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RECENT REVIEW ON ETHNOMEDICINAL, PHARMACOLOGICAL AND CHEMICAL ASPECTS OF BANANA (*MUSA PARADISIACA*)

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Abstract: *Musa paradisiaca* Link (Musaceae) is not only extensively utilized in gastronomy worldwide but also holds significant relevance in ethnomedicine. This review aims to compile information regarding the traditional applications, pharmacological activities, and phytochemical constituents of this species. A systematic literature search was conducted using Scopus, ScienceDirect, PubMed Central, and Alicia databases, yielding 70 relevant documents, mainly published between 2015 and 2025. In traditional medicine, the fruit of *M. paradisiaca* is primarily employed for the treatment of diarrhea, whereas other plant organs exhibit diverse therapeutic functions, including wound healing and the management of diabetes and colds. Phytochemical analyses reveal that flavonoids, phenolic acids, fatty acids, calcium, and potassium constitute the principal bioactive compounds in mature fruits, while distinct metabolites are present in other plant parts. Recent *in vitro* and *in vivo* pharmacological studies have demonstrated a broad spectrum of bioactivities for *M. paradisiaca*, with antimicrobial, antioxidant, anti-inflammatory, antidiabetic, and wound-healing properties being the most extensively investigated. Furthermore, soluble fibers, flavonoids, tannins, and saponins have been identified as the primary bioactive compound classes responsible for these effects. In conclusion, recent ethnobotanical, phytochemical, and pharmacological research on *M. paradisiaca* has expanded scientific knowledge regarding its medicinal applications, providing a foundation for its appropriate utilization in various health-related fields, including nutrition, pharmacy, and medicine.

.**Key words:** *banana, medicinal use, phytoconstituents, diarrhea, wound healing*

INTRODUCTION

Musa paradisiaca is commonly known as plantain (plátano), banana, or guineo. Taxonomically, it belongs to the Musaceae family and is distributed across tropical and sub-tropical regions worldwide, particularly in the Americas, Africa, and Asia (Alcalde Quis-

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quiche & Huaman Muñoz, 2022). The parthenocarpic fruit is widely consumed due to its palatable flavor and its high content of essential minerals, including calcium, potassium, and iron (Sojinu et al., 2021). Its nutritional value and affordability make it one of the most widely consumed fruits in developing countries (Kumari, Parmar, Sathish Kumar, Lad & Mahera, 2022). Additionally, various parts of the plant are utilized in traditional medicine due to their bioactive properties, such as antioxidant, anti-inflammatory, and hypoglycemic effects (Rai et al., 2021).

In Asian countries, particularly India, the root is traditionally used to alleviate symptoms associated with venereal and dermatological conditions (Narayan, Purohit, Arun & Arun, 2003). Similarly, in Africa, the fruit is employed as a diuretic, while leaf extracts are applied topically to treat wounds resulting from cuts or insect stings (Yakubu et al., 2015). In the Peruvian Amazon, the leaves are tradetionally used for the treatment of muscle contractures and wound healing (Mejía Carhuanca and Rengifo Salgado, 2000), as well as in the Bolivian Amazon, fruit peel is used for dysentery and mycotic cutaneous infections of the foot, and the inflorescence for diarrhea (Hajdu & Hohmann, 2012).

The various organs of *M. paradisiaca* contain flavornoids, phenolic acids, tannins, phytosterols, vitamins, lipids, calcium, and potassium as their main chemical classes, followed by saponins, alkaloids, and others (Imam & Akter, 2011; Maseko et al., 2022; Sarma et al., 2022; Zulfiqar et al., 2025). This diversity of compounds explains the wide range of ethnobotanical uses and pharmacological activities attributed to the species, as well as its nutriational value and other practical applications. Extensive pharmacological literature on *M. paradisiaca* reports a plethora of biological activities, mainly analgesic, anti-inflammatory, anti-lipidemic, cytotoxic, antidiarrhoeal, antiurolithiatic, antidiabetic, antimicrobial, hepatoprotective, antiulcerative, antiparasitic, reproductive, and wound-healing effects, as well as neurological properties such as antide-pressant, adaptogenic, anticonvulsant, and CNS-depressant activities. Other pharma-cological effects with more specific targets include antihypertensive, antiatherosclerotic, thrombolytic, antimalarial, antisnake venom, mutagenic, and hair-growth-promoting activities (Galani, 2019; Al-Snafi, Talab & Jafari-Sales, 2023). Furthermore, *M. paradisiaca* possesses high antioxidant capacity and exhibits potential for pharmaceutical applications, such as bioadsorptive activity, tablet disintegration, and metal corrosion protection, among others (Galani, 2019; Vashi, 2025). In addition, its nutritional uses are well recognized, highlighting *M. paradisiaca* as important source of vitamins, minerals and antioxidants (Lakshmi et al., 2015; Al-Snafi et al., 2023).

Given the extensive traditional uses, recognized medicinal potential, and the growing number of scientific publications in recent years regarding *M. paradisiaca*, this systematic review aims to compile and organize recent scientific data concerning the ethnopharmacological uses, pharmacological activities, and phytochemical composition of *M. paradisiaca*.

METHODOLOGY

Search was made in Scopus, ScienceDirect, PubMed Central and Alicia databases, so that the scientific information collected was obtained from research articles that were published from 2015 to 2025. The study employed specific search terms such as "Musa paradisiaca" AND "ethnobotany" OR "chemical" OR "activity" to identify relevant articles. Most documents were excluded during the initial screening because they were unrelated to the topic or consisted solely of citations. In the subsequent selection phase, duplicate entries and studies referring only to functional properties or to other *Musa* species were removed. After this detailed evaluation, the publications directly aligned with the central theme were selected and included in the following sections of the review.

RESULTS

Traditional use

Bananas are among the world's most popular fruits, serving both as a staple starch source for millions and as a key income-generating crop across tropical and subtropical regions. They originated and diversified as giant perennial herbs inhabiting open areas within the humid forests of Southeast Asia and Western Oceania, and were domesticated approximately 7,000 years ago through a series of hybridization events. Nowadays, the global banana production and trade system has long been marked by power imbalances between multinational corporations controlling plantations and markets, and the local agricultural workers responsible for cultivation and harvest. Furthermore, climate change poses an increasing threat to the economic sustainability of major banana-producing regions, demanding adaptive responses such as efficient irrigation practices to ensure productivity and water security (Bebber, 2023). Meanwhile, the organic banana market continues to expand, driven by health-conscious consumers seeking environmentally friendly products. Although organic cultivation initially supported the growth of small-scale producers, recent updates to organic product regulations in the United States and the European Union have created new challenges for them. Nevertheless, in many developing countries, banana production for local farmers and its trade remain vital economic activities, particularly in rural communities, as well as its ethnobotanical uses keep an important place in some localities (Dawson & van der Waal, 2022; Alcalde Quisquiche & Huaman Muñoz, 2022).

