Chapter

Pharmacological Activities of Banana

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Abstract

Plants have been in use in traditional medicine since antiquity, and many active metabolic products with biological significance are obtained from them. Recently, pharmaceutical industries have developed great interest in utilizing these products as an alternative to the chemically synthesized drugs. This is due to the discovery of important new medicines from the plants, because of studies on how people of different background use plants as cure and treatment for many diseases, and side effects of the synthesized drugs. Banana, an eatable fruit produced by some herbaceous flowering plants of the genus *Musa*, is one of the valuable fruits with proven pharmacological potentials. Bananas are spread almost all over the world. Different chemical constituents like apigenin glycosides, myricetin-3-O-rutinoside, kaempferol-3-O-rutinoside, dopamine, and serotonin have been reported in different parts and varieties of banana. The presence of carbohydrate, proteins as well as flavonoids, makes bananas useful in both nutrition and therapeutics. Pharmacologically, bananas have been shown to possess antiulcer, antimicrobial, and antioxidant activities. This chapter discusses the essential information on banana, including its varieties, distribution, pharmacological actions, and its relevance in pharmaceutical industries. This will be beneficial for researchers to further harness the robustness of this fruit in controlling many diseases and modification of drugs.

Keywords: banana, traditional medicine, phyto-constituents, pharmacological activities, pharmaceutical formulation

1. Introduction

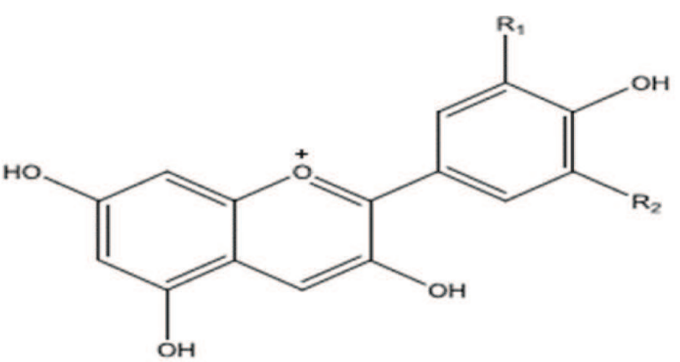
The general term "banana" describes the cultivated varieties of the genus *Musa*, made up of two subgroups, the sweet bananas and plantain [1]. It has different parts, such as fruit, peel, leaves, roots, and pseudostem, which have shown various pharmacological effects [2]. Banana is of great use both traditionally and pharmacologically and this is attributed to the presence of its diverse phyto-constituents as the pulp and peel extracts of banana are shown to have fatty acids, steryl esters, and sterols, besides oleic and linoleic acids [3]. The fruit is also a rich source of valuable phytonutrients, including phenolic compounds and vitamins [4, 5]. The bioactive components produced by plant secondary metabolism, in addition to elements such as phosphorus, and potassium, have obvious therapeutic potential by contributing toward its pharmacological activities [6].

Various parts of ripe and unripe forms of banana plant have been shown to possess prominent anti-diabetic [7], antiulcer [8], and radical scavenging activities. Lately, banana has been utilized as a vector for many vaccines due to increased bioavailability and easy administration [9]. Not only that, pectin extracted from banana is said to be used as pharmaceutical excipient in tablet formulation [10]. This chapter focuses mainly on the pharmacological studies that validate the traditional uses of banana for different types of diseases and highlights the geographical distribution of banana and its uses in pharmaceutical industries.

2. Banana phyto-constituents

Several researches have been carried out to determine the phyto-constituents of various parts of banana. The flower of *Musa paradisiaca* was reported to contain tannins, saponins, reducing and non-reducing sugars, sterols, and triterpenes. In addition, hemiterpenoid glucoside (1,1-dimethylallyl alcohol), syringin, and benzyl alcohol glucoside have been isolated from the flower [11]. The structure of a tetracyclic triterpene isolated from the flowers of *Musa paradisiaca* was established as (24R)-4α-14α, 24-trimethyl-5-cholesta-8, 25 (27)-dien-3β-oil [12]. Banana bracts were also investigated as a potential source of natural colorants. Monomeric anthocyanin content was found to be 32.30 mg/100 g. Other anthocyanins include 3-rutinoside derivatives of delphinidin, pelargonidin, peonidin, and malvidin [13].

