

# Antimicrobial and Antioxidant Efficiency of Different Extracts of Banana Flower: A Meta Review

## Review Article

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### Abstract

Banana (*Musa spp.*) flower is an unutilized agricultural by-product with growing academic interest in light of its well-balanced content of bioactive phytochemicals and possible therapeutic benefits. This review will discuss and critically evaluate the available literature on the antimicrobial and antioxidant potential of banana flower extracts obtained by the use of various solvents. To extract these compounds, many different solvents have been commonly used, like methanol, ethanol, chloroform, hydro-ethanol, hydro-chloroform, and the polarity of the solvents has been found to be a significant factor in extraction yield. Many studies have indicated that polar solvents especially methanol and ethanol tend to achieve higher concentrations of phenolic substances and strong antioxidant properties, which are usually measured using techniques like DPPH radical scavenging frameworks. In the same manner, antimicrobial effect on a number of pathogenic microorganisms has been reported using conventional microbiological tests which means that banana flower extracts have potential as natural antimicrobial agents. The evidence obtained indicates that extracts of banana flowers have high antioxidant and antimicrobial activity and can be used as potential natural alternatives to be applied in food preservation, pharmaceutical preparation, and in the development of nutraceuticals. Moreover, the fact that banana flower is used as a value-added product demonstrates the need to consider agricultural by-products as renewable sources of bioactive compounds with possible industrial and therapeutic use.

**Keywords:** Banana Flower; Antioxidant Activity; Antimicrobial Activity; Phytochemical Compounds; Solvent Extraction

## Introduction

Banana (*Musa spp.*, often formerly referred to as *Musa sapientum* L.) is an example of a climacteric fruit, that define the staple foods in tropical regions of world. According to, FAOSTAT (2014) [1] has indicated that world banana production is about 126 million beyond 150 countries, which means that plantains and bananas are one of the ten essential food crops along with export commodities in the world. Over the last few years, plant-derived proteins have

received significant consideration towards their use in the feed, food, pharmaceutical, cosmetics sector (Kitts and Weiler 2003) [2]. Banana is also industrially processed to produce several products, which include canned flowers in brine, dried vegetables, pickles, and some pharmaceutical preparations, especially banana blossoms (Wickramarachchi and Ranamukhaarachchi 2005) [3]. Plant sources of bioactive peptides have been shown to inhibit growth of Gram-negative and Gram-positive bacteria with some also having antiviral and antifungal properties (Shai 2002; Reddy et al. 2004) [4,5].

Moreover, these peptides of vegetable source are linked to various medicinal activities, such as anticancer, antioxidant, proteinase inhibitory and chitinase (Hoskin and Ramamoorthy 2008; Sinha et al. 2014) [6,7].

The trend that leans towards natural food additives has also escalated the study on plant-derived antibacterial agents (Tiwari et al., 2009) [8] whose applications in food systems have great potentials. However, the sustainability of these natural antibacterials in the long term is highly determined by the sources of the raw materials of these substances in terms of accessibility and quantity (McChesney et al., 2007) [9]. Agro-response, especially banana plantation can be considered a promising and sustainable resource. Banana is also one of the fruits most produced in the world with an estimated annual production of around 120 million tons in banana varieties, including plantain fruits (FAO, 2008) [10]. Nevertheless, even with this scale-based production, significant amounts of biomass, which are approximately 220 tons per hectare (Shah et al., 2005) [11], are still not utilized and in most cases, they are treated as agricultural by-products instead of value-added products.

Banana inflorescence, which is a unique floral arrangement that grows in the end part of the bunch of fruits and continues to grow till fruit maturity is one of these products. It is traditionally eaten in various Asian societies either raw or cooked as a vegetable. The inflorescence provides an appropriate target to be used in studying the antibacterial properties given that it is widely available. Previously, the studies of the different banana byproducts of the various cultivars have shown significant antibacterial properties (Mokbe and Hashmaka, 2005) [12], antioxidant properties in the fruit peels (Someya et al., 2002) [13] and flowers (Ho et al., 2007) [14], and antifungal properties in fruits (Roobha et al., 2011) [15].

The studies of various banana flower extracts (*Musa spp.*, *Musa acuminata* and *Musa paradisiaca*) are underway due to the fact that the biological activity of this plant is extremely dependent on the extraction method and solvent. Various phytochemicals in banana inflorescence include phenolic acids, flavonoids, tannin, anthocyanin, however, they vary in terms of polarity and solubility. Consequently, methanol, ethanol, aqueous, acetone or other solvent systems films off various categories of bioactive constituents at different concentrations. As the antioxidant and antimicrobial activities are directly proportional to the total phenolic and flavonoid content, comparative extraction investigations are required to reveal which solvent system is best to extract phytochemical and biological activity. Dosage cannot be standardized, reproducibility cannot be ensured, no extract can be optimized to be used in preservation of pharmaceutical, nutraceutical, or food products without investigating the various extracts (Sulaiman et al., 2011; Singh et al., 2016) [16,17].