The traditional use of *Musa paradisiaca* across various countries involves both oral and topical administration (Table 1). Among the different plant parts, the leaves are the most frequently utilized, followed by the fruit, while the bark, stem, and root are also cited in ethnomedicinal practices (Mejía Carhuanca & Rengifo Salgado, 2000; Hajdu & Hohmann, 2012; Yakubu et al., 2015; Gunasekaran et al., 2020; Owusu-Boadi, Akuoko Essuman, Mensah, Ayamba Ayimbissa & Boye, 2021; Firempong et al., 2023).

Table 1.
Traditional use of *M. paradisiaca*

Country	Common Name	Traditional Use	Plant Organ	Way to Use	Reference
Nigeria	Cambur	Diarrhea	Fruit	Crude	Yakubu et al., 2015
	Cambur	Cuts, insect bites	Leaves	Juice	Yakubu et al., 2015
	No data	Ulcers	Unripe pulp	Aqueous extract	Onyeto et al., 2024
India	Banana	Anemia, scabies, skin diseases	Roots	Cold infusion	Yakubu et al., 2015
	Banana	Diarrhea	Green Fruit	Cooked	Gunasekaran et al., 2020
	Banana	Wounds	Leaves	Dressing	Chendake, Kale, Manavadaria & Motimath, 2021
Ghana	Guineo	Mouth cleaning	Stem	No data	Owusu-Boadi et al., 2021
	Brodeɛ	Diabetes	Bark	Decoction	Firempong et al., 2023
México	Banano	Prebiotic	Pulp	Crude	Gómez et al., 2022
Peru	Plátano	Contractures (Torticollis)	Leaves	Heated on fire	Meija Carhuanca & Rengifo Salgado, 2020
Republic of Guinea	Banana	Icterus	Leaves	Decoction	Valdez et al., 2024
Tanzania	Mgomba	Cold, bronchitis	Leaves	Dried leaves made into syrup	Kacholi & Amir, 2024

In several regions, including Asia (India), Africa (Nigeria, Ghana, Guinea, and Tanzania), and the Americas (Mexico and Peru), bananas are traditionally used for the treatment of cuts, skin lesions, and other ailments, such as diarrhea and anemia (Alcalde Quisquiche & Huaman Muñoz, 2022). Furthermore, the plant has been employed for managing ulcers, diabetes, jaundice, colds, and bronchitis (Firempong et al., 2023; Kacholi & Amir, 2024; Onyeto, Onwuka, Peter, Nworu & Akah, 2024; Valdez et al., 2024). Additionally, *M. paradesiaca* is widely consumed as food and serves as raw material for preparing desserts and various culinary products (Narayan et al., 2003).

One of the most well-documented ethnomedicinal applications of *M. paradisiaca* is the use of mature or unripe fruits and fruit peel for the treatment of diarrhea. This therapeutic effect is likely associated with the presence of polysaccharide fibers and/or the high tannin content in immature fruits. Polysaccharide fibers facilitate the formation of the intestinal bolus, while tannins are known to reduce intestinal secretions, inhibit neural stimuli that promote peristalsis, and exert a general antibacterial effect (Tadesse, Engidawork, Nedi & Mengistu, 2017).

Tannins also play a crucial role in wound healing by decreasing local vascular permeability, promoting rapid wound edge approximation, and providing antimicrobial activity (Albuquerque, 2018). Finally, in addition to the various plant parts utilized, the modes of administration are also diverse, including infusion, decoction, juices, syrups, and direct consumption, among others. The mode of preparation is influenced by the physical characteristics of the plant part used, as well as its mode of action, which can be either systemic or localized.

Chemical composition

Flavonoids

The chemical composition of *Musa paradesiaca* (Table 2) is characterized by the presence of various bioactive metabolites, with flavonoids being among the most predominant (Aubert & Chalot, 2018). Among these, anthocyanins are responsible for the pigmentation of the fruit and have been utilized in the management of type 2 diabetes mellitus due to their potent antioxidant properties (Damián-Medina et al., 2018). Additionally, anthocyanins exhibit neuroprotective effects, as they mitigate memory deficits and provide protection against oxidative damage in the brain (Pacheco et al., 2018).

Phenolic acids

High-performance liquid chromatography with diode-array detection and mass spectrometry (HPLC-DAD/MS) analysis has identified acetylated derivatives of *p*-coumaric acid and caffeic acid in banana flowers and bracts (Vilhena et al., 2020). *p*-coumaric acid has demonstrated immunomodulatory effects, which may be partially attributed to its cytoprotective and antioxidant properties (Kilani-Jaziri et al., 2017). Furthermore, it has been reported to exhibit strong antidiabetic activity (Shairibha, Rajadurai & Kumar, 2014). Caffeic acid is one of the principal hydroxycinnamic acids and is recognized as a potent antioxidant (Gülçin, 2006). Additionally, it possesses anti-inflammatory and anticarcinogenic activities, as demonstrated in both *in vitro* and *in vivo* studies (Choi et al., 2010; Espíndola et al., 2019). On the other hand, shikimic acid, *p*-hydroxybenzoic acid, vanillic acid, ferulic acid, sinapic acid, caffeic acid, syringic acid, chlorogenic acid, transcinnamic acid and two essential fatty acids - linolenic and linoleic acids, have been identified by HPLC in the pulp of the pseudofruit (Sarma et al., 2022). Shikimic acid itself, in addition to being a biosynthetic precursor in plants, is also an intermediate in the synthesis of many drugs, including the most relevant antiviral agent oseltamivir (Estevez & Estevez 2012). Vanillic acid, ferulic acid and chlorogenic acid have effective antioxidant, anti-inflammatory and neuroprotective properties (Table 2) (Miao & Xiang, 2020; Ingole et al., 2021; Li et al., 2021).

Terpenoids

Likewise, in the pulp of the fruit, the following antimicrobial metabolites have been identified using GC-MS and bioautographic TLC: α-thujene, γ-terpinene, α- and β-pinene, sabinene, β-myrcene, limonene, α-copaene, caryophyllene and (Z,E)-α farnesene (Table 2) (Fahim et al., 2019).

Other phytochemicals

Interestingly, the chemical profile of the banana stem through GC-MS showed active components of the amine class such as p-hydroxynorephedrine, phenylephrine and norpseudoephedrine.

