

A Comprehensive Review on Phytochemical, Nutritional, and Therapeutic Importance of *Musa acuminata*

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ABSTRACT

Introduction: *Musa acuminata*, Musaceae, popularly known as 'banana', is a perennial tree-like herb cultivated in many tropical and subtropical regions around the world. Banana, eaten as a fruit or a vegetable, is one of the most important crops in several countries due to its enriched food and versatile medicinal value. Plant contains apigenin glycosides, myricetin glycoside, myricetin-3-O-rutinoside, delphinidin, pelargonidin, peonidin, and malvidin. naringenin glycosides, kaempferol-3-Orutinoside, dopamine, N-acetyl serotonin, and rutin, has been reported in the plant. They found higher content of polyphenols, flavonoids, total dietary fibre, insoluble dietary fibre, lignin, hemicellulose, cellulose, lipids, proteins, and minerals.

Objective: The prime objective of the current study is to validate and highlighting the medicinal and nutritional importance of *Musa acuminata*.

Methods: A literature review has indicated the use of *Musa acuminata* in the treatment of various diseases such as fever, cough, bronchitis, dysentery, allergic infections, sexually transmitted infections, and some non-communicable diseases. The reported pharmacological activities of *Musa acuminata* include antioxidant, antidiabetic, immunomodulatory, hypolipidemic, anticancer, and antimicrobial especially anti-HIV activity.

Results: Pharmacological investigations support the traditional importance of the medicinal plant and probably support the folk uses of *Musa acuminata* by the indigenous people to treat and heal many infections and diseases. However, individual bioactive constituent(s) from different parts of this plant need further investigations to confirm various pharmacological claims and to explore the potential of *Musa acuminata* in the development of drugs and use in functional foods.

Conclusion: A comprehensive assessment of the biological activities of *Musa acuminata* is included and possible mechanisms and phytochemicals involved have also been correlated to provide effective intervention strategies for preventing or managing diseases.

Key Words: *Musa acuminata*, Banana, Musaceae, Nutritional value, Phytochemistry, Pharmacology

INTRODUCTION

Throughout evolution, the importance of botanicals for medicine and health has been enormous. Ethnobotanical literature has described the traditional usage of plant extracts, infusions, and powders for years against many diseases. For ages, plant parts have been the sole means to treat diseases and injuries in several cultures around the world, and are still in use as a traditional treatment in various countries.¹ Many of these plants have been used solely based on a traditional notion and studies are now providing evidence of their efficacy. The World Health Organization WHO believes that

the significant population of developing countries relies on traditional medicine for their primary health care needs. Therefore, there is an increased demand for medicinal plants in developing and developed countries. However, most of them are still obtained from wild sources without applying scientific management; hence many species are under the threat of extinction.² Fruits and vegetables are an important component of a healthy diet. Some fruits like bananas offer great medical benefits. This is partly because bananas aid in the body's retention of calcium, nitrogen, and phosphorus, all of which work to build healthy and regenerated tissues. *Musa acuminata* Colla is a wild species of banana

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that is native to Southeast Asia. Various parts of the *Musa* plants have been used orally or topically as remedies in folk medicine and some studies have demonstrated this medicinal potential. It is known for many pharmacological activities and reports show that phenolic compounds present in *Musa acuminata* mainly contribute to this trait. All parts of the plant which include the roots, stem, pseudostems, leaves, fruits, and flowers have long been used in local and traditional medicine in America, Asia, Oceania, India, and Africa. The present review paper highlights the food and medicinal importance of different parts of the *Musa acuminata* plant. An integrated profile of the composition and nutritive value of the edible fruit is also provided. A comprehensive assessment of the biological activities of different plant parts is included and possible mechanisms and phytochemicals involved have also been correlated.³

Taxonomy and Classification⁴

Kingdom: Plantae

Clade: Tracheophytes

Clade: Tracheophytes

Clade: Angiosperms

Order: Zingiberales

Family: Musaceae

Genus: *Musa*

Species: *M. acuminata*

Synonyms

Musa acuminata is highly variable and the number of species. The following are the most commonly accepted species are *Musa cavendishii* Lamb, *Musa Chinensis* Sweet, *Musa corniculata* Kurz, *Musa nana* Lour, *Musa × sapientum* var. *suaveolens* Blanco Malag, *Musa rumphiana* Kurz, *Musa simiarum* Kurz, and *Musa sinensis* Sagot ex Bake, etc.⁵

The *Musa acuminata* plant exhibits considerable variation and has been split up into eight subspecies namely *Musa acuminata* subsp. *acuminata*, *Musa acuminata* subsp. *burmannica*, *Musa acuminata* subsp. *errans*, *Musa acuminata* subsp. *halabanensis*, *Musa acuminata* subsp. *malaccensis*, *Musa acuminata* subsp. *microcarpa*, *Musa acuminata* subsp. *siamea*, *M. acuminata* subsp. *truncate*, and three varieties namely *Musa acuminata* var. *chinensis*, *Musa acuminata* var. *sumatrana*, and *Musa acuminata* var. *tomentosa*.⁶