This study as well conducted in order to fulfill more scientific and general public health requirements. The growing need to

combat oxidative stress-related diseases, the world-wide epidemic of antimicrobial resistance, has made the quest to find safe bioactive compounds of plant origin even more demanding. The banana flower is an agricultural by-product, which is underutilized but can be used as an antimicrobial and antioxidant, and is thus the potential natural alternative to synthetic additives and food conventional antibiotics. Through the examination of various extracts, scientists strive to determine the most productive fraction that has a high biological activity and low toxicity and, in such a way, promotes the creation of natural therapeutic agents and value-added products of low cost (Vijayakumar et al., 2019) [18]. Essentially, the study is motivated by secure natural antioxidant, new antimicrobial agent and efficient use of agro-resources (Table 1) (Table 2).

### Overall Trend

Polar solvents, particularly methanol, ethanol, and hydroethanolic mixtures, consistently demonstrate superior extraction of phenolic and flavonoid compounds, resulting in stronger antioxidant and antimicrobial activities. In contrast, non-polar solvents such as hexane and petroleum ether generally show lower biological activity because of their limited ability to extract phenolic constituents.

### Antimicrobial Assay

It is undisputed that plant secondary metabolites are bioactive and have been historically utilized as therapeutic agents and natural preservatives (Tiwari et al., 2009) [8]. These are compounds that be a major contribute in the defense of plants to various environmental stressors, microbial infestations, and herbivore attacks (Munne-Bosch et al., 2001; Huang et al., 2006) [19,20]. It has been shown that a number of plants possess the potential to produce antibacterial and antioxidant compounds that can find applications in pharmaceutical and food sectors (Oyelana et al., 2011) [21]. Nevertheless, the problem of antimicrobial resistance in bacteria that are growing increasingly with genetic mutations and horizontal gene transfer between species underscores the necessity of new natural antibacterial agents (Davidson and Brannen, 2005; Adeleke and Omafuvbe, 2011) [22,23].

Based on the established significance of plant secondary metabolites as natural antimicrobial agents, the analysis of banana flower (*Musa spp.*, *Musa acuminata* and *Musa paradisiaca*) by use of standardized antimicrobial tests has gained growing importance. The most common antimicrobial evaluation techniques including agar well diffusion, disc diffusion, minimum bactericidal concentration (MBC) and minimum inhibitory concentration (MIC) determination are extensively accustomed measure the inhibitory activity of plant extracts against pathogenic microorganisms. These tests will give crucial information on antimicrobial spectrum, potency and dose-dependent response. Balouiri M et al. (2016) [24] argue that reproducibility and sound cross-comparisons of plant-derived

| Table 1: Review Study of Banana Flower. |                                                                                                                                       |                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
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| Year                                    | Name of the paper                                                                                                                     | Authors name                                                                                                   | Findings                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 2024                                    | Antidiabetic and Antibacterial Activity of Musa Flower Extract by using urine Sample from Gestational Diabetes Patients               | A. NASHIKA FATHIMA<br>DR.K. ARUNTHATHI                                                                         | It is assessed in this study that hydro-alcoholic extract of <i>Musa paradisiaca</i> flower is capable of antibacterial activity against bacterial isolates in the urine samples of pregnant women with gestational diabetes in identifying <i>Citrobacter freundii</i> and showing significant inhibitory activity as well as promising a-amylase and b-glucosidase inhibition. The results indicate its possible importance in prevention and care of infections and diabetes in maternal health.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 2017                                    | Extraction and characterization of proteins from banana ( <i>Musa sapientum</i> L.) flower and evaluation of antimicrobial activities | kewalee Sitthiya, Lavarai Devkota, Anil chaurasia                                                              | <p>Response surface methodology was used in optimizing sonication alkaline extraction of protein in banana flower. Fourier transform infrared spectroscopy was used to evaluate the purified proteins, and gel electrophoresis was used to determine the molecular weight distribution. Optimal extraction conditions of 252.25 mg/g protein were achieved at a temperature of 50°C, 30 min extraction time, and 1 M NaOH concentration. The alkaline extraction gave a considerably large yield of protein relative to enzyme extraction of banana flower. Protein fingerprinting chemistry demonstrates that tyrosine, tryptophan, and amide bonds were present in extracted protein. Protein extracts of banana flowers that had alkaline and pepsin as aids exhibited a typical band at 40 and 10 KDa, respectively. The obtained proteins possessed antimicrobial potential of Gram- positive and Gram- negative microorganisms. These properties are that it contains protein-rich content and germicide activity, which means that banana flower can be utilized in provisions and feed production.</p>                                                                                                                                                                                                                 |
| 2021                                    | Emida Mohamed<br>Siti Nazrina Camalxaman<br>Azlin Sham Rambely<br>Norhisham Haron                                                     | The medicinal benefits, phytochemical constituents and antioxidant properties of banana blossom: A mini review | <p>Banana (<i>Musaceae</i> spp.) is a common food crop and is primarily eaten as an important product in most third-world countries. Nevertheless, its flowers will always go to waste as agricultural products. They contain bioactive compounds as well, and such by-products are of great demand in our health maintenance. Although the recent research indicated banana blossom as having similar plant metabolism. This analysis thus attempts to examine the flavonoids composition, flavonoids effects, and curative uses of banana heart; hence, that is a possible desired foods that has a wide range of nutraceutical applications. All the source and learning utilized in this analysis have been retrieved out of different computer databases, including Web of Science, Scopus, medline, ScienceDirect, and Google Scholar. The writing investigations had revealed to this review the bio effective compounds of this banana blossom: phenolics, flavonoids, dietary fibers, tannin, saponins, and vitamins; and possible bioactive of this banana flower, which include antioxidant, anti-hyperglycemic, anti-inflammatory, and disinfectant. Therefore, it can be achieved that banana flowers have the right amount of valuable secondary metabolites, which are essential in ensuring proper health.</p> |