Table 2.
Chemical composition of *M. paradisiaca*

Synonym	Chemical Composition	Plant Organ	Method	Reference
Musa paradisiaca	Potassium: 1690.55 ± 0.02mg kg^{-1}	Fruit	EAA	Sojinu et al., 2021
	Total Flavonoids: 2109.55 ± 10.33 GAE mg/100g Total Phenols: 2870.28 ± 6.09 GAE mg/100g	Fruit peel Fruit peel	GC-MS	Akinwunmi, 2022
	Oleracein-E	Flower	NMR, LC-MS	Rai et al., 2021
	10-mubenoside A, 25-(R)-ruscogenine-1-O-β-D-glucopyranosyl (1→2)-β-D-fucopyranoside, oleanólic acid 3-O-β-D-xylopiranosyl-(1→2)-α-L-arabinopyranosyl-28-O-β-D glucopiranosyl-(1→6)-β-D glucopyranoside; raddeanoside, baicaleín-6-glucuronide, undulatoside A, 26-deoxyacein, methylofiopogonone A, ginsenoside Rh4, eclalbasaponin VIII, lupeol, stigmasterol, cyclolanostan, obtusifoliol	Stem	LCMS/MS-QTOF	Sari, Kaban & Alfian, 2020; Sari & Misran, 2021
	Bioactive constituents: diethyl sulfate (0.62%), 2-heptanol, 6-amino-2-methyl- (0.48%), vanillic acid (3.05%), n-hexadecanoic acid (7.08%), octadecanoic acid (3.90%), 9-octadecenoic acid, (E)- (7.53%), atomoxetine (1.33%), p-hydroxynorephedrine (0.93%), phenylephrine (0.76%), norpseudoephedrine (1.90%), metaraminol (1.02%), β-sitosterol (7.81%) Others: N-methyl-2-phenyl-1-propylamine, 2-formylhistamine, 3-methyl-3,5–(cyanoethyl)tetrahyd ro-4-thiopyranone, 3-hydroxy-N-methylphenethylamine, 2-oxo-3-methyl-cis-perhydro-1,3-benzoxazine, hexadecanoic acid, 1,1-dimethylethyl ester, 9-octadecenamide, (Z)-; 1-adamantanemethylamine, .alpha.-methyl-; n-propyl 11-octadecenoate, N-acetyl-l-alanyl-l-alanyl-l-alanine ethylamide, paradrine, −)-norephedrine, 1,2-benzenedicarboxylic acid, isodecyl octyl ester, N-desmethyltapentadol, 1-hexadecanesulfonamide, N-(2-aminoethyl)-; benzeneethanamine, 4-fluoro-.beta.,3-dihydroxy-N-methyl; ethyl isopropyl dimethylphosphoramidate, 1,3-adamantanediacetamide, 3-carbobenzyloxy-4-ketoproline, 9,19-cyclolanostan-3-ol, acetate, (3.beta.)-	Stem	GC-MS	Ekweogu et al., 2024
	Citric acid, taurine, pantotenic acid, nicotinic acid	Flower	HPLC	Liu et al., 2018
	1-kestose (GF2)	Fruit peel	HPLC-RID, HSCC Cromatography	Chelliah et al., 2022

Table 2. Continued

	Glycosylated and acetylated phenylpropanoids from p-coumaric acid and caffeic acid, as well as a glycosylated flavonol, anthocyanins	Flower, bract	HPLC-DAD-MS	Vilhena et al., 2020
	α-thujene, γ-terpinene, α- and β-pinene, sabinene, β-myrcene, limonene, α-capaene, caryophyllene, (Z,E)-α farnesene, aceteugenol, palmitic acid, stearic acid, palmitin, stearin	Pulp	GC-MS y TLC	Fahim et al., 2019
	Kaempferol, gallic acid, quercetin, rutin, ethyl gallate, protocatechuic acid	Flower	HPLC-MS/MS	Gadelha et al., 2024
	Tannins (24.21%), flavonoids (6.33%), saponins (25.08%), phenol (0.34%), and alkaloids (3.74%)	Bract	Specific methods for each metabolite class identification	Falowo, Ejidike, Lajide & Clayton, 2021
	Ascorbic acid	Fruit peel	GC-MS	Sofini et al., 2024
Musa paradisiaca var. balbisiana	Shikimic acid, p-hydroxybenzoic acid, vanillic acid, ferulic acid, sinapic acid, caffeic acid, syringic acid, chlorogenic acid, transcinnamic acid, and two essential fatty acids; linolenic acid, linoleic acid	Pulp	HPLC, LC-MS	Sarma et al., 2022
	Calcium and potassium 15.74 ± 0.43 and 395.20 ± 9.5 mg/100 g of raw pulp, respectively	Pulp	EAA	Sarma et al., 2022; Maseko et al., 2022
	Rutin	Leaves	HPLC	Yingyuen, Sukrong & Phisalaphong, 2020
Musa paradisiaca var. balbisiana	Cellulose 34.61 ± 1.06% and Lignin 9.13 ± 0.31%	Bract	Kurschner-Hoffer Method, Klason Lignine	Falowo et al., 2021
Musa paradisiaca var. balbisiana	Phenolic acids, aglyconic flavonoids, glycoside flavonoids and catecholamines	Fruit peel	HPLC-UV/Vis	Barroso et al., 2019

***GC: Gas Chromatography; MS: Mass Spectrometry; EAA: Atomic Absorption Spectrophotometry; HPLC: High Performance Liquid Chromatography; RID: Refraction Index; HSCC: High Performance Countercurrent Chromatography; DAD: Diode Array Detection; Q-TOF: Quadropole Time-of-Flight; TLC: Bioautographic with Thin Layer Chromatography*
***This table does not include chemical tests analyzed only by class identification through TLC*

These substances were related to the healing, analgesic and anti-inflammatory activities of the banana stem extract, as well as the phytosteroid β-sitosterol, dimethyl sulfate and vanillic acid, in addition to the fatty acids n-hexadecanoic, octadecenoic and 9-octadecenoic acid, present in higher concentrations in the extract (Table 2) (Ekweogu et al., 2024).

Pharmacological effects

Antimicrobial activity

The *in vitro* antibacterial properties of *Musa paradisiaca* extracts have been well-documented (Table 3). These effects are primarily attributed to the presence of alkaloids and polyphenols in the extract. Notably, the inhibition of both methicillin-resistant and methicillin-susceptible *Staphylococcus aureus* (MRSA) has been linked to sanguinarine, an alkaloid that disrupts the cytoplasmic membrane of MRSA, thereby exerting a bacteriostatic effect. Additionally, flavonoids contribute to antibacterial activity by interfering with bacterial metabolism, disrupting cell membrane integrity, and inhibiting DNA gyrase function (Sivasamugham, Nimalan & Subramaniam, 2021). This antibacterial activity was particularly pronounced in ethanolic leaf extracts, which also demonstrated efficacy against *Escherichia coli* (Abdullah et al., 2024). Furthermore, soluble dietary fibers derived from bananas have exhibited inhibitory effects against *Clostridioides difficile*, a pathogen implicated in diarrhea. The proposed mechanism of action involves the prevention of bacterial adhesion to the intestinal epithelium. Additionally, dietary fibers enhance stool volume and viscosity, thereby improving stool consistency (Simpson et al., 2021).

Antioxidant activity

The antioxidant capacity of the fruit has been measured by *in vitro* studies (Table 3). The elimination capacity of ABTS was studied, which is based on the reduction of ABTS°+, besides the antioxidant evaluation by DPPH method, which consists of the capture of free radicals. The antioxidant activity of the fruit was positively correlated with the contents of phenol, flavonoids and tannins (Ayoola-Oresanya et al., 2020; Putri et al., 2022).

Antidiabetic activity

The antidiabetic capacity of the fruit has been demonstrated by *in vivo* and *in vitro* studies (Tables 3 and 4). *In vitro*, the ability of the methanolic extract of the fruit with the peel to inhibit alpha amylase was tested. This inhibition competitively prevents it from binding to its substrate, starch, thus preventing its breakdown into smaller molecules (glucose), which significantly reduces the postprandial increase in blood glucose, therefore being a good therapeutic strategy for the management of diabetes mellitus. The molecules responsible for the effect have not been identified, but tannins have the potential to inhibit alpha amylase and possess antioxidant activity (Ahmed, Bala & Umaru, 2022). Through *in vivo* studies, it has been shown that the boiled fruit also inhibits alpha amylase and prevents lipid peroxidation (Ajiboye & Shodehinde, 2022), reducing blood sugar levels.

