 265–271. [CrossRef]
25. Rho, H.S.; Ghimeray, A.K.; Yoo, D.S.; Ahn, S.M.; Kwon, S.S.; Lee, K.H.; Cho, D.H.; Cho, J.Y. Kaempferol and Kaempferol Rhamnosides with Depigmenting and Anti-Inflammatory Properties. *Molecules* **2011**, *16*, 3338–3344. [CrossRef] [PubMed]
26. Zhu, L.; Xue, L. Kaempferol Suppresses Proliferation and Induces Cell Cycle Arrest, Apoptosis, and DNA Damage in Breast Cancer Cells. *Oncol. Res.* **2019**, *27*, 629–634. [CrossRef] [PubMed]
27. Cai, Q.; Rahn, R.O.; Zhang, R. Dietary flavonoids, quercetin, luteolin and genistein, reduce oxidative DNA damage and lipid peroxidation and quench free radicals. *Cancer Lett.* **1997**, *119*, 99–107. [CrossRef]
28. Liu, S.; Tian, L.; Chai, G.; Wen, B.; Wang, B. Targeting heme oxygenase-1 by quercetin ameliorates alcohol-induced acute liver injury via inhibiting NLRP3 inflammasome activation. *Food Funct.* **2018**, *9*, 4184–4193. [CrossRef]
29. Chi, G.; Zhong, W.; Liu, Y.; Lu, G.; Lu, H.; Wang, D.; Sun, F. Isorhamnetin protects mice from lipopolysaccharide-induced acute lung injury via the inhibition of inflammatory responses. *Inflamm. Res.* **2016**, *65*, 33–41. [CrossRef]
30. Jang, S.A.; Park, D.W.; Kwon, J.E.; Song, H.S.; Park, B.; Jeon, H.; Sohn, E.H.; Koo, H.K.; Kang, S.C. Quinic acid inhibits vascular inflammation in TNF-α-stimulated vascular smooth muscle cells. *Biomed. Pharmacother.* **2017**, *96*, 563–571. [CrossRef]
31. Wang, G.F.; Shi, L.P.; Ren, Y.D.; Liu, Q.F.; Liu, H.F.; Zhang, R.J.; Li, Z.; Zhu, F.H.; He, P.L.; Tang, W.; et al. Anti-hepatitis B virus activity of chlorogenic acid, quinic acid and caffeic acid in vivo and in vitro. *Antivir. Res.* **2009**, *83*, 186–190. [CrossRef] [PubMed]
32. Ramalhete, C.; Spengler, G.; Martins, A.; Martins, M.; Viveiros, M.; Mulhovo, S.; Ferreira, M.J.U.; Amaral, L. Inhibition of efflux pumps in meticillin-resistant Staphylococcus aureus and Enterococcus faecalis resistant strains by triterpenoids from *Momordica balsamina*. *Int. J. Antimicrob. Agents* **2011**, *37*, 70–74. [CrossRef]
33. Avato, P.; Argentieri, M.P. Editorial to the special issue: “Phytochemicals in nutrition and health: Advances and challenges”. *Phytochem. Rev.* **2022**, *21*, 313–316. [CrossRef]
34. Hassan, L.G.; Umar, K.J. Nutritional value of Balsam Apple (*Momordica balsamina* L.) leaves. *Pak. J. Nutr.* **2006**, *5*, 522–529. [CrossRef]
35. Karumi, Y.; Onyeyili, P.A.; Ogugbuaja, V.O. Identification of active principles of *M. balsamina* (Balsam Apple) leaf extract. *J. Med. Sci.* **2004**, *4*, 179–182.
36. Chinthan, K.N.; Manjunathagowda, D.C.; Rathod, V.; Devan, S.R.; Anjanappa, M. Southern balsam pear (*Momordica balsamina* L.): Characterization of underutilized cucurbitaceous vegetable. *S. Afr. J. Bot.* **2022**, *145*, 95–98. [CrossRef]
37. Institute of Medicine. *Dietary Reference Intakes: The Essential Guide to Nutrient Requirements*; Meyers, L.D., Hellwig, J.P., Otten, J.J., Eds.; The National Academies Press: Washington, DC, USA, 2006. [CrossRef]
38. WHO-World Health Organization. Energy and Protein Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation [Held in Rome from 5 to 17 October 1981]. Available online: https://apps.who.int/iris/handle/10665/62734 (accessed on 10 August 2023).