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| 2020 | Shu-Hua Chiang, Kia-Min Yang, Ying-Chiao Lai                                                                                                                                                                | Evaluation of the <i>in vitro</i> biological activities of Banana flower and bract extracts and their bioactive compounds                                                                           | <p>The banana flower used in this study was separated leaf and staminate flower and tack out using aqua and ethyl alcohol as to various warmth, and subsequently the usefulness of the take out was tested and the phytochemicals in the extract were tested. The results revealed that the banana flower take out of 50 percent ethanol and a warmth of 50°F (FE-50 percent 50°F) exhibited the most DPPH radical scavenging capacity and hydroxyl radical scavenging capacity of 97.44 percent and 38.86 percent, respectively. In addition, FE-50%-500 also had the best reducing power. The banana flower ethanol 50% extract at room temperature (FE-50%-RT) was the extract with the best ferrous ion chelating ability of 96.82.</p> <p>The 95 percent ethanol extract of the banana flower inhibited the activity of 95 percent, 31.75 84.17 percent, 84.17, and 70.59 percent of 95 percent alpha amylase, alpha glucosidase, and lipase activity, respectively. The greatest alcohol reductase activity was 74.92 at FE-50 percent-50°C. Moreover, FE-95%-50°C contained the most amount of clerdol and skimmetin, with 40.10 and 90.83 1g/mg, separate.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 2024 | Extraction of bioactive phytochemicals on Berlin banana flower ( <i>Musa acuminata</i> AA.) using continuous system-designed ultrasound machine                                                             | Bambang Susilo<br>Abd. Rohim<br>Wirawan<br>Midia Lestari Wahyu Handayani<br>Muhamad Nur Azis<br>Melenio Eko Haryono                                                                                 | <p>The banana flower, Berliner (<i>Musa acuminata</i> AA), was also prevalent in Indonesia and is said to have rich bioactive phytochemical constituents. An ultrasound machine with the design of a continuous system (CDUM) was used as a novel prototype to obtain the constituents of the Berlin banana flower. Three parts of the Berlin banana flower (inner bud, outer bud, and male flower) were extracted, after every 15 min each, in the various polarities (distilled water, 100% ethanol, and 50% ethanol). A new component, CDUM, that was installed is a double-jacket chiller to maintain a constant temperature (<math>\leq 30^{\circ}\text{C}</math>) to operate. Findings: the 50% ethanol produced the best extract yields of all extracted parts of the Berlin banana flower of the parts. The average yield of extract of each part was, however, equal. The extract of the male flower part contained the greatest percentage of antioxidant capacity. The extracts of the various parts of Berlin banana flowers contained bioactive phytochemical classes, i.e., phenolics, terpenoids, ergo-alkaloid, aminoalkanoic acid descendant, fatty esters, organic sulfide compounds, and plant-based. The 12 compounds of the staminate flower part extract contained the richest phenolics, including gallic acid, caffeic acid, 2, 3-Dihydro-1-benzofuran-2-carboxylic acid, 4-(hydroxymethyl) benzoic acid, and 2, 5-di-tert-Butylhydroquinone, only present in the male flower part extract. The CDUM made the banana flower in Berlin more productive (dense harvest, consuming less energy) compared to the traditional method.</p> |
| 2025 | Therapeutic Potential of Banana Pseudo-Stem Extracts: A Systematic Review and Meta-Analysis of Antioxidant, Anti-Inflammatory, Antimicrobial, and Anti-Urolithiatic Properties with Risk of Bias Assessment | D Govindan Devi,<br>Sangeetha ,S<br>Arbind Kumar Choudhary,<br>Panneer Selvam                                                                                                                       | <p>The systematic review and comprehensive review study assesses the reducing agents, anti-inflammatory, prophylactic and anti-urolithiatic features of banana pseudo-stem extracts with regard to efficacy and safety under rigorous bias assessment and quantitative analysis. The expected outcomes would be to identify the therapeutic potential, safety and clinical applicability as well as research gaps that can be used to conduct further research on banana pseudo-stem as a plant-based therapy.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 2025 | Banana ( <i>Musa acuminata</i> & <i>Musa balbisiana</i> ): India's Beloved Plant with a Wealth of Pharmacological Treasures                                                                                 | Nabam Piya, Hiyashree Sharmah, Hasmi Waris, Prasurjya Saikia, Himanshu Gogoi, Dhiman Patowary, Hemanga Mazumdar, Topobon Bordoloi, Izaz Hussain, Lakhyajit Borah, Sneha Parbin & Kangkan Jyoti Saud | <p><i>Musa acuminata</i> and <i>Musa balbisiana</i> are highly endowed in bioactive substances such as flavonoids, alkaloids or phenolics which are beneficial to antioxidant, antimicrobial, antidiabetic and anticancer effects.</p> <p>These banana species can be very therapeutic in the development of modern drugs, but more research is required to isolate active compounds and confirm clinical outcome.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