Cytotoxic activity

The extract of *M. paradisiaca* flowers presents apoptotic activity in prostatic cancer cells, due to the presence of polyphenols and flavonoids (Ariffin et al., 2021), which reportedly reduced colony formation capacity, promoted cell cycle arrests at G_0/G_1 phase, suppressed MMP-2 and MMP-9, and upregulated active caspase-3 in DU-145 cells (Chen et al., 2007).

Antidiarrheal effect

The *M. paradisiaca* fruit has antidiarrheal action in humans and animals by increasing the absorption of fluids and electrolytes in the gastrointestinal tract, through intensifying Na^+/K^+ ATPase activity, probably by *de novo* synthesis, and/or reducing nitric oxide/prostaglandin levels. These mechanisms are considered essential in the treatment of diarrhea, so that agents that cause diarrhea do so through several mechanisms, including active electrolyte secretion, decreasing electrolyte absorption, increasing luminal osmolality, changes in mucosal morphology and permeability, and impaired motor activity (Table 4) (Yakubu et al., 2015).

Antiallergic, immunomodulatory and anti-inflammatory activities

The antiallergic, immunomodulatory, and anti-inflammatory effects of *M. paradisiaca* extracts have been demonstrated *in vivo* (Table 4). The mechanism refers to the inhibition of NF-κB signaling, through the decrease in the activation of the p65 subunit, in addition to the decrease in the expression of CD86 and HLA-DR receptors in human M1 macrophages independent of their modulation by M2 (Gadelha et al., 2021). More recently, other anti-inflammatory mechanisms were identified such as inhibition of inducible nitric oxide synthase (iNOS), 15-lipoxygenase (15-LOX) and PGE2, as well as reduction of pro-inflammatory cytokines and promotion of endogenous antioxidants against LPS stimulation (Al Masri & Ameen, 2023; Widoyanti et al., 2023; Spigarelli et al., 2024). Furthermore, *in vivo* assays demonstrated that the hydroethanolic extract from flowers deactivated neutronphils by decreasing CD18 receptor, free DNA release, and metalloproteinase (MPO) activity and also induced IL-10 production in mice, which in turn are mechanisms related to the presence of polyphenolic compounds identified in the extract, such as ethyl gallate, protocatechuic acid, quercetin, rutin and kaempferol (Gadelha et al., 2024). Part of these compounds, including gallic acid, are also involved with the antiallergic property, leading to the reduction of allergenic IgE production, as well as the release of histamine in mast cells and TH1 bias (Gadelha et al., 2021). Moreover, the anti-inflammatory and antiallergic activities were also observed through *in vivo* analysis, notably reducing paw edema and writhes, as well as pain inhibition in rats (Ekweogu et al., 2024).

Wound healing activity

It is known that the antioxidant and anti-inflammatory effects also contributed to wound healing activity, since the inflammation and generation of oxidative molecules are involved in the first steps of wound healing process (Albuquerque, 2018). In this sense, different organs of *M. paradisiaca* have proven to be effective in the improvement of wound healing in different experimental models, including those of diabetic origin. Cheng, Liu, Cheng, Lin and Liu (2020) patented the use of a banana extract that showed promising activity in the treatment of diabetic wounds, leading to the local reduction of inflammatory cells, increase of collagen deposition and acceleration of re-epithelialization process in mice. Interestingly, the most diluted concentration (1/6000) produced the most efficient result (Cheng et al., 2020). The stem and fruit peel extracts also demonstrated similar effects in wound healing process, so that the stem extract also shortened the epithelialization period and increased the tensile strength, wound contraction and wound resistance fracture in rats. Part of these events are probably related to the major presence of β-sitosterol, a phytosteroid involved in epithelial growth promotion mechanisms (Ekweogu et al., 2024). In its turn, nanocomposite hydrogels containing peel aqueous extract prevented the formation of scars, a fact that may have been enhanced by the relevant concentration of ascorbic acid in the extract, since it is a substance with high antioxidant power and probably contributes to minimizing the first stage of healing, thus promoting better tissue organization (Table 4) (Sofini et al., 2024).

Osteogenic activity

The osteogenic activity of *M. paradisiaca* has been demonstrated *in vivo* (Table 4). The ethanolic extract of the flower has been purified, and the substance oleracein E has been identified as the compound with the greatest osteogenic activity, inducing greater bone formation, mineralization, mRNA and protein expression, in addition to having antioxidant activity. This property plays an important role for bone remodeling. Likewise, Olearacein E increases osteoblast activity and decreases osteoclastic activity, thus preventing bone loss (Rai et al., 2021).

Antiurolithiasis activity

The antiurolithiasis activity of the aqueous and ethanolic extracts of *M. paradisiaca* pseudostem has been demonstrated with *in vivo* studies (Table 4). The main risk factors in the formation of kidney stones are hyperoxaluria and hypercalciuria. Hypercalciuria promotes the formation of CaOx crystals, whereas hyperoxaluria is related to the production of free radicals and oxidative damage at the level of the renal epithelium, facilitating the union of crystals, the retention and aggregation of crystals in the renal tubules. Therefore, the lower oxidative stress caused by the presence of polyphenols leads to a concentration decreasing of oxalates in urine and less deposition of crystals (Panigrahi, Dey, Sahoo & Dan, 2017).

Antihyperlipidemic and cardioprotective activities

The antihyperlipidemic and cardioprotective activity of the hydroetenolic extracts of *M. paradisiaca* leaves and peel were demonstrated *in vivo* (Table 4), so that these activities may be mediated by improved glycemic status, antioxidant mechanisms, and improved beta-cell function. The molecules involved in this action have not been identified, but a GC-MS analysis has identified phytochemicals that may contribute to the activity of the plant, such as n-hexadecanoic acid, phytol and 9,12,15-octadecatrienoic acid, methyl ester in the leaves, while a high percentage of vitamin E, ethyl hexadecanoic acid, epicatechin, gallocatechin, ethyl ester and oleamide of p-coumaric acid were identified in the peel (Ahmed et al., 2021; Zaini et al., 2022).

Hepatoprotective and anticonvulsant activities

The *in vivo* hepatoprotective and anticonvulsant activity of the aqueous and alcoholic extract of the stem is associated with its antioxidant capacity and the elimination of free radicals (Nirmala, Girija, Lakshman & Divya, 2012; Reddy et al., 2018), which in turn is related to its content of phenols, flavonoids and tannins (Ayoola-Oresanya et al. 2020; Putri et al., 2022). The extracts from stem and leaves of *M. paradisiaca* were able to reduce the levels of liver marker enzymes, such as alkaline phosphatase (ALP), alanine aminotransferase (ALT), aspartate aminotransferase (AST), urea, whereas enhanced the level of catalase (Table 4) (Ekweogu et al., 2024; George-Opuda, Adegoke, Odeghe, Awopeju & Okeahialam, 2023).