ORIGIN AND DISTRIBUTION

Musa acuminata belongs to the *Musaceae* family distributed in the hot, tropical regions of Southeast Asia.^{7,8} *Musa acuminata* has a relatively wide distribution, and Malaysia is con-

sidered as the primary centre of origin of *Musa acuminata*.^{9,10} Later it spread to India and Burma¹¹, the home of the native species of *M. balbisiana*. In the Indo-Burman peripheral area, natural hybridization of both *Musa acuminata* and *M. balbisiana* occurred and triploid AAA cultivars of banana arose, and therefore India is regarded as the major centre of origin for more than 300 types of banana cultivars out of the 600 types of *Musa* germplasm.¹²⁻¹⁸ Mention of banana in ancient Indian treatises such as Ramayana 2000 BC, Arthashastra 250 BC, and the Chilappthikaram 500 AD suggests the antiquity and long period of domestication of banana fruit in India. The genus name was adapted in the honor of Roman physician and botanist Antonius Musa 63 BC- 14 AD, and the species name *acuminata* is a Latin word for sharp or acuminate referring to the sharp apex of its fruits. *Musa acuminata* has been identified in the natural habitats of the Kaziranga forest range of Assam, Khasi hill ranges of Meghalaya, southern and middle Andamans, and in the Western Ghats of Karnataka in India.¹⁹ At present, *Musa acuminata* is grown in many countries worldwide, and the major producers are Brazil, China, India, Ecuador, Columbia, and Venezuela. The global distribution of *Musa acuminata* is shown in Figure 1.^{20,21}

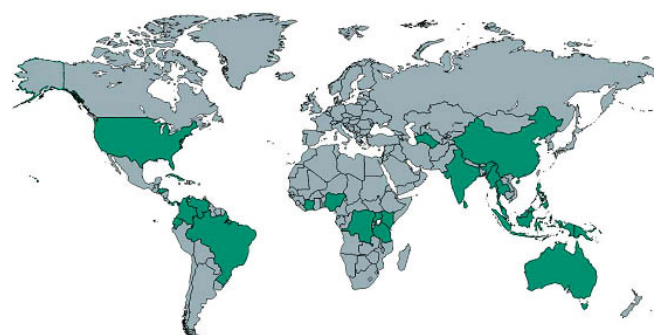


Figure 1: The global distribution of *Musa acuminata*

BOTANICAL DESCRIPTION

The plants are perennial and stooling sparsely 1- 2 stems or freely 4 - 30 stems. The leaf sheaths and petioles are more or less glaucous or pruinose. Leaf-blades are oblong 2.0- 2.5 m long x 0.4- 0.6 m wide, truncated at the apex, and usually rounded at the base, but leaf blades rounded on one side and acute on the other side are also reported. The inflorescence is subhorizontal or vertically deflexed. Fruits are narrowed at base into a pedicel of about 1 cm, and apex into a prominent acumen of 0.6- 1.5 cm length. The pericarp is about 2 mm thick with bright yellow colour at full ripeness, and the pulp is of white or cream-yellow to yellow colour. Seeds are dull black, smooth or minutely tuberculate, irregularly angulate, and measure 6- 7 mm in length and are of about 3 mm height (Figure 2).^{22,23}



Figure 2: The Whole plant (A), unripe fruit (B) and ripened fruits (C) of *Musa acuminata*.

PHYTOCHEMISTRY

The phytochemical analysis of different parts of *Musa acuminata* such as fruit, peel, flower, leaf, pseudostem, and rhizome has shown the presence of a rich diversity of phytochemicals like saponins, terpenoids, steroids, anthocyanins, fatty acids, tannins, phenols, and alkaloids. Phytochemicals content is reported to vary with the extraction method employed, and compounds identified in various plant parts of *Musa acuminata* are presented in Table 1.²⁴ Plants continue to be an important source of bioactive compounds and involve a multidisciplinary approach combining ethnobotanical, phytochemical, and biological techniques to provide new chemical compounds. The presence of bioactive compounds like apigenin glycosides, myricetin glycoside, myricetin-3-*O*-rutinoside, naringenin glycosides, kaempferol-3-*O*-rutinoside, dopamine, *N*-acetyl serotonin, and rutin, has been reported in different species of *Musa*.²⁵ The detailed structural presentations are reported in figure 3.