Banana pulp contains antioxidants, including, vitamins, carotenoids, and phenolic compounds such as catechin, epicatechin, lignin, tannins, flavonoids as well as anthocyanins [14]. Serotonin, norepinephrine, tryptophan, indole compounds, starch, iron, crystallizable and non-crystallizable sugars, vitamin C, B-vitamins, fats, and mineral salts have been noted in the fruit pulp of *Musa paradisiaca var. sapientum* [15]. Cellulose, hemicelluloses, and amino acids like arginine, aspartic acid, glutamic acid, leucine, valine, phenylalanine, and threonine have been isolated from the pulp and peel of *Musa paradisiaca* [16]. Acyl steryl glycosides like sitoindoside-I, II, III, and IV as well as steryl glycosides such as sitosterol gentiobioside,



General Structure of Anthocyanin

Anthocyanidin	R_1	R_2
Delphinidin	OH	OH
Pelargonidin	H	H
Peonidin	OCH_3	H
Malvidin	OCH_3	OCH_3

Figure 1.
General structure of anthocyanin and some common anthocyanins found in banana [69].

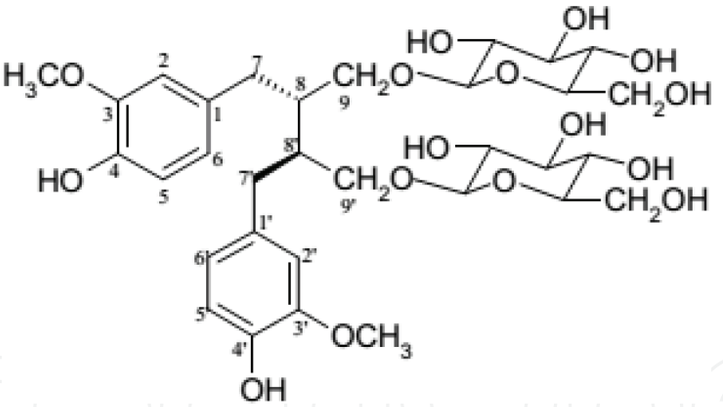


Figure 2.
Structure of lignin [70].

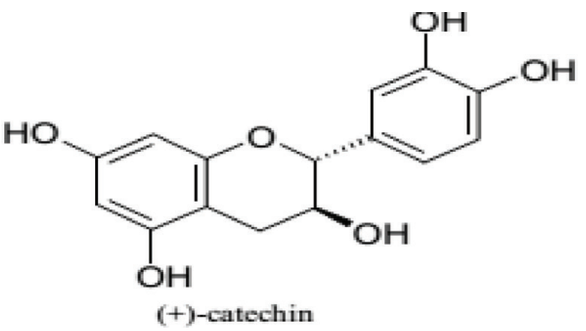


Figure 3.
The class of flavonoid present in banana fruit (Flavan-3-ol) [70].

sitosterol myo-inositol-β-D-glucoside were isolated from the fruit of *Musa paradisiaca* [17]. Banana peel is generally discarded as a waste; however, it is a very rich source of important phyto-constituents. The peel contains 6–9% dry matter of protein and 20–30% fiber. Usually the ripe banana peels contain 30% free sugar and 15% more starch than green banana peels. Moreover, banana peel is a good source of lignin, cellulose, and hemicellulose with variety of active functional groups (carboxyl, hydroxyl, and amine) [18, 19]. Phytochemical analysis of *Musa paradisiaca* and *Musa acuminata* peels revealed the presence of phenols, carbohydrates, terpenoids, and saponins [20]. The presence of such potent phyto-constituents in banana makes it a great target for nutritional and therapeutic researches. The structures of some of the important isolated compounds in banana are shown in **Figures 1–3**.

3. Pharmacological activities of banana

Banana has various pharmacological effects. The prominent ones of more relevance to health care are discussed in this section.

3.1 Antioxidant activity

Reactive oxygen species (ROS) are oxygen radicals with unpaired electron involved in both physiological and pathological conditions. Antioxidants, on the other hand, prevent free radical damage by scavenging the radicals. Banana contains various compounds that exert such antioxidant activity [21].