Haemostatic activity

The haemostatic activity of the stem extract of *M. paradisiaca* was demonstrated by *in vivo* studies (Table 4), in which the extracts had the potential to shorten the bleeding time in the tail wound of mice without interfering with platelet count. The phytochemical analysis showed that the extract contained flavonoids, tannins and saponins as active compounds in the hemostasis process.

Flavonoids and saponins play an important role as inhibitors of cyclooxygenase, due the fact that it decreases the production of prostaglandin, responsible for vasodilation. On the other hand, tannins facilitate the adherence of platelets to subendo-thelial blood vessels, releasing ADP and thromboxane (Budi, Juliastuti & Sulistyowati, 2021; Budi, Ramadan, Anitasari & Pangestika, 2022).

Reproductive effects

Finally, the aqueous extract from unripe pulps of *M. paradisiaca* showed pro-reproductive properties in rats, so that it significantly enhanced sperm count and motility, and reduced SOD, CAT, and glutathione levels, whereas it was observed a significantly elevation of estrogen LH, FSH, and MDA levels in both male and female rats. Also, the estrogen and progesterone levels in female rats were slightly increased.

However, discrepancies were noted when it was compared the histological examination between male and female organs, so that no alterations were seen in tests structures, whereas significant structural damage to the ovaries were revealed in these examinations.

The presence of saponins as main substances of this extract could be related to the reproductive effects of *M. paradisiaca*, since some of these compounds possess steroidal nucleus in their structures, which in turn are associated with hormonal activities (Table 4) (Onyeto et al., 2024).

Table 3.
In vitro pharmacological effects of *M. paradisiaca*

Pharmacological effect	**Plant organ**	**Botanical product (Effective conc.)**	**Metabolites**	**Activity description**	**Reference**
Antibacterial	Leaves	Ethanolic extract (2.86 g/mL)	Alkaloids and Tannins	Inhibition of methicillin resistant and susceptible *Staphylococcus aureus*	Sivasamugham et al., 2021
	Fruit	Dietetic fiber (10 mg/mL)	Soluble Dietetic Fiber	Disrupts epithelial adhesion of *C. difficile* vegetative cells and spores, with inhibitory activity against *C. difficile*	Simpson et al., 2021
	Fruit peel	Banana peel extract zinc oxide nanoparticles (0.1-5 mg/mL)	No data	MIC of 100 µg/mL for all test, effective on *S. aureus* > *B. cereus* > *K. pneumoniae* > *S. enterica*.	Imade, Ajiboye, Fadiji, Onwudiwe & Babalola, 2022
	Leaves	Ethanolic extract (100 µL)	Alkaloids, flavonoids, phenols, terpenoids, steroids, glycosides, saponins, carbohydrates, proteins and tannins	Activity against *S. aureus* and *E. coli* (11 and 10 mm zone inhibition, respectively).	Abdullah et al., 2024

Table 3. Continued

Antioxidant	Leaves	Methanolic extract (IC^{50} data)	Phenols, Flavonoids and Tannins	IC_{50} DPPH ranged from 10.7 ± 0.3 to 257.9 ± 2.3 µg/mL	Ayoola-Oresanya et al., 2020
	Fruit peel	Methanolic extract (IC^{50} data)	Phenols	DPPH and FRAP methods showed IC_{50} values of 143.97 ± 0.17 mg/L and 151.08 ± 0.32 mg/L	Putri et al., 2022
Anti-inflammatory	Leaves	Ethyl acetate extract (0.1 %)	Phenols, flavonoids	Inhibition of inducible nitric oxide synthase (iNOS) and 15-lipoxygenase (15-LOX)	Widoyanti et al., 2023
	Bract	Ethanolic extract with 1% citric acid (6.25 - 100 µg/mL)	Phenols, phenolic acids, flavonoids, anthocyanins	Lipopolysaccharide (LPS) stimulation decreased cell viability whereas the treatment preserved the macrophage cell viability against LPS. It suppressed the LPS-stimulated NO, pro-inflammatory and PGE2 production in RAW 264.7 cells. Increased the endogenous antioxidants level against LPS-stimulation, and inhibited the nuclear translocation of NF-κB under LPS-stimulated conditions.	Al Masri & Ameen, 2023
Antidiabetic	Fruit peel	Methanolic extract (2.5 – 10 mg/mL)	Tannins	Extract at 2.50 mg/mL and 10.0 mg/mL inhibition greater than 50% of alpha amylase	Ahmed et al., 2022
Reduces uric acid levels	Fruit peel	Methanolic extract (100 mg/L)	No data	Antigout activity was obtained 27.95 ± 0.08%	Putri et al., 2022
Cytotoxic	Flower	Ethyl acetate fraction (IC^{50} data)	Polyphenols	Moderate cytotoxicity against DU-145 cancer cells with an inhibitory concentration IC_{50} value of 37.94 µg/mL	Ariffin et al., 2021

Toxicity

The results obtained by Abirami, Brindha and David (2014) demonstrated that administration of *Musa paradisiaca* L. (pseudostem) juice at a dose of 2000 mg/kg for 28 days was well tolerated and did not produce any significant alterations in body weight or biochemical parameters. Moreover, the acute oral toxicity of *Musa paradisiaca* peel extract was evaluated

Table 4.
In vivo pharmacological effects of *M. paradisiaca*

Pharmacological effect	Plant organ	Botanical product (Dosis)	Metabolites	Activity description	Reference
Antiallergic, immunomodulatory and anti-inflammatory	Flower	Hydroalcoholic extract (100 mg/kg)	Kaempferol, gallic acid and quercetin	Inhibits eosinophil migration, production of cytokines such as IL-4, IL-5, IL-13 and IL-17A dependent on IFN-ɣ production in the airways	Gadelha et al., 2021
Anti-inflammatory	Flower	Hydroalcoholic extract (25-100 mg/kg)	Quercetin, rutin, ethyl gallate, protocatechuic acid, kaempferol	Deactivated neutrophils by decreasing CD18 receptor, free DNA release, and MPO activity and inducing IL-10 production in mice.	Gadelha et al., 2024
	Fruit	Fruit drying process (1-3 mg/mL)	Vitamins (C, A and B group), minerals (including potassium, magnesium, calcium and iron), carbohydrates, dietary fiber, phenolic compounds and flavonoids, phytosterols, amino acids (mainly tryptophan); malic acid and citric acid.	Decreased the secretion of the proinflammatory cytokines IL-6, IL-1β and IL-8 in the HCl-Induced GERD model	Spigarelli et al., 2024
Anti-inflammatory and analgesic	Stem	Methanolic extract (500-5000 mg/kg)	2-heptanol, 6-amino-2-methyl; n-hexadecanoic acid, octadecanoic acid, 9-octadecenoic acid, (E)-, β-sitosterol, norpseudoephedrine	Reduced paw edema and writhes, and pain inhibition in rat.	Ekweogu et al., 2024
Antidiabetic	Bract and flower	Aqueous extract (200 mg/kg)	Phenylpropanoids, glycosylated flavonol, anthocyanins	Decreased fasting blood glucose compared with the untreated diabetic group	Vilhena et al., 2020
	Fruit	Boiled unriped fruit (20-40 % free daily diet)	No data	Disrupts several pathways involved in macromolecule metabolism, inhibition of starch hydrolyzing enzymes, enhancement of enzymatic antioxidant status, and prevention of lipid peroxidation	Ajiboye & Shodehinde, 2022
	Stem	Ethanolic extract (100-300 mg/kg)	Lupeol, stigmasterol, cyclolanostan, obtusifoliol	Reduces blood sugar levels	Sari et al., 2020