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| 2014 | Evaluation of antibacterial properties of <i>Musa paradisiaca</i> L. Leaves                                                                               | Naikwade P.V., Salavi Gaurav, Dalavi Sharayu and Jadhav Kailas                                                                                                | Antibacterial activity of banana leaves ( <i>Musa paradisiaca</i> L.) was evaluated with the help of various solvent extracts made by means of Soxhlet extraction. Ethanol extract exhibited good broad-spectrum antibacterial activities against <i>E.coli</i> and <i>Staphylococcus aureus</i> just like Ciprofloxacin.                                                      |
| 2023 | The Extraction and Impact of Essential Oils on Bioactive Films and Food Preservation, with Emphasis on Antioxidant and Antibacterial Activities—A Review. | SohailKhan, Abdulah A. A.Abdo, Ying Shu, Zhisheng Zhang and Tiegiang Liangs.                                                                                  | This review brings to the fore the antibiotics and reducing agent effects of volatile oils and their request in preserving food stuffs in a natural manner. It explains their integration into bioactive films to overcome food preservation, better phenolic stability and prolonged shelf life, their methods of extraction and their associated advantages and constraints. |
| 2020 | Phytochemical Analysis and Antibacterial Efficacy of Ethanolic Extract of <i>Musa paradisiaca</i>                                                         | B. Deepa & T. Sivakumar                                                                                                                                       | The agar well diffusion technique indicated the alcoholic extract of the plant <i>Musa sapientum</i> L. had antibiotic properties against <i>Staphylococcus aureus</i> , <i>Bacillus subtilis</i> and <i>E. coli</i> . Its efficiency can be attributed to high levels of phenols; hence it usable as a realistic bioactive agent substance processing sectors.                |
| 2021 | Cancer Preventive and Therapeutic Potential of Banana and Its Bioactive Constituents: A Systematic, Comprehensive, and Mechanistic Review.                | Arijit Mondal, Sabyasachi Banerjee, Sankhadip Bose, Partha Pratim Das, Elise N. Sandberg, Atanas G. Atanasov, and Anupam Bishayee.                            | Banana plants particularly <i>Musa acuminata</i> and <i>Musa balbisiana</i> are found to have varied bioactive compounds in every part which leads to various health benefits. They also have several pharmacological behaviour such as antioxidant, antimicrobial, hypoglycemic and anticancer, which are yet to be critically reviewed.                                      |
| 2021 | In vitro antibacterial, antioxidant, and cytotoxicity evaluations of <i>Musa paradisiaca</i> cv. Sekaki florets from Sarawak, Malaysia                    | Muhammad Mirza Ariffin, Heng Yen Khong, Nyotia Nyokat, Gee Moi Liew, Ahmad Sazali Hamzah, and Korawinwich Boonpisuttinant                                     | Solvents extracts of the florets of <i>Musa paradisiaca</i> had good contents of phenolic and flavonoid, which has contributed to significant antioxidant and antimicrobial activities. The ethyl acetate extract also exhibited moderate cytotoxic activity in cancer cells meaning that it would have therapeutic effects.                                                   |
| 2022 | Extraction and Evaluation of the Antimicrobial Activity of Polyphenols from Banana Peels Employing Different Extraction Techniques                        | Faiqa Chaudhry, Muhammad Laiq Ahmad, Zafar Hayat, Muhammad Modassar Ali Nawaz Ranjha, Komal Chaudhry, Nouredine Elboughdiri, Mutarref Asmari, and Jalal Uddin | Another agro industrial waste that was discovered excellent source of natural polyphenols with antioxidant properties was banana peels. The extraction using sonication was more effective than the extraction using maceration and the highest content of polyphenols were obtained using ethanol.                                                                            |

**Table 2:** Comparison of Different Extraction Solvents and Their Reported Antimicrobial and Antioxidant Efficiencies in Banana Flower Extracts.