The antioxidant property of banana peel extracts *(Musa paradisiaca L.)* was explored using a group of rats exposed to a normal diet and compared to another

group fed with fatty acid-rich diet. Oxidation markers like malondialdehyde (MDA) were measured. It was observed that subjects treated with banana peel extract displayed a significant decrease in concentrations of the peroxidation products (MDA), peroxides, as well as conjugated dienes. Meanwhile, antioxidant enzymes, catalase, and superoxide dismutase activities were raised significantly in the treated subjects. The level of an important antioxidant, reduced glutathione (GSH), also increased [22]. In another research conducted by [23], powdered candi banana (*Musa paradisiaca*) was extracted using ethanol and ethyl acetate in an ultrasonic bath. The results indicated that the antioxidant activity (IC_{50}–50% inhibitory concentration) of ethanol extract and ethyl acetate was 3374.13 ± 123.46 and 40318.19 ± 1014.90 ppm, respectively, hence, leading to the conclusion that the antioxidant activity of ethanol extract is higher than that of ethyl acetate.

An *in vitro* antioxidant study of *Musa sapientum, Musa paradisiaca, Musa cavendish,* and *Musa acuminata* peels was conducted using 2,2-diphenyl-1-picrylhydrazyl radical (DPPH), hydrogen peroxide (H_2O_2) radical scavenging assay, and ferric reducing power assay. The results showed that *Musa acuminata* has the highest antioxidant activity followed by *Musa cavendish* against DPPH radical. In ferric reducing power and H_2O_2 scavenging assay, *Musa acuminata* also showed best antioxidant activity when compared with other extracts. The study revealed that the peels of *Musa* species possess significant *in vitro* antioxidant activity, hence, the conclusion that eating the peel of banana fruit would be beneficial considering its potential antioxidant property [24]. It was also reported that ethanol extracts of unripe Cavendish (*Musa acuminata L)* and Dream banana *(Musa acuminata colla. AAA cv* Berangan) peels have excellent radical scavenging activities with an IC_{50} of 90.28 μg/mL (for Cavendish) and 113.09 μg/mL (for Dream banana). The researchers ascribed this effect to the abundant phenols, flavonoids, and tannins detected in the peel extracts [25]. It can therefore be inferred that the antioxidant compounds like phenols and flavonoids present in the peel are involved in DPPH radical inhibition.

In another study that investigated the antioxidant activity of banana flowers of six distinct Malaysian cultivars, namely *Musa balbisiana* cultivars pisang Abu (P. Abu) and pisang Nipah (P. Nipah); *Musa acuminata* cultivars pisang Berangan (P. Berangan), pisang Susu (P. Susu), and pisang Mas (*P. Mas*); and *Musa paradisiaca* cultivar pisang Rastali (P. Rastali), it was found that, of all the six cultivars, P. Susu possess the highest phenolic content (80.13 ± 4.64 mg of GAE/g of extract) and the highest 2,2′-azido-bis (3-ethylbenzothiazoline-6-sulphonic acid) $ABTS^+$ and DPPH free radical scavenging activities. This is indicative of a strong relationship between the phenolic contents and radical scavenging power of the flowers [26]. The study of antioxidant activity of banana parts, namely tepal (methanol, ethanol, and aqueous extracts), peel, and pulp (methanol extracts) as well as pure syringin was carried out using DPPH radical scavenging assay and the result showed excellent antioxidant activity in tepal methanol extract, moderate activity in both tepal and peel ethanol and aqueous extracts. Meanwhile, mild activity was observed in pure syringin and pulp extracts. The DPPH radical scavenging activity of the different successive extracts of *Musa paradisiaca* showed direct proportion with sample concentration and the researchers attributed this role to the abundant phenols and flavonoids present in the extracts (**Figure 4**) [27]**.** DPPH and ferric ion reducing antioxidant power (FRAP) assay methods were employed to determine the radical scavenging ability of banana fruit extracts. The extract prepared from ethanol had higher antioxidant activity, while solvent hexane fraction showed moderate scavenging activity. Moreover, banana peels extracted with ethanol demonstrated potent antioxidant activity on DPPH, with an IC_{50} of 19.10 μg/mL. In the same vein, the ethanol extract of the peels exhibited significant antioxidant activity