Table 4. Continued

Osteogenic (prevention of bone loss)	Flower	Ethanolic extract (100- 250 mg/kg) and Butanolic Fraction (25-50 mg/kg)	Oleracein-E	They elevated serum procollagen type I N-terminal propeptide (P1NP), a marker of bone formation, and suppressed serum collagen type I C-telopeptide (CTX-1), a marker of bone resorption.	Rai et al., 2021
Diabetic wound healing	No data	Patented extract (1/6000-1/500 dilutions)	No data	Fewer inflammatory cells, accelerated re-epithelialization, increased collagen deposition in mice. The gene expression levels of tumor necrosis factor-α, interleukin-1β, and interleukin-6 were decreased and the levels of type I and type III collagen were increased.	Cheng et al., 2020
Wound healing	Stem	Methanolic extract (500-5000 mg/kg)	β-sitosterol	Shorter epithelialization period, increase in tensile strength, greater percent wound contraction and wound resistance fracture in rat.	Ekweogu et al., 2024
Scarless wound healing	Fruit peel	Aqueous extract (1:40 dilution)	Ascorbic acid	Carboxymethyl cellulose based nanocomposite hydrogels containing silver nanoparticles and banana peel extract prevented scar formation in rat.	Sofini et al., 2024
Antiurolithiasic	Pseudostem	Hydroethanolic extract (100-300 mg/kg)	No data	Significantly restores the deterioration in the renal function test.	Panigrahi et al., 2017
Antidiarrheal	Stem sap	“Extract” (0.25-1 mL)	Flavonoids, Phenols, Saponins and Alkaloids	Improve fluid and electrolyte absorption through *de novo* synthesis of sodium and potassium ATPase and/or reduction of nitric concentration.	Yakubu et al., 2015

Table 4. Continued

Antihyperlipidemic	Leaves	Hydroethanolic extract (100 mg/kg)	n-hexadecanoic acid, phytol and 9,12,15-octadecatrienoic acid and methyl ester	Decreased the elevated fasting and post-prandial serum glucose, total cholesterol, triglycerides, LDL-cholesterol and vLDL-cholesterol levels and increased serum insulin level, liver glycogen content, serum HDL-cholesterol level. Normalized hepatic glutathione content and superoxide dismutase, glutathione peroxidase, and glutathione-S-transferase activities.	Ahmed et al., 2021
Cardioprotective	Fruit peel	Hydroethanolic extract (100 mg/kg)	Estragole, vitamin E, ethyl hexadecanoic acid, epicatechin, gallocatechin, ethyl ester and oleamide of p-coumaric acid	Decreased elevated serum creatine kinase-MB, lactate dehydrogenase, and aspartate aminotransferase activities.	
	Fruit peel	Aqueous extract (5000 mg/kg)	(Z,Z,Z) 9,12,15-Octadecatrien-1-ol, n-Hexadecanoic acid, phytol	Promoted restoration of cardiomyocytes with no side effect compared to aspirin and increased CAT, SOD, and Na^+/K^+ ATPase activities. Decreased pro-inflammatory cytokines, MDA, and Troponin I (cTn-I), reducing the elevation of ST-segment on the ECG to near normal.	Suleiman et al., 2021
	Stem	Alcoholic and aqueous extract (500 mg/kg)	Phenols, flavonoids, tannins	Reduced elevated levels of serum enzymes such as serum glutamic-oxaloacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), alkaline phosphatase (ALP)	Nirmala et al., 2012

Table 4. Continued

Hepatoprotective	Stem	Methanolic extract (500-5000 mg/kg)	Vanillic acid, octadecanoic acid, β-sitosterol	Reduction in ALP, ALT AST, urea, sodium, chloride, total cholesterol, triglycerides, and low-density lipoprotein cholesterol, while high density lipoprotein cholesterol, glutathione and superoxide dismutase increased in rat.	Ekweogu et al., 2024
	Leaves	Ethanolic extract (25-100 mg/kg)	Phenols, flavonoids and tannins	Increased catalase, reduced glutathione, glutathione peroxidase and protein, while reducing malondialdehyde, in mice infected with *Plasmodium berghei*.	Reddy et al., 2018
Anxiolytic	Fruit peel	Oligossacaride enzymatic extract (1-10 mg/mL)	1-kestose (GF2)	Reduced stress and corticosterone levels.	Chelliah et al., 2022
Probiotic	Fruit peel	Oligossacaride enzymatic extract (1-10 mg/mL)	1-kestose (GF2)	Enhanced the growth of *Lactobacillus rhamnosus*.	Chelliah et al., 2022
Anticonvulsivant	Stem	Ethanolic extract (25-100 mg/kg)	Phenols, flavonoids and tannins	Significant decrease in MDA levels in the brain, although there was an increase in GSH levels.	Reddy et al., 2018
Haemostatic		"Extract" (25-50 % free daily diet)	Flavonoids, taninns, saponins	Shorted the bleeding time in the tail wound of mice without interfering with platelet counts.	Budi et al., 2021, 2022
Reproduction	Unripe pulp	Aqueous extract (500 mg/kg)	Saponins, tannins, alkaloids, resins	Significantly enhanced sperm count and motility, significantly reduced SOD, CAT, and glutathione levels, while significantly elevated LH, FSH, and MDA levels in male and female rats. Histological examination revealed significant structural damage to the ovaries.	Onyeto et al., 2024

in mice at doses of 125, 250, 500, 1000, and 2000 mg/kg body weight. No mortality or signs of toxicity were observed either within the first 24 hours or after 2 weeks at any of the tested doses (Padilla-Camberos et al., 2016). Similarly, the aqueous extract of *M. paradesiaca* stamen, administered at a maximum dose of 5000 mg/kg, produced no signs of toxicity or behavioral alterations in rats (Ashish, Reddy, Gautam, Maurya & Ankit, 2016).

The hydroalcoholic extract of *M. paradisiaca* flower was also found to be safe up to 2000 mg/kg body weight when administered orally to albino rats, being well tolerated (Patro et al., 2016). In acute toxicity studies, no mortality or toxic symptoms were recorded in rats treated with the fermented extract of *M. paradisiaca*, and the LD_{50} value was estimated to be greater than 5 g/kg. During subacute toxicity evaluation, oral administration of the fermented extract caused no significant adverse effects ($P > 0.05$) on relative organ weights, body weight gain, hemoglobin concentration, red blood cell count, electrolyte balance, lymphocyte and basophil counts, or hepatic enzyme activities (AST and ALP). However, significant variations ($P < 0.05$) were observed in white blood cell, eosinophil, platelet, neutrophil, and monocyte counts, as well as in urea, creatinine, alanine aminotransferase (ALT), and high-density lipoprotein (HDL) levels. No histo-pathological alterations were detected in liver or kidney tissues (Ugbogu et al., 2018).

