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VALORIZATION OF BANANA FLOWER RESIDUES: POTENTIAL THERAPEUTIC AND ANTIOXIDANT APPLICATIONS

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João Paulo Souza Simão da Silva[1], Mirian Bomfim Fernandes[2], Jociel Honorato de Jesus[3] and Taline Canto Tristão[4]

ABSTRACT

Various parts of the banana tree (Musa spp.), such as leaves, fruits, inflorescences, roots, peels and stems are used in traditional medicine, in several cultures around the world, for the treatment of diarrhea, ulcers, pain, inflammation, and diabetes mellitus. The inflorescence, in turn, stands out as a promising by-product of the banana agroindustry, since it is rich in micronutrients and bioactive compounds relevant to the human health, such as β-sitosterol, flavonoids, saponins, and phenolics like catechin and isoquercetin. Studies reveal that the consumption of banana inflorescences can provide various health benefits, including improved intestinal function, weight management and reduced risk of cardiovascular diseases. For this work, a bibliographic narrative review was carried out with a focus on the valorization of banana flower residues, exploring its therapeutic and antioxidant potential. The research was developed through the analysis of scientific articles and relevant studies, highlighting the bioactive properties of these by-products and their potential applications in the pharmaceutical and food industries. This review showed that banana inflorescences are rich in phenolic compounds, flavonoids and terpenoids, which have antioxidant, antidiabetic, anti-inflammatory and antimicrobial properties. Therefore, these by-products can be used by the pharmaceutical and food industries and can contribute to the circular economy and sustainable management of agricultural resources.

Keywords: Banana Inflorescences. Bioactive Compounds. Antioxidant Potential.

[1] Master's student in Pharmaceutical Sciences
Federal University of Juiz de Fora (UFJF)
E-mail: joaopaulosouza_@hotmail.com
ORCID: https://orcid.org/0000-0002-7761-3919
[2] Pharmacy student
Federal University of Juiz de Fora (UFJF)
E-mail: mirian.fbomfim@gmail.com
ORCID: https://orcid.org/0009-0005-5244-7829
[3] PhD student in Geography
Federal University of Rondônia (UNIR)
E-mail: jociel.honorato@unifaema.edu.br
ORCID: https://orcid.org/0000-0002-4588-2508
[4] PhD in Infectious Diseases
Faema University Center (UNIFAEMA)
E-mail: taline.tristao@unifaema.edu.br
ORCID: https://orcid.org/0000-0003-2787-080X

INTRODUCTION

The Musaceae family is widely recognized for including some of the world's most significant fruits, such as bananas and plantains (Christelová *et al*., 2011). While bananas, scientifically known as *Musa spp*., have Asian origins, plantains (*M. paradisiaca*), which result from the combination of Musa acuminata and Musa balbisiana, are predominant in Africa, especially in Central and Western regions (Embrapa, 2019; Ploetz *et al*., 2007).

Various parts of *Musa spp*., including leaves, fruits, inflorescences, roots, peels, and stems (Figure 1), are used in traditional medicine to treat several health conditions, such as diarrhea, ulcers, pain, inflammation, and diabetes mellitus (Nirmala *et al*., 2012). This medicinal use is widespread and observed in various cultures around the world, particularly in the Americas, Asia, Oceania, India, and Africa (Tsamo *et al*., 2015).

Among the various by-products generated by the banana agro-industry, the inflorescence stands out as a promising nutritional resource. It is rich in micronutrients and bioactive compounds relevant to human health (Lau *et al*., 2020; Silva *et al*., 2023). Bioactive compounds such as β-sitosterol, flavonoids, saponins, and phenolics like catechin and isoquercetin are present in the inflorescence (Bortolanza; Nunes; Quináia, 2024; Fingolo *et al*., 2012).

The consumption of banana inflorescences can provide various health benefits, including improved intestinal function, weight management, and reduced risk of cardiovascular diseases (Nogueira *et al*., 2022). Moreover, these bioactive compounds serve as a beneficial alternative for postpartum mothers, aiding in breastfeeding (Amornlerdpison *et al*., 2020).