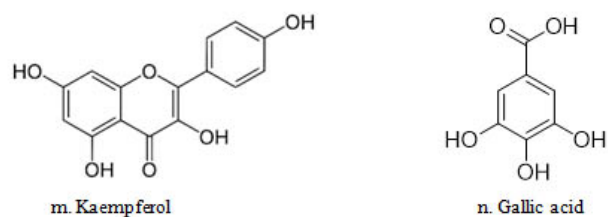
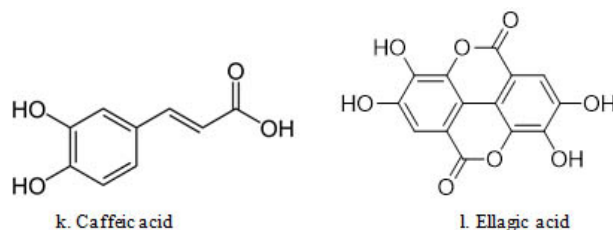
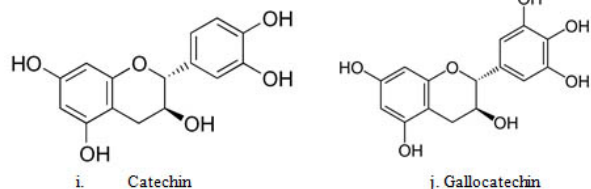
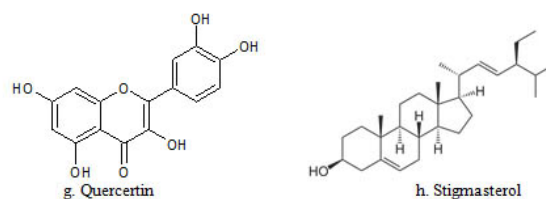
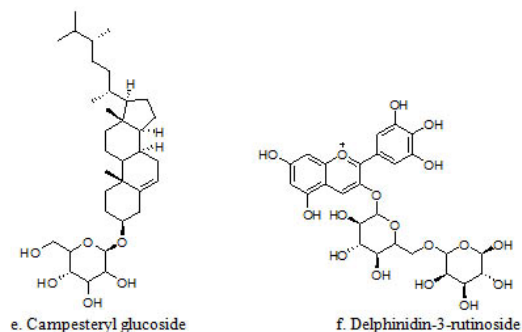
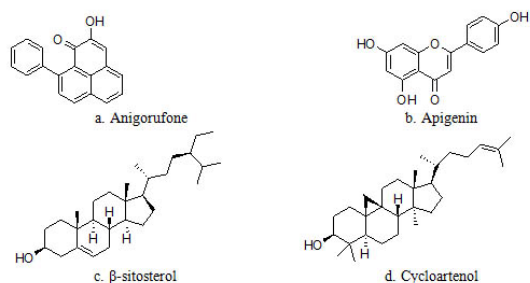


Figure 3: The General structural formulae active phytoconstituents reported in different parts of the *M. acuminata*.

Table 1: Major active phytoconstituents reported in different parts of the *M. acuminata*

Part of the plant	Extract	Active phytoconstituents	References
Ripe fruit	Pulp	phenolics, vitamin C, flavonoids (quercetin (fig. 3g), proanthocyanidins, catechin) pro-vitamin carotenoids, Banana Lectin (Ban-Lec), Banana thaumatin-like protein (Ban-TLP), Banana endo- β 1,3-glucanase (Ban-Glu)	26-28
	Ethanol	Alkaloids, saponins, tannins, terpenes, flavonoids, anthraquinones, cardiac glycosides, carbohydrates, glycosides, proteins, phenols, Kaempferol (fig. 3m).	29,30
	Dichloromethane	Fatty acids, octadeca- 9,12,15 trienoic acid, octadeca-9,12-dienoic acid, long chain aliphatic alcohols, sterols (campesterol, stigmasterol (fig.3h), β sitosterol) , cycloartenol, α - tocopherol	31
	Methanol	Saponins, triterpenes, tannins, (+) catechin (fig. 3i), gallicocatechin (fig. 3j), (-) epicatechin, procyanidins, phenolics	32,33
	Acetone	(+) Catechin hydrate, vanillic acid, caffeic acid (fig. 3k), epicatechin, ellagic acid (fig. 3l), Gallic acid (fig. 3n).	34
Unripe fruit	Pulp	2-(4'-hydroxyphenyl)- naphthalic anhydride, methyl 2-benzimidazole carbamate.	35
	Methanol	(+) catechin, gallicocatechin, (-) epicatechin, procyanidins, phenolics	32
Peel	Acetone: water	Phenolics, anthocyanins, dopamine, catecholamines	36
	Methanol	Glycosides, tannins, saponins, flavonoids, alkaloids, steroids, terpenoids, triterpenes, phenols, palmitic, oleic and linoleic acids and their methyl esters, 2,3- dihydro-3,5-dihydroxy-6- methyl-4H-pyran-4-one, 5-(hydroxymethyl) 2furancarboxyaldehyde, methyl hexadecanoate, methyl-9,12- octadienoate, methyl 1-9- octadecanoate, 9,12-ocatadecanoic acid, 13- octadecanoic acid, octadecanoic acid, 2- methyl-5-(1- methyl ethyl) phenol, pentadecanoic acid, cis-9- hexadecenal, cis-9- hexadecenoic acid, benzoic acid, pyrogallol, sesamin, epi-sesamin	37-40
	Hexane	Glycosides, tannins, saponins, flavonoids, carbohydrates	38
	Ethanol	Saponins, carotenoids, phenolics, flavonoids, tannins	38,41
Flower	Methanol	Glycosides, tannins, saponins, phenols, steroids, flavonoids	42
	Ethanol	Phenolics, tannic acid	43
Leaf	Acetone	Phenolics, tannic acid	43
	Petroleum ether	Phenolics, tannic acid	43
	Leaf powder	Cinnamic acid, ferulic acid	44
	Methanol	Anthocyanin, delphinidin-3-rutinoside (fig. 3f), cyanidin-3-rutinoside, petunidin-3-rutinoside, peonidin-3-rutinoside, malvidin-3-rutinoside, alkaloids, saponins, tannins, flavonoids, terpenoids, coumarins, cycloglycosides, total phenols, steroids	45-47
Bract	Petroleum ether	Alkaloids, cycloglycosides	45
	Ethyl acetate	Flavonoids	45
	Aqueous	Tannins, coumarins, total phenols.	45
	Ethanol	Sterols, flavonoids, glycosides, terpenoids, tannins, quinones	48
Corm	Extract	(S)-(+)-6-methoxy- α -methyl-2 naphthaleneacetic acid (Naproxen), Anigorufone, 2-methoxy- 9-phenyl-phenalen-1-one (REF2o), Anigorufone (fig. 3a)	
Rhizome	Extract	(S)-(+)-6-methoxy- α -methyl-2 naphthaleneacetic acid (Naproxen), Anigorufone, 2-methoxy- 9-phenyl-phenalen-1-one (REF2o), Anigorufone (fig. 3a)	
Root	Methanol	2-hydroxy-9- phenylphenalen-1-one (Anigorufone)	49
Seeds	Acetone	Leucoanthocyanidin	50
Sap	Ethanol	Hydrocinnamic acid, caffeoylquinic acid, Flavonoids (apigenin, myricetin, kaempferol, quercetin), dopamine, Nacetylserotonin, Campesterol glucoside (fig. 3e)	51