DISCUSSION

Recent publications on the pharmacology, chemistry, and ethnobotany of *Musa paradisiaca* strengthen and deepen the understanding of the medicinal use of the species, such that at least about 20 different pharmacological activities have been studied in the last ten years, largely correlated with the 10 ethnobotanical studies presented in this review. The antimicrobial activity of *M. paradisiaca* has been observed for extracts or dietary fibers from leaves and fruits, mainly against *S. aureus*, an important agent of cutaneous and systemic infections. Leaf extracts showed high levels of alkaloids and tannins, which in turn exhibit diverse mechanisms for antibacterial activity. Tannins, specifically, destabilize the bacterial cell membrane, precipitate membrane and intracellular proteins, minimize adhesion to surfaces, and interfere with virulence mechanisms (Pervaiz et al., 2016; Farha et al., 2020). Dietary fibers from the fruit were also able to inhibit epithelial adhesion of *C. difficile*, a causative agent of colon infection, which may explain its ethnomedicinal use as an antidiarrheal. Banana leaves and fruits also demonstrate high antioxidant power, but this can vary widely depending on the type of antioxidant test used, as well as the variety of banana evaluated (Ayoola-Oresanya et al., 2020). The outstanding antioxidant activity may partly explain other pharmacological effects cited in the review, such as anti-inflammatory activity, due to the inactivation of free radicals in the initial stages of the inflammatory process (Ekweogu et al. 2024), as well as hepatoprotective activity, by reducing oxidative damage in heaptocytes, antidiabetic activity, preventing lipid peroxidation and systemic oxidative damage, and wound healing activity, by reducing the duration of inflammatory activity in the wound healing process (Cheng et al., 2020; Ekweogu et al., 2024).

In turn, the anti-inflammatory activity of *M. paradisiaca* could be observed through in vitro and in vivo studies. Different plant organs were able to produce various anti-inflammatory mechanisms, including the suppression of the release of anti-inflammatory interleukins, as well as the inhibition of metalloproteinases, inducible nitric oxide synthase (iNOS) and 15-lipoxygenase (15-LOX), the production of PGE2 and events related to LPS stimulation, in addition to the deactivation of neutrophils through the inhibition of CD18 receptors, reduction of free DNA and stimulation of IL-10. These anti-inflammatory mechanisms may be related to some ethnobotanical uses, such as in the relief of stomach ulcers, wound treatment, contractures and bronchitis, due to the fact that these conditions have inflammatory characteristics. The study by Spigarelli et al. (2024) demonstrates the anti-inflammatory effect of the dry fruit extract in gastroesophageal reflux models, corroborating its potential for treating inflammation in the digestive tract. In fact, the most polar components of *M. paradisiaca*, which in turn become more concentrated in ethnomedicinal preparations such as infusions, decoctions, and aqueous extracts, have recognized anti-inflammatory activity, including flavonoids, tannins, and phenolic acids, exhibiting some of the mechanisms mentioned above (Al-Khayri et al., 2022; Maugeri et al., 2022; Xie et al., 2024). Furthermore, inhibition of interleukins involved in eosinophil migration (IL-4, IL-5 and IL-13) characterized the antiallergic and inmunomodullatory activity of *M. parasidiaca*, specifically when respiratory affections such as asthma are considered (Gadelha et al., 2021). Kaempferol, one of the main flavonoids of the flower extract, is known for its anti-asthma effect and could be responsible for the *M. paradisiaca* antiallergic activity (Molitorisova et al., 2021). Additionally, the methanolic extract of *M. paradisiaca* stem showed analgesic activity, which may be related to the presence of norpseudoephedrine, since it is involved in nociceptive mechanisms inherent to central monoamines (Nencini, Fraioli, Pascucci & Nucerito, 1998).

Regarding antidiabetic activity, the *in vivo* activity of cooked banana fruit is corroborated by an *in vitro* study of alpha-amylase inhibition, a known property of tannins present in the fruit peel (Ahmed et al., 2022). Furthermore, the cooking process increases tannin extraction, which may have contributed to the in vivo activity. Although an ethnomedicinal study conducted in Ghana reports that stem peels are used to treat diabetes (Firempong et al., 2023), it should be considered that these peels also contain tannins in high concentrations (Falowo et al., 2021). Other antioxidant polyphenolic components may also contribute to mitigating the oxidative damage of diabetes, as observed in the study with cooked fruit (Ajiboye & Shodehinde, 2022). One of the main flavonol glycosides in bananas, rutin, has been identified to possess anti-hyperglycemic activity by inhibiting alpha-amylase (Dubey, Ganeshpurkar, Bansal & Dubey, 2017; Yingyuen et al., 2020). In their turn, anthocyanins inhibit weight gain, avoiding lipid peroxidation and the production of free radicals, in such a way that it reduces lipid levels in the blood, decreasing the insulin resistance (Vilhena et al., 2020), so these compounds are considered antidiabetic. Finally, the reduction in blood sugar levels through treatment with the stem ethanolic extract can be explained by the presence of stigmasterol, which is related to lower blood glucose, according to the study by Ramu et al. (2016).

In turn, polyphenolics, including flavonoids and tannins, are possibly responsible for the decrease in serum uric acid levels, since they are inhibitors of xanthine oxidase, the enzyme that synthesizes uric acid, and are concentrated in the banana peel (Ebadollahi-Natanzi, Arab-Rahmatipour & Abedi, 2024). Regarding the urolytic effect of the ethanolic extract of the pseudostem of *M. paradisiaca*, the pathological mechanism is not yet fully understood, and the study lacks chemical analysis, including bio-guided analysis. However, the hydroethanolic extract used in the study is characterrized by encompassing a wide variety of substances with different polarities, which may contribute to an associated effect, since more polar substances such as flavonoids have an affinity for the renal filtrate and decrease oxidative stress in the renal tubule, thus minimizing the effects of oxalate crystal nucleation. Furthermore, some phytosteroids such as stigmasterol present in the pseudostem exhibit an antagonistic function to testosterone, which increases renal levels of osteopontin, which in turn prevents oxalate excretion (Panigrahi et al., 2017; Buț, Tero-Vescan, Pușcaș, Jîtcă & Marc, 2024).

The wound healing activity has been linked to different parts of *M. paradisiaca*, which, in the case of the fruit peel, is due to its high content of tannins and polyphenols. Both exhibit significant antioxidant activity, which reduces the inflammatory stage of cicatrization, accelerating the process and improving scar quality. Furthermore, tannins cause local vasoconstriction, preventing fluid loss, and complex with epidermal proteins, facilitating the approximation of wound edges (Albuquerque, 2018). The vasoconstriction mechanism is also purposed to explain the haemostatic effect observed in the study of Budi et al. (2021, 2022). These events, combined with the antibacterial activity also observed in the fruit peel, contribute to the healing action. In its turn, oleracein-E was the main compound in the butanolic fraction from flowers ethanolic extract and is the most probable substance responsible for elevate serum procollagen type I N-terminal propeptide (P1NP), a marker of bone formation, and suppress serum collagen type I C-telopeptide (CTX-1), a marker of bone resorption (Rai et al., 2021).