| Solvent System                | Relative Extraction Efficiency of Phenolics | Reported Antioxidant Activity                                                                      | Reported Antimicrobial Activity                                                      | Key Observations                                                      | References                                                                        |
|-------------------------------|---------------------------------------------|----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Methanol                      | Very High                                   | Strong DPPH radical scavenging activity; high phenolic content                                     | Strong inhibition against Gram-positive and Gram-negative bacteria; lower MIC values | Most effective polar solvent for extracting phenolics and flavonoids. | Ao et al., 2008[30]<br>Sulaiman et al., 2011[15]<br>Vijayakumar et al., 2019 [17] |
| Ethanol                       | High                                        | Strong antioxidant activity; lower EC values than aqueous extracts                                 | Significant antimicrobial activity with large inhibition zones                       | Food-grade solvent with high extraction efficiency and safety.        | Jamuna et al., 2012 [29]<br>Chiang et al., 2021 [48]<br>Ariffin et al., 2021 [45] |
| Hydro ethanol (Ethanol–Water) | High                                        | Comparable or superior antioxidant activity due to extraction of a broader range of phytochemicals | Effective antibacterial activity reported against clinical isolates                  | Combines advantages of water and ethanol for phytochemical recovery.  | Fathima, 2024 [51]<br>Vijayakumar et al., 2019 [17] ; Sulaiman et al., 2011[15]   |
| Acetone                       | Moderate to High                            | Good antioxidant activity associated with phenolic extraction                                      | Limited antimicrobial data available                                                 | Efficient extraction of certain flavonoids and phenolics.             | Yang et al., 2007 [31];<br>Sulaiman et al., 2011 [15]                             |
| Ethyl Acetate                 | Moderate                                    | Moderate antioxidant activity                                                                      | Moderate antimicrobial activity                                                      | Selectively extracts semi-polar compounds.                            | Yang et al., 2007 [31];<br>Chaudhry et al., 2022 [47]                             |
| Water (Aqueous)               | Moderate                                    | Antioxidant activity present but generally lower than ethanol or methanol extracts                 | Mild to moderate antimicrobial activity                                              | Safe and inexpensive, but less efficient for phenolic extraction.     | Shodehinde & Oboh, 2013 [27];<br>Jamuna et al., 2012 [29]                         |

|                              |                 |                                                |                                 |                                                            |                                                                                                                 |
|------------------------------|-----------------|------------------------------------------------|---------------------------------|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| Chloroform / Hydrochloroform | Low to Moderate | Lower antioxidant activity than polar solvents | Variable antimicrobial activity | Extracts less polar constituents; lower phenolic recovery. | Mentioned in extraction studies; support can be cited from Chiang et al., 2021[48] and Jamuna et al., 2012 [29] |
| Petroleum Ether / Hexane     | Low             | Weak antioxidant activity                      | Weak antimicrobial activity     | Poor extraction of phenolic compounds due to low polarity. | Yang et al., 2007 [31]; Sulaiman et al., 2011[15]                                                               |

extracts and traditional antimicrobial agents is achieved by the use of standardized in vitro susceptibility testing methods. Methanolic and ethanolic extracts have often been found in banana flower to have larger inhibitory zones and a lower MIC value than non-polar fractions depending on the solvent polarity effect on antimicrobial activity.

Banana flower extracts have a close relationship between their phytochemical properties and the antimicrobial activity, with the presence of phenolic acids, flavonoid, tannin, and anthocyanin. These substances have the ability to destabilize cell membranes of microbes, precipitate proteins within the cell, chelate necessary metal ions and disrupt the production of nucleic acids. The various ways in which plant phenolics act as antimicrobials were described as proposed by Cowan MM (1999) [25] as follows; membrane disruption and enzyme inhibition are some of the pathways. Dalia M (2012) [26], on the same note, indicated that polyphenols are highly active against pathogenic organisms in food and clinically-relevant organisms, which explains their possible use as natural food preservatives and natural therapeutic agents. Besides, Burt S (2004) [27] emphasized the capacity of phenolic compounds of plant origin to change the permeability of the membranes and disrupt the metabolic activity of microorganisms. This multi-target mode of action is especially relevant when it comes to the increased antimicrobial resistance where it is less likely to induce resistance unlike the single-site synthetic antibiotics. As such, the whole antimicrobial testing of various banana flower extracts is critical not only in the validation of their bioactivity but also to determine powerful fractions that can be used to develop new antimicrobial agents derived using plants.

### Toxicity Study

Banana flower (*Musa spp.*) extracts have in general been toxicologically tested in the in vivo and in vitro contexts with a positive safety profile. In an acute oral toxicity study carried out following OECD guidelines, once administered at graded doses up to 2000mg/kg body weight, Wistar rat showed zero mortality, behaviour abnormalities, change in body mass, food intake, and body part morphology; thus, indicating an LD<sub>50</sub> of more than 2000mg/kg (Shodehinde and Oboh, 2013) [28]. The biochemical parameters such as serum aspartate aminotransferase (AST), alanine aminotransferase (ALT), creatinine, and urea were within the normal physiological values, and this showed there were no evident hepatotoxic or nephrotoxic conditions. Equally, in streptozotocin-

induced diabetic animals, the use of banana flower extract as a supplement was able to markedly ameliorate the glycaemic and oxidative stress markers without causing histopathological changes to the liver or kidney tissues, which would confirm the systemic safety of banana flower extract in sub-acute exposures (Pari & Maheswari, 1999) [29]. The *in vitro* cytotoxicity studies with the use of mammalian cell lines (3T3-L1 preadipocytes) have also shown that banana flower extracts do not affect cell viability at concentrations of lower therapeutic relevance and did not cause any noticeable membrane rupture or apoptotic effects in the cell lines (Jamuna et al., 2012) [30]. The non-toxicity is explained by the fact that predominantly the naturally occurring phenolics and flavonoids are present, and those, although being bioactive, do not have cytotoxicity in the traditional experimental relationships. Nevertheless, although acute and sub-acute explorations are promising results, all-inclusive chronic toxicity, genotoxicity, and clinical safety testing have not been done, and additional standard toxicology studies are needed to be completed before the large-scale pharmaceutical or nutraceutical utilization can be completely approved.