39. De Wet, H.; Ramulondi, M.; Ngcobo, Z.N. The use of indigenous medicine for the treatment of hypertension by a rural community in northern Maputaland, South Africa. *S. Afr. J. Bot.* **2016**, *103*, 78–88. [CrossRef]
40. Bhardwaj, N.; Gauttam, V.; Kalia, A.N. Evaluation of antidiabetic activity of *Momordica balsamina* Linn seeds in experimentally-induced diabetes. *J. Chem. Pharm. Res.* **2010**, *2*, 701–707.
41. Souda, S.; George, S.; Mannathoko, N.; Goercke, I.; Chabaesele, K. Antioxidant and Antibacterial Activity of Methanol Extract of *Momordica balsamina*. *IRA-Int. J. Appl. Sci* **2018**, *10*, 7–17. [CrossRef]
42. Benoit-Vical, F.; Grellier, P.; Abdoulaye, A.; Moussa, I.; Ousmane, A.; Berry, A.; Ikhiri, K.; Poupat, C. In vitro and in vivo Antiplasmodial Activity of *Momordica balsamina* Alone or in a Traditional Mixture. *Chimiothérapie* **2006**, *52*, 288–292. [CrossRef]
43. Clarkson, C.; Maharaj, V.J.; Crouch, N.R.; Grace, O.M.; Pillay, P.; Matsabisa, M.G.; Bhagwandin, N.; Smith, P.J.; Folb, P.I. In vitro antiplasmodial activity of medicinal plants native to or naturalised in South Africa. *J. Ethnopharmacol.* **2004**, *92*, 177–191. [CrossRef]
44. Abdulhamid, A.; Jega, S.A.; Sani, I.; Bagudo, A.I.; Abubakar, R. Phytochemical and antibacterial activity of *Momordica balsamina* leaves crude extract and fractions. *Drug Discov.* **2023**, *17*, e11dd1012. [CrossRef]
45. Otimenyin, S.O.; Uguru, M.O.; Ogbonna, A. Antimicrobial and hypoglycemic effects of *Momordica balsamina*. Linn. *J. Nat. Prod.* **2008**, *1*, 3–9. Available online: http://hdl.handle.net/123456789/3130 (accessed on 1 September 2023).
46. Jigam, A.A.; Akanya, H.O.; Adeyemi, D.J. Antimicrobial and antiplasmodial effects of *Momordica balsamina*. *Nig. J. Nat. Prod. Et Med.* **2004**, *8*, 11–12. [CrossRef]
47. Madureira, A.M.; Ramalhete, C.; Mulhovo, S.; Duarte, A.; Ferreira, M.J.U. Antibacterial activity of some African medicinal plants used traditionally against infectious diseases. *Pharm. Biol.* **2012**, *50*, 481–489. [CrossRef]
48. Khan, M.; Diop, A.; Gbodossou, E.; Xiao, P.; Coleman, M.; De Barros, K.; Duong, H.; Bond, V.C.; Floyd, V.; Kondwani, K.; et al. Anti-human immunodeficiency virus-1 activity of MoMo30 protein isolated from the traditional African medicinal plant *Momordica balsamina*. *J. Virol.* **2023**, *20*, 50. [CrossRef]

49. Coleman, M.I.; Khan, M.; Gbodossou, E.; Diop, A.; DeBarros, K.; Duong, H.; Bond, V.C.; Floyd, V.; Kondwani, K.; Montgomery, R.V.; et al. Identification of a Novel Anti-HIV-1 Protein from *Momordica balsamina* Leaf Extract. *Int. J. Environ. Res. Public Health* **2022**, *19*, 15227. [CrossRef]
50. Chollom, S.C.; Olawuyi, A.K.; Danjuma, L.D.; Nanbol, L.D.; Makinde, I.O.; Hashimu, G.A.; Alesa, M.U.; Esilonu, J.T.; Ogundeji, E.B.; Kwatjel, J.S. Antiviral Potential of Aqueous Extracts of Some Parts of *Momordica balsamina* plant against Newcastle Disease Virus. *J. Adv. Pharm. Educ. Res.* **2012**, *3*, 82–92.