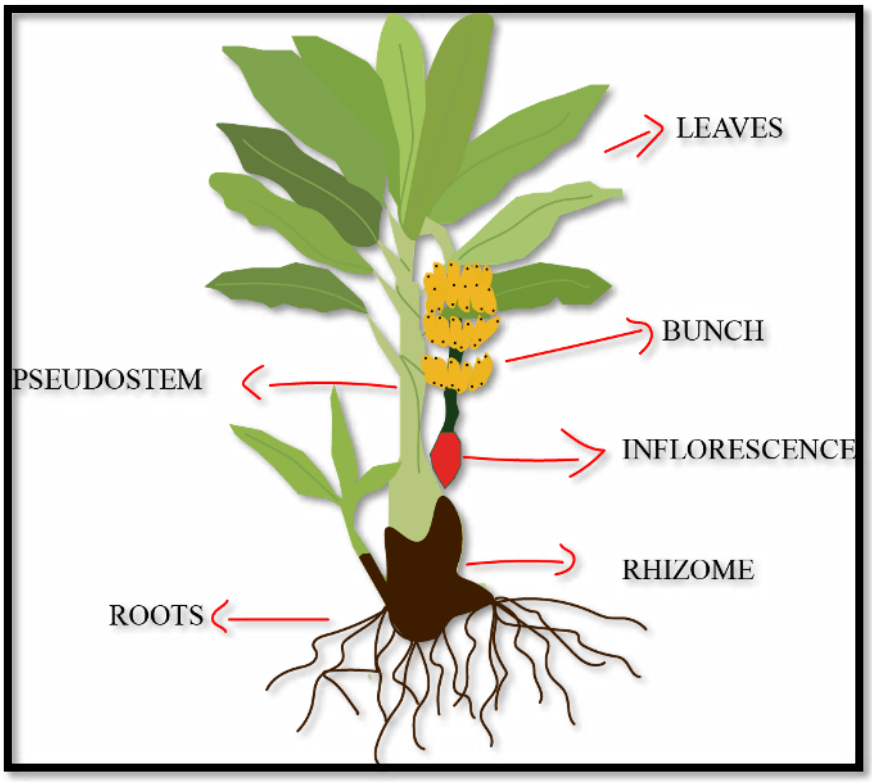
Once frequently discarded during harvest, the inflorescence is now gaining attention as a functional food ingredient due to its nutritional value and bioactive compounds (Lau *et al*., 2020; Bortolanza; Nunes; Quináia, 2024). The utilization of these parts can have a significant impact on both functionality and income generation for small-scale farmers, while also contributing to environmental waste reduction (Nogueira *et al*., 2022).

For this study, a literature review was conducted focusing on the valorization of banana flower residues, exploring their therapeutic and antioxidant potential. Various scientific articles and studies were analyzed to highlight the bioactive properties of these byproducts, as well as their potential applications in the pharmaceutical and food industries (Ravindran; John; Jacob, 2021). The methodology included collecting data from reliable sources and critically evaluating the presented results.

The objective of this study is to emphasize the benefits of the bioactive compounds present in banana flowers and bracts, promoting awareness of the importance of utilizing

these resources sustainably and efficiently.

Figure 1. Banana Tree (*Musa spp.*).



Source: Created by the authors (2024).