### Total phenolic content of different extracts of banana flower

Banana flower (*Musa spp.*) phenolic extracts have been widely determined by Folin Cicaldeau colorimetric method, and the results are usually expressed in gallic acid equivalents (GAE). It is always shown in studies that the phenolic concentration is highly variable according to the polarity of the medium as well as the method of extraction used. Polar solvents like methanol and ethanol tend to produce high levels of phenolic content in contrast to the non-polar solvents like hexane or petroleum ether. As an example, Ao et al. (2008) [31] found that the total phenolic values of methanolic extracts were much larger and the antioxidant activities of the same extracts was much higher as compared to the less polar fractions. Likewise, it was noted that the extracts of acetone, ethanol, methanol, and ethyl acetate were excessive in phenolic concentration compared to the petroleum ether extracts (Yang et al., 2007) [32]. This observation highlighted the influence of solvent polarity in extracting the highest level of phenols. The banana inflorescence in particular, bud extracts often show higher levels of phenolics than bract extracts, which is associated with the presence of a positive relationship with DPPH radical scavenging ability and low EC<sub>50</sub>. High level of phenolic compounds has been explained by occurrence phenolic acids, flavonoids, and anthocyanins including cyanidin derivatives

that also give it hydrogen-donating and metal-chelating properties. According to these findings, the conditions of extraction of banana flower extracts are critical determinants of such phenolic yield and, by extension, the biological activity of the extracts, making solvent choice the key to phytochemical recovery in banana flower extracts.

### Antioxidant assay

Water, alcohols, acetone, and ethyl acetate are more ideal solvents in the extraction of antioxidants in banana inflorescence with over 50% of DPPH radical scavenging activity at  $1.0 \text{ mg mL}^{-1}$ , whereas non-polar solvents have little. The antioxidant activity has been attributed to such compounds as cyanidin rutinoside in *Musa acuminata bracts* (Roobha et al., 2011) [15] and the hydrogen-donating capacity of extracts that cause DPPH discoloration (Ao et al., 2008) [31]. The scavenging of DPPH was found to be dose dependent, with the ability of banana inflorescence leaf extract synthesized FeONPs reaching 87% at  $100 \text{ }\mu\text{g/mL}$ , inferior to ascorbic acid at the same concentration (Tabassum et al., 2023) [33].

It was found that the redox activity of the take out was ascertained utilize the setup test of the 1,1-dimethyl-2-phenylethyl formate. Picrylhydrazyl radical (DPPH) is an example of a thorough founded on a process determined by (Villano et al. 2007) [34] with some exceptions.

The DPPH test is a widely employed test in the antioxidant activity study. Ascorbic in the measurement of the percentage of radical scavenging activity, acid ( $\text{C}_6\text{H}_8\text{O}_6$ ) was employed as a standard. For in this test, 1 ml of 4 various concentrations (30, 50, 80, and  $100 \text{ }\mu\text{g/mL}$ ) of FeONPs was combined with 1 ml of freshly prepared DPPH (1 mM in methanol) solution. In it were mixed the DPPH radical solution and the DPPH radical. The solution was stirred with methanol for a reaction time of 30 minutes. The optical density of the mixture was calculated at 718 nm. In the antioxidant test, DPPH, it was taken as a positive control, and the methanol was used as a blank solution. The decrease of the presence of DPPH radicals due to the action of an antioxidant leads to deformation of the test solution.

Analysis of the activity of antioxidants in *M. paradisiaca* flowers showed that the ethanol extract used needed a lesser amount of substrate compared to the aqueous extract to prevent a 50% DPPH colour. This implies that ethanol was found to be more antioxidant active compared to aqueous extracts. The outcomes represent the occurrence of antioxidant principles in the extractives. The antioxidant activities were supposed to be there in the *M. paradisiaca* flower, as it has been so.

It is said to have vitamin E (Sheng et al., 2010) [35], vitamin C (Sun, Chu, Wu, and Liu, 2002) [36], and vitamin- E (Ching and Mohamed, 2001) [37]. The naturally occurring plant compounds tend to naturally correlate with their physiological activity as antioxidants. The difficulty of comparing them, however, is quite high.

The data of the DPPH scavenging capacity across various

laboratories is attributed to a limited number of reasons, which include response time, the attentiveness of DPPH, and the presence of antioxidant(s) in the mixture. The antioxidant effect of *M. paradisiaca* flowers could be linked to the attending of polyphenolic amalgam in the take out, including flavonoids, alkaloids, and tannins.

### Phytochemical Analysis:

The plant extracts were conducted using standard qualitative strategies such as those suggested by different authors. The stocking of the plant extracts was determined in relation to the presence of biologically active compounds. as in the glycosides, alkaloids, flavonoids, phenolics, saponins, steroids, and quinine and tannin. They are subjected to chemical analyses. plant sample of both the aqueous extract of the plant sample and the powdered plant. similar to ordinary sampling (Edeoga et al., 2005) [38].