NUTRITIVE VALUE

Banana, tropical fruit with high calorie, provides exceptional nutrition in different forms. Banana, tropical fruit with high calorie, provides exceptional nutrition in different forms. Musa family contains starch, fructans, phenolic acid, anthocyanins, terpenoids, and sterols. In unripe plantains, starch is present over 80% of the dry weight of the pulp. The fat content of plantains and bananas are very less about 0.5% and so fats do not contribute much to the energy content.⁵² The total protein value of plantain is related to dry weight is more than 3.5% in ripe pulp and it is slightly less in fresh fruit. About 1.3% of sugars are present in total dry matter in unripe plantains, but this rise to around 17% in the ripe fruit. It is an excellent source of some vitamins like carotene (vitamin A), Thiamine (vitamin B₁), riboflavin (vitamin B₂), niacin (vitamin B₃), pyridoxine (vitamin B₆) and ascorbic acid (vitamin C). Pyridoxine is an important B-complex vitamin that plays a vital role in the treatment and management of neuritis and anaemia. Moreover, it helps to decrease homocysteine one of the causative factors in coronary artery disease CHD and stroke episodes level inside the body.⁵³ Potassium, an important component of cell and body fluids, supports muscles and nerves. Banana is rich in starch and it is a rich source of potassium. Potassium benefits the muscles as it helps maintain their proper working and prevents muscle spasms. Also, recent studies are showing that potassium can help to decrease blood pressure in individuals who are potassium deficient. Potassium also reduces the risk of stroke. In addition to manganese, magnesium is essential elements for strong bone and has a cardiac active role. Manganese is used as a co-factor in the body for the enzyme, superoxide dismutase oxidation. Copper is playing an important role in the production of RBCs. Banana is rich in fructose and sucrose. It replenishes energy and revitalizes the body instantly. It is a moderate source of health-promoting flavonoid and poly-phenolic antioxidants such as lutein and zeaxanthin. It contains β - and α -carotenes in small quantities. These compounds help act as protective scavengers and neutralize oxygen-derived free radicals and reactive oxygen species ROS.⁵⁴ Banana is rich in fatty acids, phytosterols, and steryl glucosides Steryl esters and free sterols such as campesterol, β -sitosterol (Figure 3c), cycloartenol (Figure 3d), and stigmasterol (Figure 3h) are the major lipophilic component found in the unripe banana peel.⁵⁵ Steryl esters and free sterols are the major lipophilic component found in unripe banana peel, while free fatty acids and sterols dominate banana pulp. Banana fruits contain a major quantity of essential mineral elements and could serve as a source of minerals in human and animal daily routine diets.^{56,57} Detail description of the nutritional importance of *Musa acuminata* is described in Table 2.