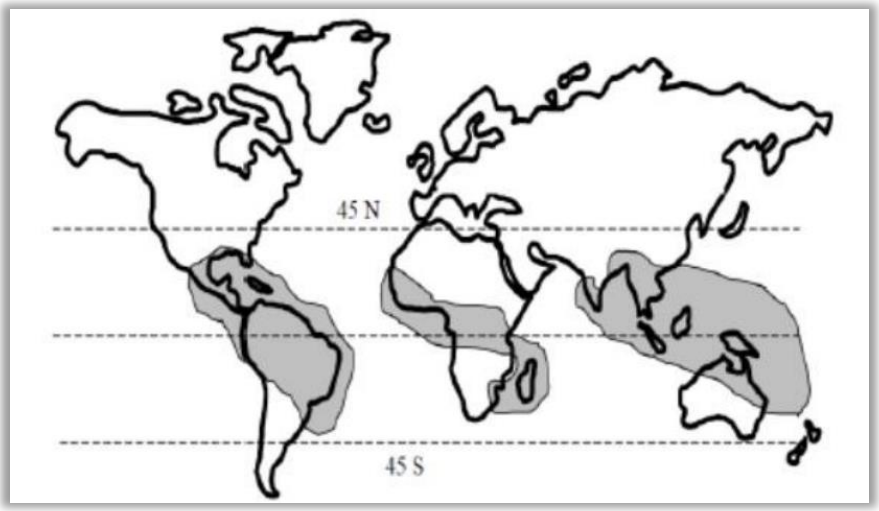
THEORETICAL FRAMEWORK

MUSA SPP

Cultivation, Geographic Distribution, and Global Consumption of Banana Plants

Banana cultivation, typically a tropical crop, is predominantly carried out between the latitudes of 30° S and 30° N of the Equator, with ideal conditions lying between 15° South and North. In Brazil, banana plants are cultivated in all states, adapting to a wide variety of ecosystems. Although the ideal conditions for their growth include tropical climates with temperatures ranging between 15°C and 35°C (Figure 2), and preferably 18°C at night and 25°C during the day, banana plants can also be cultivated in cold subtropical regions or semi-arid tropics, although extreme temperatures and water scarcity may limit their productivity. Generally, the closer to the Equator, the better the climatic conditions for cultivation, given the plant's need for constant warmth, high humidity, and well-distributed rainfall (De Olanda Souza *et al.*, 2022; Silva *et al.*, 2012; Van Den Bergh *et al.*, 2012).

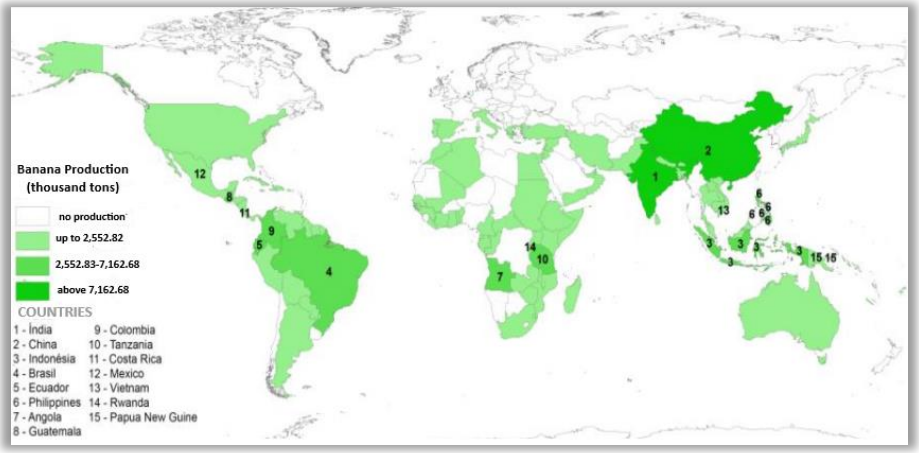
Figure 2. Distribution of Banana Culture in the World



Source: Adapted from Vieira (2011, p.3).

Bananas are widely consumed globally, both in their natural form and in various processed forms such as fried, baked, sweets, and chips. In 2017, the FAO (Food and Agriculture Organization of the United Nations) reported that bananas are produced in 128 countries, making it one of the most popular fruits worldwide (Figure 3).

Figure 3 – Spatial Distribution of World Banana Production.



Source: Adapted from FAO – Spatial Distribution of Banana (2017).

DIVERSITY AND GENETIC IMPROVEMENT

The Musa genus, belonging to the Musaceae family, encompasses over 50 species with various subspecies, taxonomically divided into five distinct sections. Callimusa and Rhodochlamys are known for their ornamental uses. The Ingentimusa section stands out for having only one species, *Musa ingens*. The section Australimusa includes the edible banana *Musa maclayi* and *Musa textilis*, cultivated for fiber production. However, the most significant section is Eumusa, which contains the majority of banana cultivars used in

agriculture. This section houses ten species, such as *Musa acuminata* and *Musa balbisiana*, which are fundamental for commercial banana production (Souza, 2002; Ribeiro, 2010).

Genetic studies reveal that varieties such as *Musa paradisiaca* and *Musa sapientum* are, in fact, hybrids, and not separate species. This classification is based on groups with 10 or 11 chromosomes. Diploid forms of *Musa acuminata* (genome A) crossed with *Musa balbisiana* (genome B) have given rise to edible hybrid diploids (AA, AB, BB) and triploids (AAA, AAB, ABB). The complexity increases with the occurrence of tetraploidy (AAAA, AAAB, AABB, ABBB) and the potential contribution of a third wild species, indicating a significant human intervention in the diversification of these hybrids, thus complicating the nomenclature of bananas (Simmonds; Shepherd, 1955; Martins *et al.*, 2005; Castro; Kluge; Sestari, 2008; Santos, 2012).