Banana (*Musa* spp.) is the most important of all the tropical fruits. All the known cultivars of banana are high in concentrations of numerous of the main health-promoting phytochemicals of the diet, such as carbohydrates, potassium, vitamin C, carotenoids of fiber, and provitamin A. Vitamin A is the product of the precursor beta-carotene. The most prevalent nutritional issue is vitamin A deficiency around the world, among malnourished children (Davey et al., 2003) [39].

Most epidemiological research papers have discovered that enriched intake of plant-based foods is abundant. Nutritionists have an interconnecting relationship with lower risk of various diseases such as cancers and cardiovascular diseases (Englberger et al., 2003) [40].

Therefore, the most profitable and sustainable strategies are food-based. prophylaxis of vitamin A deficiency. Hence a wholesome inventory of all the genetic diversity that can be offered in the of all the genetic diversity that is there (Slavin & Lloyd, 2012) [41]. They make banana species very indispensable at this time, as they are sexually compatible species (Arvanitoyannis & Mavromatis, 2009) [42].

It is also necessary to know the numerous characteristics, such as the botanical, agronomic, nutritional, and processing quality of the fruits (Perrier et al., 2011) [43]. It turned out that there is a very huge amount of genetic diversity that the *Musa* species holds, and, unfortunately, only modest data are known as to the nutritional composition of even the wild species and the popular ones, often (WHO, 2009) [44-5] (Figure 1) (Figure 2).

### Discussion

The banana flower (*Musa* spp. has become a viable source of naturally occurring bioactive substances with strong antioxidant and antimicrobial qualities. The results presented in this review demonstrate the presence of significant phytochemicals that support the biological activities of banana flower extracts including phenolic

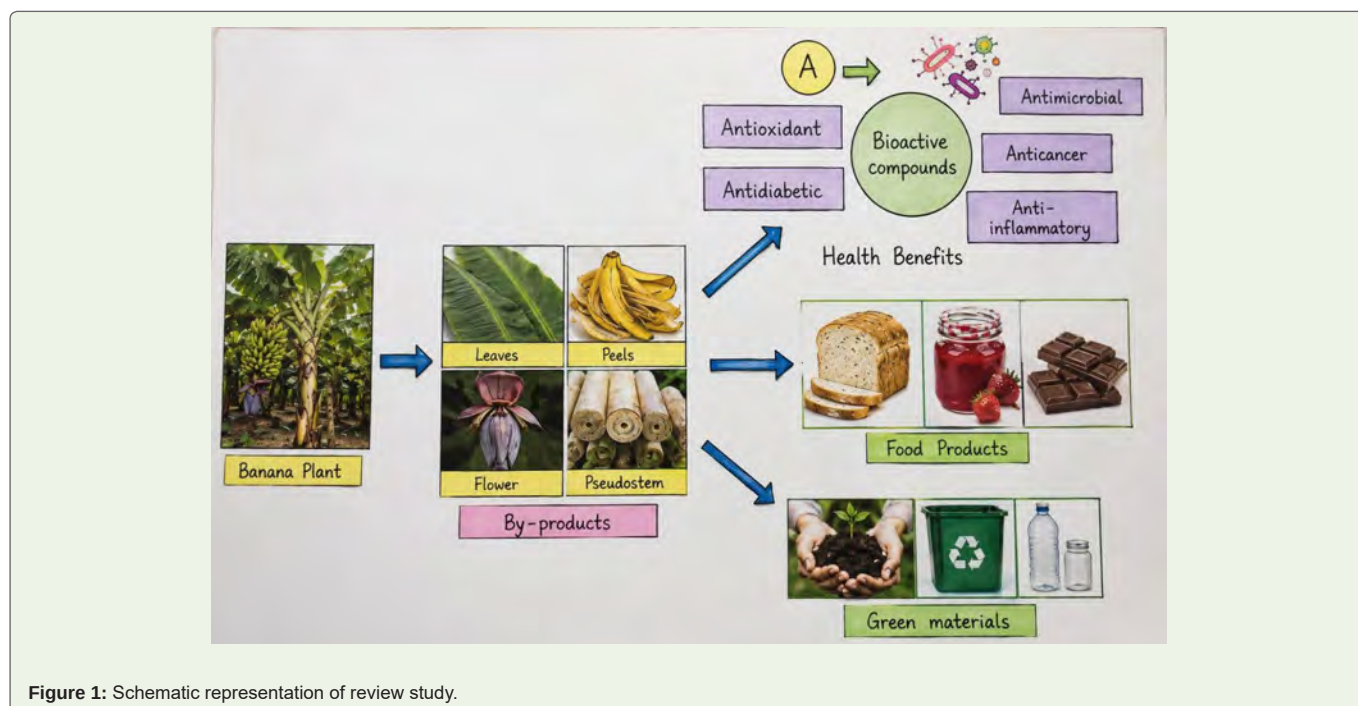


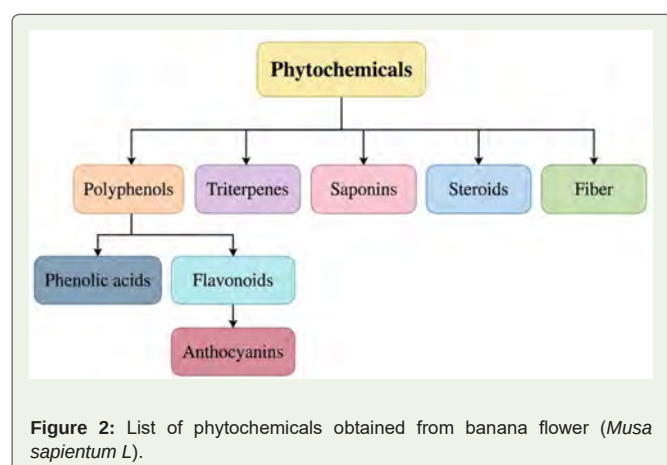
Figure 1: Schematic representation of review study.