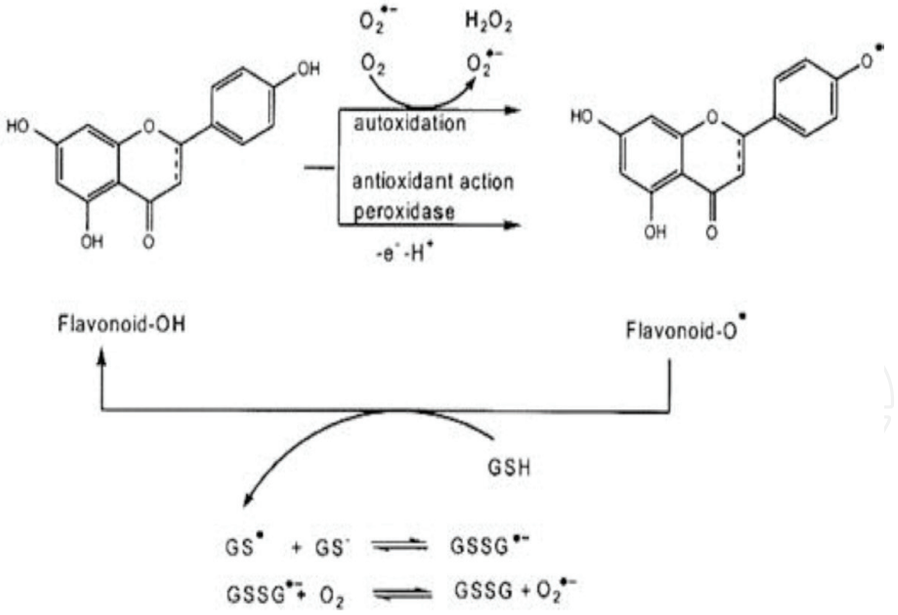


Figure 4.
Antioxidant mechanism of flavonoids detected in banana. Enzymatic and/or chemical auto-oxidation of the flavonoids generates the flavonoid semiquinone radical, which may be scavenged by reduced glutathione (GSH), thereby generating the flavonoid and generating thiyl radical of glutathione. This thiyl radical may react with GSH to generate a disulfide radical anion which rapidly reduces molecular oxygen superoxide anion radical, which can be further detoxified by superoxide dismutase enzyme [71].

on FRAP with IC_{50} values of 55.10 μg/mL. The pulp extracted with ethanol showed excellent FRAP radical scavenging activity with IC_{50} of 46.40 μM of Fe^{2+}/mg [28]. A comparative study of antioxidant effects of banana and papaya peels was carried out using DPPD and ferric reducing activity methods. The outcome showed clearly that banana peel extract scavenges more free radicals than that of papaya [29].

3.2 Anticancer effect

Cancer is currently among the major world health concerns. It is characterized by abnormal cell growth. Natural products like banana are being utilized to combat the deadly disease. Banana is found to possess anticancer (colorectal) property by an *in vitro* assay of hill banana (Virupakshi). The fruit juice inhibits human colorectal adenocarcinoma cell line (HT-29) and causes mortality at a very low concentration [30]. It was hypothesized that CellQuest, a patented formula comprising high level of tannic acid (TA) extracted from *Musa paradisiaca* (plantain), suppressed the tumor cell proteasome activity. This study suggested that CellQuest aims at the proteasome selectively in tumor cells, which possibly contributes to the anticancer effect [31]. Anticarcinogenic substances present in banana peels like saponins can combat abnormal cells (**Figure 5**). The degree of anticancer effect corresponds to the degree of ripeness of the fruit. A research was conducted by a Tokyo university professor in which numerous health advantages of diverse fruits such as banana, grape, water melon, apple, pineapple, persimmon as well as pear were related. The result showed that banana displayed better augmentation of leucocytes, improvement of body immunity, and production of anticancer substance [32].

3.2.1 Cytotoxic effects

Banana extracts were tested for their ability to suppress the growth of breast cancer cell line (MCF-7) and human colorectal carcinoma (HCT-116) tumor cell lines along with the human umbilical vein endothelial cells (HUVEC cell).