Table 2: Nutritional compositions of *Musa acuminata* fruit per 100 g on a fresh weight basis⁵⁸⁻⁶¹

Ingredients	Nutritional Value	Recommended daily allowance		
Energy	90 kcal	4.5 %		
Carbohydrates	22.84 g	18 %		
Protein	1.09 g	2 %		
Fat	0.33 mg	1 %		
Cholesterol	0 mg	0 %		
Dietary fiber	260 mg	7 %		
Vitamin	Folates	20 μ g	5 %	
	Niacin	0.66 mg	4 %	
	Pantothenic acid	0.33 mg	7 %	
	Pyridoxine	0.36 mg	28 %	
	Riboflavin	0.07 mg	5 %	
	Thiamin	0.031 mg	2 %	
	Vitamin A	64 IU	2 %	
	Vitamin C	8.7 mg	15 %	
	Vitamin E	0.10 mg	1 %	
	Vitamin K	0.5 μ g	1 %	
Electrolytes	Sodium	1 mg	0 %	
	Potassium	358 mg	8 %	
	Calcium	5 mg	0.5 %	
	Copper	0.07 mg	8 %	
	Iron	0.26 mg	2 %	
	Magnesium	27 mg	7 %	
	Manganese	0.27 mg	13 %	
Minerals	Phosphorus	22 mg	3 %	
	Selenium	1.0 μ g	2 %	
	Zinc	0.15 mg	1 %	
	α - Carotene	25 μ g	--	
	Phytonutrients	β - Carotene	26 μ g	--
		Lutein-Zeaxanthine	22 μ g	--
Glucose		22.84 g	18 %	
Carbohydrates	Fructose			
	Sucrose			

PHARMACOLOGICAL ACTIVITIES

Different parts of the *Musa acuminata* plant have shown potential for disease prevention in traditional medicine, which may be attributed to the rich and diversified content of phytochemicals present in them. Various models were used to investigate the health-promoting properties of *M. acuminata*, and description of available in-vitro and in-vivo models are detailed here.

Blood cholesterol-lowering property

The antioxidants property of kepok banana peel is due to the presence of saponin, tannin, and flavonoid and responsible for the decrease in the blood total cholesterol level. The current study determines whether saponin, tannin, and flavonoid in kepok banana peels are effective against total blood cholesterol levels in obese mice. This experiment using 20 obese male mice *Mus musculus L.* strain *Deutschland-Denken-Yoken* and divided into four groups, which are normal control group, obese control group, and groups that were given an extract of Kepok Banana Peel *Musa acuminata* treatment with dose 8,4 mg/day and 16,8 mg/day. The treatment was given in 14 days. The total cholesterol level of each group was measured by spectrophotometer. The results obtained $p=0,000$, in a one-way ANOVA test. Furthermore, the Post Hoc Test generally found that there were significant differences between groups. There is an effect of giving kepok banana peel to decrease the total cholesterol level of obese mice. The effect of kapok Banana peel extract level of 8.4 mg/day remarkably decreases total blood cholesterol level compared to banana peel extract level of 16.8 mg/day. The anti-cholesterol effect of banana fibre ethanol extract proved to a significant decrease in total cholesterol in obese male mice *Mus musculus L.* strain *Deutschland-Denken-Yoken*.⁶²

Antioxidative properties

Banana fruits *Musa acuminata* Juss. are important foods, but there have been very few studies evaluating the phenolics associated with their cell walls. In the present study, + catechin, gallic acid, and – epicatechin, as well as condensed tannins, were detected in the soluble extract of the fruit pulp; neither soluble anthocyanidins nor anthocyanins were present. In the soluble cell wall fraction, two hydroxycinnamic acid derivatives were predominant, whereas in the insoluble cell wall fraction, the anthocyanidin delphinidin, which is reported in banana cell walls for the first time, was predominant. Cell wall fractions showed remarkable antioxidant capacity, especially after acid and enzymatic hydrolysis, which was correlated with the total phenolic content released after the hydrolysis of the water-insoluble polymer, but not for the post hydrolysis water-soluble polymer. The acid hydrolysis released various monosaccharides, whereas enzymatic hydrolysis released one peak of oligosaccharides. These results indicate that banana cell walls could be a suitable source of natural antioxidants and that they could be bioaccessible in the human gut.⁶³

Hepatoprotective and Antiulcer activity

Plant-based natural remedies remain the treatment of choice as they are deemed effective, safe, and with minimal adverse side effects. The Natural Products Discovery Laboratory at the Institute of Bio-IT Selangor, Universiti Selangor, Malaysia carried out studies on the hepatoprotective, antiulcerogenic,

antioxidant, and cytotoxic activities of *Musa acuminata*. The results showed that under certain conditions, the methanolic extracts of unripe *Musa acuminata* showed equivalent activity to the commercial hepatoprotective drug silymarin and anti-ulcer drug omeprazole as demonstrated in the animal model. The extracts were not cytotoxic and exhibited low to moderate antioxidant activity. These ameliorative effects could be related to the saponins, flavonoids, and triterpenes in the peel and pulp extracts, and the tannins present in the peel extract. Further investigations are required to optimize the extraction of bioactive compounds that work synergistically to produce the ameliorative or protective effects described in our studies.⁶⁴