In the context of the genetic complexity of the Musa genus, significant efforts are being made to develop genetically enhanced banana plants. EMBRAPA in Brazil and the Honduran Agricultural Research Foundation are leaders in this field, developing tetraploid hybrids (AAAB), such as FHIA 17 (AAAA) and FHIA 18 (AAAB). These new hybrids, designed to resist pathogens such as *Mycosphaerella fijiensis Morelet*, *Mycosphaerella musicola*, and *Fusarium oxysporum* f.sp. *cubense*, offer a dual advantage: they are resistant to nematodes and fungi, reducing the dependency on fungicides, and consequently, improving the quality of the products by decreasing the use of chemical products in the cultivars (Nomura *et al.*, 2020).

The BRS Pacoua is a variety of the Pacovan banana type, developed by EMBRAPA Cassava and Fruit Culture, recommended mainly for the Northern region of Brazil, particularly Pará. It is characterized by its resistance to fruit drop and high rusticity, qualities valued in family farming. Commonly used in agroforestry systems, BRS Pacoua is often intercropped with crops like black pepper, guarana, cupuaçu, and cocoa. This variety is popular for fresh consumption and has good commercial acceptance in Pará (Amorim *et al.,* 2013).

The banana cultivar BRS Vitória stands out for its resistance to key diseases such as Black Sigatoka, Yellow Sigatoka, and Panama disease, as well as anthracnose in post-harvest. These characteristics provide significant economic advantages for producers. BRS Vitória has high-quality fruits with a longer shelf life, making it commercially attractive. Its fruits, when ripe, feature an intense yellow peel, cream pulp, sweet flavor, and lower acidity compared to the common silver banana, making it appealing to consumers (Reis *et al.,* 2016; Silva *et al.,* 2020).

The cultivar also excels in productivity, exceeding 44 tons per hectare from the second cycle under ideal cultivation conditions, and adapts well to different planting spacings. Its resistance to major banana diseases, including Panama disease and the Sigatokas, is particularly valuable, given that these diseases can cause significant production losses. The BRS Vitória, being resistant and productive, meets the demand for bananas in the State of Amazonas and is a viable alternative for expanding banana cultivation in areas affected by these diseases (Weber *et al.,* 2017).

CHEMICAL COMPOSITION

Bananas are an energetic food consumed worldwide in both their green and ripe forms due to their nutritional value (Table 1), offering sugars, polyunsaturated fatty acids, sterols, minerals such as potassium, and vitamins such as pro-vitamin A and vitamins B1, B2, and C. Moreover, they are rich in bioactive compounds, including glycosides and acids like malic and oxalic acids. Heating at 65°C for 30 minutes can reduce the enzymatic activity of the pulp without degrading the total phenolics (Arinzechukwu & Nkama, 2019; Mathew & Negi, 2017; Rao *et al*., 2016).

Table 1. Chemical Composition of *Musa spp.*

Parameter	Content (g)
Energy	371kJ (89Kcal)
Moisture	65.5-75.3
Protein	0.9-4.9
Lipids	0.3-2.9
Crude Fiber	1.6-2.9
Sugars	23.9-43.8
Ash	0.9-2.22
Vitamins	(mg, daily value)
Pantothenic Acid	0.334 (7%)
Pyridoxine	0.4 (31%)
Choline	9.8 (2%)
Vitamin C	8.7 (10%)
Minerals	(mg)
Magnesium	27 (8%)
Phosphorus	22 (3%)
Potassium	358 (8%)
Sodium	1 (0%)
Zinc	0.15 (2%)

Source: Adapted from Kookal & Thimmaiah (2018); Dotto, Matemu, & Ndakidemi (2019).

BIOACTIVE CONSITITUENTS PROFILE

Bananas' bioactive components are categorized into polyphenols, phytosterols, triterpenoids, fatty acids, and fibers, which are associated with a broad range of beneficial biological activities. The polyphenols, including hydroxybenzoic acids such as gallic and hydroxycinnamic acids like caffeic, along with flavonoids such as catechins and flavonols

like quercetin, are recognized for their antioxidant properties and antidiabetic activities. These compounds also exhibit cytotoxic activities, induce apoptosis, and possess antimicrobial and anti-inflammatory effects. Phytosterols and triterpenoids, including compounds like β-sitosterol and lupeol, contribute to cardiovascular protection, while fatty acids, such as oleic and linoleic, and both soluble and insoluble fibers complement the nutritional and therapeutic profile of the banana, enhancing its value in healthy diets and disease prevention (Lau *et al*., 2020; Ajijolakewu *et al*., 2021).