The antidiarrhoeal activity of *Musa paradisiaca* sap is attributed to its content of alkaloids, phenolics, flavonoids, and/or saponins, which may act through multiple mechanisms, including enhanced fluid and electrolyte absorption via de novo synthesis of Na^+/K^+-ATPase and/or a reduction in nitric oxide levels. Although the use of the sap is not the same as that described in ethnobotanical data, which report the use of the fruits (one of them specifically mentions the green fruits), the explanation for its antidiarrheal use by traditional communities probably lies in the fact that the fruits, especially the green ones, contain a high level of fibers and tannins, which are known to be antidiarrheal because they complex with proteins in the intestinal epithelium and reduce its irritation (Almeida, Karinikowski, Foleto & Baldisseroto, 1995), and also due to their antibacterial activity against *C. difficile* (Simpson et al., 2021). In addition, the oligossacaride extract from banana presented a probiotic effect on *Lactobacillus rhamnosus*, which promotes a healthy balance on gut bacterial flora, also producing an anxiolytic effect by reducing the stress and decreasing corticosterone levels (Chelliah et al., 2022).

Among other recent pharmacological studies with *M. paradisiaca* is found the hepatoprotective effect of the stem and leaves, which may be related to the presence of antioxidant components such as polyphenolics and phenolic acids, as well as the presence of β-sitosterol, which is also associated with hepatoprotection and decreased blood cholesterol levels (Dwivedi, Sachan & Wal, 2024). These *in vivo* studies corroborate the ethnomedicinal use of leaf decoction for the treatment of icterus, as reported in Guinea. The reduction of cholesterol levels is also a mechanism observed in the study by Ahmed et al. (2021), which includes the promotion of homeostasis between HDL and LDL levels, in addition to the normalization of other hepatic markers. Moreover, the antioxidant properties of flavonoids, tannins and phenolics, together with extracts rich in unsaturated fatty acids, such as those found in the fruit peels, seems to contribute also to the cardioprotective activity, decreasing elevated serum creatine kinase-MB, lactate dehydrogenase and other cardiac markers (Suleiman et al., 2021), as well as to the anticonvulsant effect, reported in the study of Reddy et al. (2018), and to the cancer prevention, also presenting cytotoxic effects (Ariffin et al., 2021).

Despite the large number of *in vitro* and *in vivo* studies conducted with *Musa paradisiaca*, some gaps need to be filled for a better understanding of the pharmacological and functional potential of the species. The fact that extracts of high chemical complexity have been used most of the time does not yet allow us to see if the pharmacological effects are related to a synergistic effect or only to certain substances or special groups of metabolites, so bio-guided studies should be recommended. Furthermore, although bananas are rich in phenolic and polyphenolic substances with high antioxidant capacity, these substances have a highly polar characteristic, which hinders bioavailability. Studies with optimized formulations that improve the absorption of these active components, such as nanoparticles or liposomes, are necessary, as seen in some studies included in this review (Imade et al., 2022; Sofini et al., 2024). Equally important, differences in sample size, the *in vitro* nature of some experiments, extraction conditions and the potential variability in phytochemicals profile or their concentrations could influence in the significance of the pharmacological results, so that standardization of these parameters are necessary. Finally, the actual effectiveness for human health must be proven through clinical trials, comparing consumption through ethnobotanical forms, extracts, and processed products, in order to standardize doses and obtain conclusive experimental results.

CONCLUSIONS

The systematic review of available research highlights the extensive traditional use of *Musa paradisiaca* as an antidiarrheal agent and for the treatment of skin diseases. Among the most extensively studied pharmacological effects are its antimicrobial, antidiabetic, and anti-inflammatory activities. Recent studies indicate that soluble fiber plays a crucial role as an antidiarrheal agent in *in vitro* models, while flavonoids, tannins, and saponins have demonstrated antidiarrheal and hemostatic properties in *in vivo* studies, effectively reducing bleeding time. Additionally, phenolic acids and fatty acids are significant metabolite classes in *M. paradisiaca* and may contribute to its pharmacological properties. In this context, the recent studies presented and analyzed in this review provide an updated and comprehensive understanding of the medicinal and chemical properties of *M. paradisiaca*, a species widely cultivated worldwide. This focused knowledge aims to facilitate its more precise and evidence-based application in the fields of medicine, nutrition, and pharmacy. In addition, studies that concern standardizations, clinical assays, development of formulations and pharmaceutic associations must be carried out to mensure a complete and real extension of the *M. paradisiaca*'s pharmacological potential.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.

DATA AVAILABILITY STATEMENT

This section is not applicable to this review.

AUTHOR'S CONTRIBUTIONS

Conceptualization, formal analysis, supervision, writing – original draft, J. G. G.-V.; Project administration, visualization, E. A. V.-C.; Data curation, writing – review and editing, Zs. H.; Data curation, F. R. R.-L., M. E. G.-R., R. A. R.-P., C. N. S. B., and K. A. C. G.; Supervision, G. G.-P.; Validation, G. S. R.-R.; Formal analysis, writing – Original Draft, R.D.D.G.A.

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SAVREMENI PREGLED ETNOMEDICINSKIH, FARMAKOLOŠKIH I HEMIJSKIH ASPEKATA BANANE *(MUSA PARADISIACA)*

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Sažetak: *Musa paradisiaca* Link (Musaceae) predstavlja vrstu od značaja ne samo u gastronomiji, već i u etnomedicini. Ovaj rad pruža sistematski pregled tradicionalnih primena, farmakoloških aktivnosti i fitohemijskih sastojaka ove biljke. Analizom literature iz baza Scopus, ScienceDirect, PubMed Central i Alicia, identifikovano je 70 relevantnih radova, objavljenih pretežno između 2015. i 2025. godine. U tradicionalnoj medicini plod *M. paradisiaca* se najčešće koristi za tretman dijareje, dok drugi organi biljke pokazuju raznovrsne terapijske funkcije, uključujući zarastanje rana, kontrolu dijabetesa i ublažavanje simptoma prehlade. Fitohemijske analize ukazuju na prisustvo flavonoida, fenolnih kiselina, masnih kiselina, kalcijuma i kalijuma kao glavnih bioaktivnih jedinjenja u zrelim plodovima, dok se različiti metaboliti nalaze u drugim delovima biljke. Nedavne *in vitro* i *in vivo* studije potvrđuju širok spektar bioaktivnosti, uključujući antimikrobna, antioksidativna, antiinflamatorna, antidijabetička i svojstva zarastanja rana. Rastvorljiva vlakna, flavonoidi, tanini i saponini identifikovani su kao ključne klase bioaktivnih jedinjenja odgovorne za ove efekte. Zaključno, savremena etnobotanička, fitochemijska i farmakološka istraživanja proširuju naučna saznanja o medicinskim potencijalima *M. paradisiaca*, pružajući osnovu za njenu primenu u oblastima ishrane, farmacije i medicine.

Ključne reči: *banana, primena u medicini, fitohemikalije, dijareja, zarastanje rana*

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