Anticancer activity

The total phenols and flavonoids, anticancer and antioxidant activities ethanol extracts of three plants *Phoenix dactylifera*, *Musa acuminata*, and *Cucurbita maxima* were determined. The total phenolic contents were computed to be 342 µg/mL gallic acid equivalents in ethanol extract of banana fruit while the highest total flavonoids were in ethanol extract of molasses date 1424 µM as rutin equivalent. In vitro anticancer activity was determined using EACC and HeLa cell lines. In vitro anticancer activity against EACC revealed that the maximum inhibition was observed in ethanol extract of pumpkin seeds 100% at 100µg/ml while the maximum inhibition against the HeLa cell line was observed in ethanol extract of date seeds 90% at 100µg/ml. The antioxidant activity was determined using three different methods DPPH, ABTS scavenging activity, and reducing power. DPPH scavenging activity was found to be 85 and 84 % in ethanol extracts of date seed and banana fruit, respectively. ABTS scavenging activity was found to be 98, 98, 95, and 95 % in ethanol extracts of seeds, molasses of date, fruit, and peel of a banana, respectively. The reducing power was 873, 833, and 871 µg/mL GAE in the ethanol extracts of molasses, seeds, and fruit of date. Four different formulas were prepared from tested plants and the sensory evaluation of these formulas showed that prepared formulas were judged as highly accepted. The results showed that ethanol extracts of date parts, banana peel pumpkin seeds are promising new antioxidant and anticancer agents and prepared formulas could be used as a daily health supplement.⁶⁵

Another study was performed to evaluate the radioprotective and anticancer effect of banana peels extract on male mice. Sixty male mice weighed 18- were used, the animals divided equally into six groups as follow first group act as normal, second group Tumor control implanted with Ehrlich tumour, third group, the irradiated group exposed to a single dose of 3.0 GY of gamma rays, fourth group banana peels extract 300 mg/kg/day orally for 3weeks, fifth group tumour implanted + banana peels extract 300 mg/kg/day orally for 3weeks, sixth group irradiated with dose 3.0 GY gamma+

300 mg/kg/day for 3 weeks. At the end of the experimental mice were sacrificed by anaesthesia and the blood was collected to evaluate biochemical parameters Complete Blood Count, Carcinoembryonic antigen, Malonaldehyde, Molecular study, electrophoretic assayed. The results showed that banana peels extract ameliorate the alteration in irradiated and tumour group, and significantly decrease $p \leq 0.05$ the elevation of Carcinoembryonic antigen in tumour implanted group, significantly decrease the elevation of Malonaldehyde in tumor implanted group and irradiated group. According to protein fractions and western blotting data, it could be concluded that addition banana peels extract consider a crucial impact for Irradiation dose which is cleared through a huge increase of Polymorphism % for addition banana peels extract 20% comparing with to Irradiation treatment which didn't reflect polymorphism. Furthermore, noticeable stimulation for P53 expression level was detected for applying banana peels extract and Irradiation as a Compound dosage.⁶⁶

Inhibitory Activity

Musa species is a traditional Indian medicinal plant used for the management and treatment of many diseases. The current study was compared the anticholinesterase, anti-inflammatory, antioxidant, and antidiabetic activities of *Musa acuminata* Simili rajah, ABB fruits and leaves fractions followed by characterization of the phytoconstituents using HPTLC-HRMS and NMR. Leaf fractions exhibit a remarkable pharmacological activity than the fruit. Ethyl acetate fraction of the leaf contains a major concentration of total phenolic content 911.9 ± 1.7 mg GAE/g and gives significant DPPH scavenging activity with IC_{50} , 9.0 ± 0.4 μ g/ml. It also exhibits the remarkable inhibition of acetylcholinesterase IC_{50} , 404.4 ± 8.0 μ g/ml and α -glucosidase IC_{50} , 4.9 ± 1.6 μ g/ml, but a moderate α -amylase inhibition IC_{50} , 444.3 ± 4.0 μ g/ml. The anti-inflammatory activity of *n*-butanol IC_{50} , 34.1 ± 2.6 μ g/ml and ethyl acetate fractions IC_{50} , 43.1 ± 11.3 μ g/ml of the leaf were higher than the positive control, quercetin IC_{50} , 54.8 ± 17.1 μ g/ml. Kaempferol-3-*O*-rutoside and quercetin-3-*O*-rutoside rutin were identified as the novel medicinal agent with potent antioxidant and antidiabetic activities from the ethyl acetate fraction of *Musa acuminata* leaf.⁶⁷