INFLORESCENCE OF *MUSA SPP*

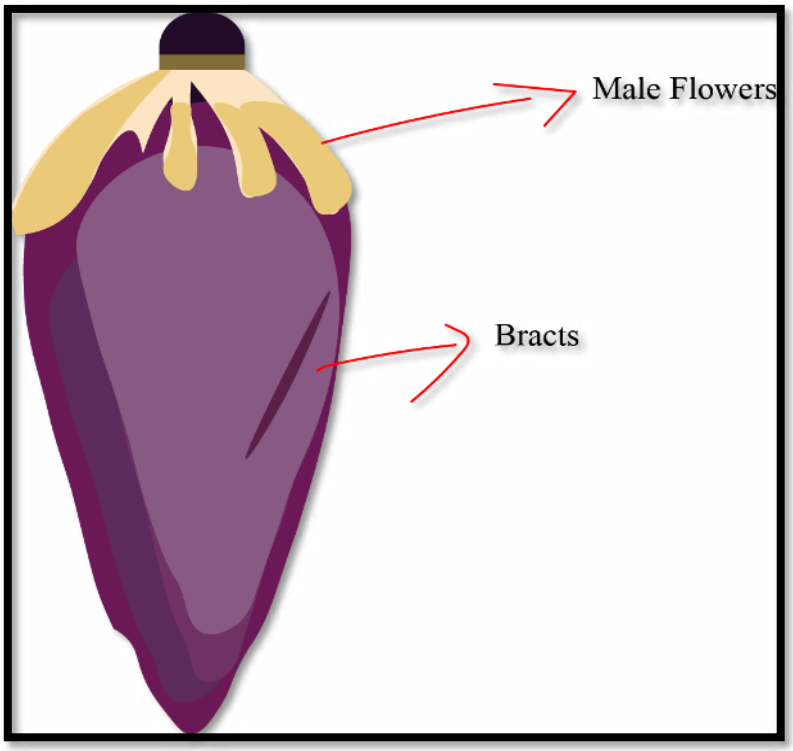
Description, Culinary use and Bioactive Potential

The structure known as the banana flower, often referred to as "umbigo" (navel), "banana flower," "banana heart," or "flower bud," encompasses male flowers wrapped in characteristic red-purple bracts (Figure 4). In banana cultivation, the bract is removed to favor fruit development, making the inflorescence a common agricultural waste (Rodrigues, 2020). While many farmers discard it during harvest, in Asian countries, it is a common ingredient in culinary preparations. In Brazil, however, its use is more typical in rural areas, in snacks or salads, linked to socioeconomic factors (Fingolo *et al*., 2012; Khanum *et al*., 2000). Additionally, it is considered that the consumption of cooked flowers has great potential for diabetes control (Kumar* *et al*., 2012).

Over time, various studies have explored the biological impacts of the banana inflorescence. These investigations have revealed several properties, including galactagogue effects (Mahmood; Omar; Ngah, 2012), anti-inflammatory (Lee, K. H. *et al*., 2011), antioxidant (Ahmad, Bashir Ado *et al*., 2015), and antihyperglycemic activities (Jawla; Kumar; Khan, 2012).

Recent studies reinforce these findings, indicating that the banana inflorescence extract possesses antidiabetic and antilipidemic properties (Ara; Tripathy; Ghosh, 2019; Vilhena *et al*., 2020). Furthermore, banana bracts are rich in fibers and have antioxidant properties, making them an economical alternative for obtaining bioactive compounds (Begum; Deka, 2019; K B, A *et al.,* 2019).

Figure 4 - Inflorescence of *Musa spp.*



Source: Created by the authors (2024).

CHARACTERIZED COMPOUNDS AND PROVEN BIOLOGICAL ACTIVITIES

The presence of chemical constituents in *Musa spp*. inflorescences is noteworthy, with flavonoids being particularly highlighted. According to studies by Ganugapati, Baldwa, and Lalani (2012), these flavonoids have been characterized and shown to possess significant antioxidant properties. These phytochemicals, particularly abundant in the bracts of the flowers, include subgroups such as anthocyanins and flavanones. Anthocyanins contribute to the vibrant colors and provide protection to the plants, while also offering cardiovascular benefits and improvements in vision for consumers. Flavanones, specifically naringenin and hesperetin, were identified in *Musa spp*. flowers and are recognized for their high antioxidant potential, as described by Ren *et al*. (2011) and Sharma *et al*. (2015). Additionally, these compounds play a therapeutic role in diabetes management and the prevention of its complications, demonstrating the therapeutic value of *Musa spp*. inflorescences and justifying the growing research into their pharmaceutical and nutraceutical applications.