51. Ampitan, T.; Garba, M.H.; Adekambi, D.I.; Ampitan, A.; Adelakun, K. Prophylactic potency of methanolic extract of *Momordica balsamina* L. against avian paramyxovirus-1 infection in broiler chickens. *Egypt. J. Anim. Prod.* **2023**, *60*, 25–32. [CrossRef]
52. Khumalo, B.; Siboto, A.; Akinnuga, A.M.; Sibiya, N.; Khathi, A.; Ngubane, P.S. Effects of *Momordica balsamina* on markers associated with renal dysfunction in a diet-induced prediabetic rat model. *Res. Squar.* **2023**, 1–20. [CrossRef]
53. Siboto, A.; Sibiya, N.; Khathi, A.; Ngubane, P. The effects of *Momordica balsamina* methanolic extract on kidney function in STZ-induced diabetic rats: Effects on selected metabolic markers. *J. Diabetes Res.* **2018**, *2018*, 7341242. [CrossRef]
54. Sani, A.A.; Idris, S.B.; Yakubu, S. Anti-Diabetic Activity of Methanolic Extract of *Momordica Balsamina* in Rabbits. *Sci. Res. J.* **2019**, *7*, 1–6. [CrossRef]
55. Kgopa, A.H.; Shai, L.J.; Mogale, M.A. *Momordica balsamina* fruit extracts enhance selected aspects of the insulin synthesis/secretion pathway. *Am. J. Biochem. Biotechnol.* **2020**, *16*, 549–560. [CrossRef]
56. Samaila, A.T. Evaluation of Antifungal Efficacy of *Lawsonia inermis*, *Momordica balsamina* and *Ziziphus mauritiana* against Clinically Isolated Candida Species (*Candida albicans*, *C. krusei*, *C. tropicalis*, and *C. parapsilosis*). In Proceedings of the BOUESTI International Conference on Education, Science and Technology (ICEST), Ikere-Ekiti, Nigeria, 21–24 November 2022.
57. Ndhlala, A.R.; Finnie, J.F.; Van Staden, J. Plant composition, pharmacological properties and mutagenic evaluation of a commercial Zulu herbal mixture: Imbiza ephuzwato. *J. Ethnopharmacol.* **2011**, *133*, 663–674. [CrossRef]
58. Silva, C.D.; Ramalhete, C.; Spengler, G.; Mulhovo, S.; Molnar, J.; Ferreira, M.J.U. Triterpenes from *Momordica balsamina* (African pumpkin): ABCB1 inhibition and synergistic interaction with doxorubicin in resistant cancer cells. *Phytochemistry* **2022**, *203*, 113354. [CrossRef]
59. Odhav, B.; Beekrum, S.; Akula, U.S.; Baijnath, H. Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal, South Africa. *J. Food Compost. Anal.* **2007**, *20*, 430–435. [CrossRef]
60. Okpara, J.O.; Salihu, A.A.; Akanni, K.N.; Ogbu, K.I.; Ochai, C.Z. Antidiarrhoel properties of the methanolic fruit extract of *Momordica balsamina* (Linneaus). *Int. J. Sci. Appl. Res.* **2017**, *2*, 17–26.
61. Karumi, Y.; Onyeyili, P.; Ogugbuaja, V. Anti-inflammatory and Antinociceptive (Analgesic) Properties of *Momordical balsamina* Linn. (Balsam Apple) Leaves in Rats. *Pak. J. Biol. Sci.* **2003**, *6*, 1515–1518. [CrossRef]
62. Bosch, C.H. *Momordica balsamina* L., Ressources Végétales De L'Afrique Tropicale. Available online: https://plantnet.org/en/ (accessed on 12 July 2023).
63. Mamadou, A.O. Étude Phytochimique Et De L'activité Antipaludique In Vivo Et In Vitro De *Momordica balsamina* Linn. (Cucurbitaceae). Ph.D. Thesis, FMPOS Bamako, Bamako, Mali, 2005.
64. Putri, H. Determination of Total Flavonoid Content of Ethanol Extract of Forest Bitter Melon (*Momordica balsamina*) Leaves by Uv-Vis Spectrophotometric Method. Ph.D. Thesis, Universitas Muhammadiyah Mataram, Kota Mataram, Indonesia, 2023.
65. Mensah, É.J.P.A.; Kindomihou, V.; Moussa, H.; Houndonougbo, F.; Vodouhè, D.S.; Aiyelaagbe, I.; Sinsin, B. Organic production potential of traditional small ruminant farming systems: A synthesis. *J. Anim. Plant Sci.* **2022**, *52*, 9404–9451.
66. Noudèkè, N.D.; Dotché, I.; Ahounou, G.S.; Karim, I.Y.A.; Farougou, S. Inventory of medicinal plants used in the treatment of diseases that limit milk production of cow in Benin. *J. Adv. Vet. Anim. Res.* **2017**, *4*, 1–14. [CrossRef]
67. Ramalhete, C.; Mulhovo, S.; Molnar, J.; Ferreira, M.J.U. Triterpenoids from *Momordica balsamina*: Reversal of ABCB1-mediated multidrug resistance. *Bioorg. Med. Chem.* **2016**, *24*, 5061–5067. [CrossRef]


**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.