Immunomodulatory activity

To explore the feasibility of *Musa acuminata* banana peels as a feed additive, the effects of banana peel flour BPF on the growth and immune functions of *Labeo rohita* were evaluated. Diets containing five different concentrations of BPF 0% basal diet, 1% B1, 3% B3, 5% B5, and 7% B7 were fed to the fish average weight: 15.3 g for 60 days. The final weight gain and specific growth rate were higher in the B5 group. The most significant improvements in immune parameters such as lysozyme, alternative complement

pathway, leukocyte phagocytic, superoxide dismutase, and catalase activities were observed in the B5 group. However, the B5 group exhibited the lowest malondialdehyde activity. IgM and glutathione peroxidase activities were significantly elevated in the treatment groups, except in B1, after only 30 days of feeding. Of the examined cytokine-related genes, IL-1 β , TNF- α , and HSP70 were upregulated in the head kidney and hepatopancreas, and expressions were generally higher in the B3 and B5 groups. Moreover, the B5 group challenged with *Aeromonas hydrophila* 60 days after feeding exhibited the highest survival rate of 70%. These results suggest that dietary BPF at 5% could promote growth performance and strengthen immunity in *L. rohita*.⁶⁸

Wound healing activity

Banana *Musa acuminata* peel is a rich source of many nutrients and is considered high in carbohydrates. It has been traditionally used to treat diarrhoea, anaemia, and ulcers. Some studies have shown that banana peels possess antioxidant and anti-inflammatory properties. This study was performed to evaluate the wound healing activity of banana peels extract BPE in the rabbit. For inducing full-thickness wound in rabbits, the excisional wound model was used. The animals were randomly divided into six experimental groups. Negative control, standard and vehicle control groups, and treatment groups. All the treatment was applied topically twice daily. Healing was assessed by wound contraction and re-epithelialization rate and the tensile strength of the wound tissue sample. Histopathological studies also showed the wound healing activity of BPE. The results of this study indicated that the hydroalcoholic extract of banana peels has a strong potential for wound healing and it can be used for different types of wounds in human beings to.⁶⁹

Antibacterial activity

An in vitro test was carried out to assess qualitatively the antibacterial activity of the *Musa acuminata* leaf methanol extract coated sample against *Staphylococcus aureus* ATCC 6538, a gram-positive microorganism, and *Escherichia coli*, a gram-negative microorganism, using nutrient agar, purchased from M/s T. Stanes & Company Limited, Coimbatore, Tamil Nadu. Nutrient agar plates were prepared by pouring 15 ml of nutrient agar medium into sterile Petri dishes. The dishes were allowed to solidify for 5 min, and 0.1% inoculum suspension was smeared uniformly and the inoculum was left to dry for 5 min. The *Musa acuminata* leaf methanol extract-finished fabric of 2.0 cm diameter was placed on the surface of the medium, and the plates were incubated at 37.5°C for 24 h AATCC Technical Manual, 2007. After completion of incubation, the fabric sample was taken out and the zone of inhibition formed in the fabric was measured in millimetres and the readings were recorded.⁷⁰

The ethanolic 96%, acetone and petroleum ether extracts of *Musa acuminata* leaf showed excellent antifungal activities against two pathogenic fungi *Aspergillus terreus* and *Penicillium solitum* with up to 5.7 cm inhibition zone diameter at 20 mg/mL of the extract.⁷¹ A formulated gel preparation containing 4% *Musa acuminata* leaf acetone extract was reported to show an inhibition zone diameter of 27 mm against *C. albicans*, which was comparable to Nystatin cream used as control.⁷²

Antidiabetic activity

In an investigation the antihyperglycemic effect of ethanolic extract of inner peels of *Musa acuminata* fruit 100- 400 mg/Kg p.o. along with control 1% gum acacia, 1 mL/Kg p.o. and standard drug Glimepiride, 0.09 mg/Kg p.o. using oral glucose tolerance test in normoglycemic Wistar rats. The extract-treated group showed a dose-dependent antihyperglycemic effect, but no significant $p < 0.05$ change in blood glucose levels was observed among control, extract-treated and drug-treated groups in normoglycemic rats; however, extracts at 200 and 400 mg kg p.o. level showed a significant decrease in $p < 0.01$ in the blood glucose levels in glucose loaded normoglycemic rats, which was almost similar to the standard drug. These observations validate the use of *Musa acuminata* fruits for diabetic patients in the traditional practice in Mauritius, and other plant parts for the control of diabetes in India and Bangladesh.⁷³

Leishmanicidal activity

A study found that the leishmanicidal activity of phytoalexins from *M. acuminata*. The antifungal phenyl-phenalenone phytoalexin REF20 and Anigorufone compounds from the rhizomes of *Musa acuminata* was target the mitochondria of *Leishmania donovani* Promastigotes and *Leishmania infantum* Amastigotes. The REF20 had a slightly better inhibitory effect on proliferation of *L. donovani* and *L. infantum* LC_{50} of 10.3 and 10.5 $\mu\text{g/mL}$ than the Anigorufone LC_{50} of 12.0 and 13.3 $\mu\text{g/mL}$. The extracts also inhibited the mitochondrial fractions with a reduction in succinate dehydrogenase activity SDH and fumarate reductase FRD activity. The REF20 showed higher EC_{50} value 59.6 $\mu\text{g/mL}$ for SDH than Anigorufone 33.5 $\mu\text{g/mL}$; however, FRD 47.8 and 53.1 $\mu\text{g/mL}$ and purified-FRD 77.2 and 89.0 $\mu\text{g/mL}$ values were lower for REF20 than Anigorufone. These results indicate that the phenylphenalenone phytoalexins have the potential to be used as a new structural motif for leishmanicidal activity, and they can be used for the development of leishmanicidal drugs.⁷⁴