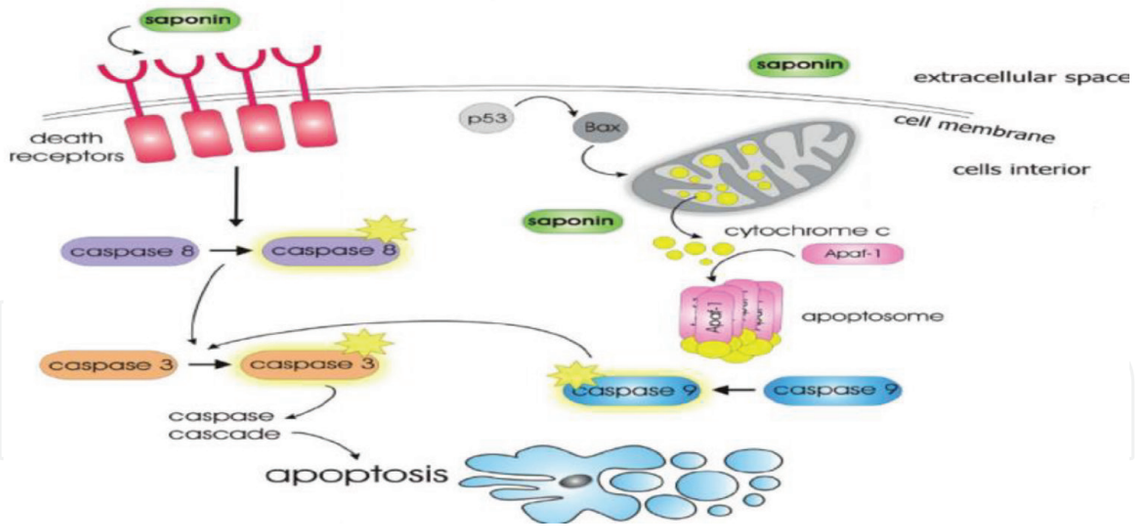


Figure 5.
Mechanism of pro-apoptotic effect of saponins, compounds present in banana [72].

The extracts showing more than 60% inhibition of cell proliferation were the active extracts. Among these, hexane extract of banana peel and pulp showed maximum toxicity against HCT-116 and MCF-7 cell lines with percentages of 62.04 and 61.21%, respectively, while the aqueous and ethanol extracts indicated low anti-proliferative activity against HCT-116 and MCF-7. Interestingly, all the tested extracts showed virtually no cytotoxic effect against the normal cell lines [28].

3.2.2 Anti-angiogenic activity

In a research that assessed the anti-angiogenic potential of different banana extracts, rat aorta ring assay was employed using suramin as a reference drug. Banana extracts exhibiting over 60% inhibition of sprouting of blood vessels were considered active extracts. Two extracts exhibited potent inhibitory activity (>60%) with maximum inhibition of 85.32% produced by the hexane extract of banana peel. These significant inhibition values were very much similar with the standard drug (suramin), which showed potent inhibition of microvessel growth [28].

3.3 Antiulcer activity

Ulcer has been a major challenge of developing nations. It is a lesion caused by factors including the bacteria *Helicobacter pylori* and excess acidity. Researchers tested the potency of banana against this complication and it was shown to have significant antiulcer activity by [33] who evaluated the ulcer index, gastric wall mucus, gastric juice pH, and volume of ulcer-induced animals. The results showed the preventive effect of tepal and peel extracts against indomethacin plus pylorus ligation-induced ulcer by 68.80 ± 20.53 and 43.22 ± 14.82%, respectively. In addition, reduced gastric juice volume and increased gastric wall mucus were observed in both the tepal and peel extract-treated groups. Finally, the study revealed that banana tepal and peel extracts were able to prevent the induced ulcer by strengthening the gastric mucosa and decreasing the acidity of the gastric juice. In another study on the antiulcer effects of chloroform and ethanol extracts of banana, in ulcer-induced rats by ethanol, it was found that, both the chloroform (200 mg/kg) and ethanol extracts (400 mg/kg) were effective against the induced ulcer by significantly ($p < 0.05$) reducing the number of ulcer and ulcer index as compared to the standard ulcer drug, ranitidine [34].

Leucocyanidin showed protective effect against ulcer induced by aspirin. The compound was extracted from *Musa paradisiaca* (plantain) by solvent fractionation and was described as the active antiulcer compound [35]. Dried plantain pulp powder is a potent herbal drug for the treatment of peptic ulcer disease as suggested in a research conducted by [8], in which the ulcer protective and curing activities of unripe plantain were explored.