Musa spp. inflorescences are also a rich source of phenolic acids, a range of compounds that includes gallic acid, catechol, protocatechuic acid, gentisic acid, vanillic acid, caffeic acid, syringic acid, p-coumaric acid, ferulic acid, and epicatechin. These phenolic acids have been shown to be effective as α-amylase and aldose reductase inhibitors, as reported by Alim *et al*. (2017) and Tundis, Loizzo, and Menichini (2010),

playing a crucial role in reducing blood sugar levels. This property highlights the therapeutic potential of *Musa spp*. flowers in diabetes management, emphasizing the importance of these compounds in modulating metabolic processes and glycemic control.

Furthermore, *Musa spp*. flowers, specifically *Musa paradisiaca* and *Musa balbisiana*, are characterized by the presence of significant terpenoids. These include compounds such as seringin, benzyl alcohol glycoside, (65R)-roseoside, 1,1 dimethylallyl alcohol β-glycoside, 3'1-norcycloaundenone, cycloartenol, and (24R)-4α,24-trimethyl-5α-cholesta-8,25(27)-dien-3β-ol. These terpenoids have shown to be effective as α-glucosidase and α-amylase inhibitors, suggesting a therapeutic potential in regulating carbohydrate digestion and blood sugar levels. The discovery of these compounds in *Musa spp*. expands the understanding of the bioactive capabilities of the plant, paving the way for new pharmacological and nutritional applications.

In addition, *Musa spp*. has shown promise as a source of antimicrobial and phytochemical compounds that could be integrated into modern medicine, as suggested by Ajijolakewu *et al*., 2021, and Mostafa *et al*., 2021 (Table 2).

Table 2 – Identified Antimicrobial Compounds

Plant Part	Compound	Action	Reference
Banana Oil	1-Nonadecene, β-caryophyllene	Antimicrobial	Fahim *et al*. (2019)
	1,2-benzenedicarboxylic acid, δ-3-Carene, β-Myrcene	Antifungal	
Banana Fruit	Tetradecanoic Acid, Hexadecanoic Acid, DL – Limonene, Epicatechin	Antibacterial	(Pereira; Maraschin, 2015)
Banana Peel	Gallocatechin, Dopamine	Antibacterial	(Vu *et al*., 2018)
	Ferulic acid, gallic acid, chlorogenic acid, hydroxybenzoic acid, malic acid	Antimicrobial	(Suleria *et al*., 2020)
Banana Pseudostem	Gentisic acid, malic acid	Antimicrobial Antifungal	(Mokbel; Hashinaga, 2005)
	(+)-Catechin, Cinnamic Acid, Caffeic Acid	Antimicrobial	(Saravanan; Aradhya, 2011)
Banana Flower	Lupeol, Umbelliferone	Antimicrobial	(Chiang *et al*., 2020)

Source: Adapted from Mostafa (2021).

The banana plant is increasingly recognized for its applications in the food industry due to its antimicrobial properties and the potential use of its various parts. It can serve as a functional ingredient in baked goods, dairy products, beverages, and meat, providing fibers/prebiotics and acting as a natural antioxidant. Additionally, waste from banana

production — about 80% of the plant's total mass — can be repurposed, enhancing sustainability. Bioactive compounds such as dopamine and ferulic acid contribute to its antimicrobial properties, which can improve food safety. The components of the banana plant are also being studied for the creation of biodegradable packaging, offering a solution to plastic waste disposal (Tibolla, 2018; Mostafa 2021).

METHODOLOGY

The present research was conducted through a narrative bibliographic review using the following databases: PubMed, Google Scholar, and Scielo. The search was filtered by free full-text access, clinical trials, meta-analyses, randomized clinical trials, and reviews. Additionally, the search was conducted using the following keywords: Banana inflorescences, Bioactive compounds, Antioxidant potential.

CONCLUSION

This review highlighted one of the underutilized byproducts generated by banana farming, which in some regions are used as food and medicinal resources, as they are rich in phenolic compounds, flavonoids and terpenoids. These bioactive compounds have several antioxidant, antidiabetic, anti-inflammatory and antimicrobial properties, which can be used by the pharmaceutical and food industries. Furthermore, these by-products can contribute to the circular economy and sustainable management of agricultural resources. Therefore, it is necessary to carry out more studies in this area that is still little explored.

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