TOXICOLOGY

The available information regarding the uses of *Musa acuminata* fruit and other parts by local and tribal people suggests

that it is non-toxic. Although not very popular, fruit and other plant part are consumed by tribal populations throughout the world. The *Musa acuminata* blossom is a popular Sri Lankan dish consumed as a curry, boiled, or used as a deep-fried salad for ages.⁷⁵ The animal models used in various studies have concluded that there were no adverse effects from the administration of *Musa acuminata* extracts.⁷⁶⁻⁷⁹ The flowering stalk of *Musa acuminata* was found to be non-toxic to the murine monocytic macrophages cell line.⁸⁰ and brine shrimp toxicity test performed on *Artemia salina* showed that *Musa acuminata* flower extract was not toxic as it showed the LC_{50} value of 9.97 mg/mL, which was much above the cut-off point of toxicity level of 1.0 mg/mL.⁸¹ The use of *Musa acuminata* peel as a major ingredient in food products suggests that it is considered safe for consumption.^{82,83} Additionally, the National Cancer Standard Institute declared that the banana peel is non-toxic to human cells.⁸⁴

CONCLUSION AND FUTURE PERSPECTIVES

All the available information on *Musa acuminata* was collected via electronic search using Pubmed, Scopus, Web of Science, Science Direct, J-Gate, Google Scholar, and a library search for articles published in peer-reviewed journals, local magazines, unpublished materials, theses, and ethnobotanical textbooks were done. The Plant List www.theplantlist.org, Promusa www.promusa.org, Musalit www.musalit.org, and the Integrated Taxonomic Information System ITIS www.itis.gov name databases were used to validate the scientific names and also provide information on the subspecies and cultivars of *M. acuminata*. This review thus may provide the scientific basis for future research work on *Musa acuminata* for the development of phytomedicines as well as edible products with functional properties. The proximate analysis of *Musa acuminata* fruits reveals that its contents can contribute to the recommended daily requirements of Vitamin C and minerals such as Potassium and Magnesium, and it can be used as an ingredient in functional foods. The rich diversity of phytochemicals present in *Musa acuminata* plant parts may be responsible for health beneficial effects and justify their use against various diseases in traditional medicine. Some studies on animal models against selected pathological conditions provide evidence of the efficacy of the *Musa acuminata* plant as a therapeutic agent and acclaim the use of *Musa acuminata* by various tribes and ethnic groups across the geographical boundaries of the world. *Musa acuminata* plant parts have been consumed in varying quantities and forms by many populations across the globe over a long period, and no toxicity has been reported. However, the major edible part of *M. acuminata*; the fruits, which provides energy, vitamins, and minerals in good amounts are rarely consumed; and food application of other plant parts also is still unknown, which opens the door

for the development of food products with potential health benefits from *M. acuminata*.

Musa acuminata has been traditionally used to treat various diseases and ailments such as fever, bronchitis, allergic reactions, sexually transmitted infections, and some non-communicable diseases. All parts of the plant including fruit, stem, pseudostem, flower, leaf, sap, inner trunk, inner core, and root have found their use in traditional medicine. The compounds isolated from

Musa acuminata have been used as anti-hypertensive, anti-diabetic, anthelmintic, and anti-HIV; and have proven useful against tuberculosis and other respiratory diseases traditionally. *Musa acuminata* has been used in antimicrobial gel formulations, and the curative effect of *Musa acuminata* in combination with western medicine has been shown in a clinical study, however, the potential of some of the parts of this plant in disease prevention is not known, which needs further study. There are promising phytochemicals present in *M. acuminata*, such as S-+6- methoxy- α -methyl-2-naphthaleneacetic acid anti-inflammatory activity, BanLec anti-HIV-1 activity, and others that show promising wound healing, anti-tuberculosis and Leishmanicidal activity, which needs to be taken to clinical trials for the possible development of drugs. Another bioactive constituents of *Musa acuminata* also need further investigations for validation of various pharmacological claims, and to explore their potential use in the development of drugs and as a functional food ingredient. Investigations are also required to characterize various phytochemicals present in *Musa acuminata* that work individually or synergistically with other compounds or known drugs to provide the ameliorative or protective effects against various diseases.

ABBREVIATIONS

ABTS, 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid); CHD, Coronary artery disease; DPPH, 2,2-diphenyl-1-picrylhydrazyl; FRD, fumarate reductase; ITIS, Integrated Taxonomic Information System; ROS, Reactive oxygen species; SDH, Succinate dehydrogenase; WHO, The World Health Organization.

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