compounds flavonoids tannins anthocyanins and other secondary metabolites. These substances are well-known for their capacity to scavenge free radicals stop the growth of microorganisms and offer defense against illnesses linked to oxidative stress. The kind of solvent used is one of the most significant variables affecting the extraction of these bioactive compounds. In comparison to nonpolar solvents like petroleum ether or hexane polar solvents like methanol ethanol and hydroalcoholic mixtures have continuously demonstrated greater extraction efficiency for phenolic compounds. Stronger antioxidant activity is strongly associated with higher phenolic content especially in tests like the DPPH radical scavenging method. According to studies banana flower ethanolic or methanolic extracts have strong antioxidant potential because they can donate hydrogen atoms and scavenge free radicals. Extracts from banana flowers have also been shown to have antimicrobial properties. Banana flower extracts have been shown to inhibit the growth of both Gram-positive and Gram-negative bacteria using standard microbiological techniques like disc diffusion agar well diffusion minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) tests. Phenolic acids flavonoids and tannins are primarily responsible for the antimicrobial effects since they can damage microbial cell membranes prevent enzyme activity and obstruct the synthesis of nucleic acids. Since plant-derived compounds are less likely to cause resistance than synthetic antibiotics this multi-target mode of action is especially crucial in light of the growing antimicrobial resistance. The medicinal potential of banana flower extracts is further supported by recent research. Hydroalcoholic extracts for example have shown antibacterial activity against pathogens isolated from patients with

gestational diabetes and other studies have reported strong enzyme inhibition potential and radical scavenging activity. Banana flower extracts have also demonstrated low toxicity in studies on animals and cell lines indicating a good safety profile for possible pharmaceutical and nutraceutical uses. The literature also emphasizes the importance of agricultural by-product valuation. Despite their great nutritional and medicinal value banana flowers are frequently thrown away during banana cultivation. In addition to adding economic value using banana flowers as a source of bioactive compounds encourages the use of renewable plant resources and reduces waste both of which support sustainable agricultural practices. But even with the encouraging results there are still a number of difficulties. Standardization is challenging because reported results frequently differ due to variations in extraction techniques solvent systems and experimental conditions. Furthermore, the majority of research has been done in vitro and thorough clinical and long-term toxicity studies are still lacking to properly validate the therapeutic uses of banana flower extracts. To isolate particular active compounds, improve extraction methods and assess their effectiveness through clinical studies more research is therefore required.

## Conclusion

Banana blossom (*Musa* spp. is an underutilized agricultural by-product that because of its rich composition of phenolic compounds flavonoids tannins and other bioactive metabolites has significant antimicrobial and antioxidant potential. According to research the polarity of the solvent is an important factor in the extraction of these compounds' polar solvents like ethanol and methanol yield extracts



with stronger biological activities and a higher phenolic content. Banana flower extracts antimicrobial qualities allow them to stop the growth of different harmful microorganisms while their antioxidant capacity is primarily linked to their capacity to neutralize free radicals and lower oxidative stress. These biological activities demonstrate the potential of banana flower extracts as natural substitutes for artificial antioxidants and antimicrobial agents in nutraceuticals pharmaceutical formulations and food preservation. Additionally, by transforming an underutilized by-product into a useful source of functional compounds the use of banana flowers supports sustainable agricultural practices. Further research is necessary to standardize extraction techniques isolate active compounds and carry out thorough clinical studies to confirm their efficacy and safety for large-scale applications even though preliminary studies show encouraging safety and therapeutic potential. All things considered the banana flower is an important natural resource with a great deal of promise for advancement in the domains of biotechnology food science and medicine.

Future research should be focused on standardizing extraction procedures, identifying and characterizing the specific bioactive compounds responsible for the observed antimicrobial and antioxidant activities, and validating their efficacy through *in vivo* and clinical studies. Advanced extraction technologies such as ultrasound-assisted, microwave-assisted, and green solvent extraction may further enhance the recovery of valuable phytochemicals while improving sustainability. From an industrial perspective, banana flower extracts show considerable potential for application as natural food preservatives, functional food ingredients, nutraceutical supplements, pharmaceutical formulations, and cosmetic products. The valorization of banana flowers, an abundant agricultural by-product, could also contribute to waste reduction, sustainable resource utilization, and the development of cost-effective bio-based products.

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## Conflicts of interest

No potential conflict of interest was reported by the authors.

## Funding and Ethical consideration

The article does not contain any studies with human participants or animals by any of the author.

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