3.4 Antidiabetic effect

Diabetes, which can be insulin dependent or non-insulin dependent, poses a great threat to humanity. High level of glucose is prominent in diabetic patients and attempts have been made to counteract that using several plants including banana. Investigation into the anti-hyperglycemic effect of ethanol extract of *Musa sapientum* (*EMS*), *M. paradisiaca (EMP), Musa cavendish (EMC),* and *M. acuminata (*EMA) peels by oral glucose tolerance test in glucose-loaded (2 g/kg p.o) normoglycemic (having normal concentration of glucose) rats was done by [24]. It was observed from this study that animals treated with EMC (500 and 1000 mg/kg, p.o) and EMA (200 and 400 mg/kg p.o) showed marked anti-hyperglycemic effect ($p < 0.01$). Also, both EMS (200 mg/kg, p.o) and EMP (500 mg/kg, p.o) depicted significant ($p < 0.01$) decrease in blood glucose level. Another study aimed at evaluating the *in vitro* antidiabetic activity of methanol extracts of three kinds of fruit peels (lemon, pomegranate, and banana) showed that banana peel exhibited maximum alpha amylase inhibitory activity (80.87% at 1000 μg/mL). Hence, banana peel is more potent among the three, having the highest hypoglycemic effect. Thus, it can be utilized as antidiabetic supplement as compared to the others [36]. The hypoglycemic effect of methanolic extract of mature green fruits of *M. paradisiaca* in normal (normoglycemic) and streptozotocin-induced diabetic (hyperglycemic) mice was evaluated. The results of this experiment indicated that the extract possesses hypoglycemic activity, and hence corroborate folkloric use of the plant in the management of type-2 diabetes mellitus [37]. The effect of *M. sapientum* Linn. sucker administration on pancreas histology, fasting blood glucose as well as body weight in experimental animals made hyperglycemic by alloxan induction were reported by [38]. The sample was found to effectively reduce the glucose level, improve the animal's body weight, and regenerate the damaged pancreas in the induced rats. Hence, banana is perhaps the best candidate for diabetic control.

3.5 Antimicrobial activity

The antimicrobial properties of ethanol and acetone extracts of banana peels were evaluated by well diffusion assay against different microbial strains. An 80% acetone extract inhibited bacterial species at 600 ppm against Gram-positive bacteria including *Bacillus subtilis* (20.60%), *Staphylococcus aureus* (19.75 mm), *Escherichia coli* (18.15 mm), and *Pseudomonas aeruginosa* (19.57 mm). The presence of phytochemicals including phenolic compounds and tannins is believed to be associated with this antimicrobial property [39]. The Kirby-Bauer sensitivity method was employed to evaluate the antibacterial activity of silver (Ag) nanoparticles synthesized from the stem waste of banana plant. The Ag nanoparticles showed remarkable activity against *E. coli* and *Staphylococcus epidermidis*, with *E. coli* (Gram negative) being more susceptible with an inhibition zone of 12 mm. The research showed that banana stem waste can generate Ag nanoparticles with antibacterial activity against Gram-negative bacteria, *E. coli,* and *S. epidermidis* [40]. In a separate work, fresh green and yellow banana peel of (*Musa*, cv. *cavendish*) fruits treated with 70% acetone were sequentially partitioned with chloroform ($CHCl_3$) and ethyl acetate

(EtOAc). The antimicrobial activities of the extracts and isolated components were evaluated using paper disc method and minimum inhibition concentration (MIC). The EtOAc and water-soluble fractions of green peel displayed high antimicrobial activity [41]. Moreover, the extracts of dried *M. paradisiaca* peel, powder and ash, possessed a good antifungal effect when tested against *Aspergillus niger* [20].

3.6 Wound healing attribute

Banana peel was reported to have wound healing activity through its predominant effects on mucosal defensive factor that enhances DNA synthesis and promotes mucosal cell proliferation. The wound healing activity of both methanol and aqueous extracts of plantain banana (*M. sapientum* var. *paradisiaca*) was assayed in rats. Both extracts were found to increase hydroxyproline, hexuronic acid, hexosamine, superoxide dismutase levels as well the wound tensile strength. The extracts also decreased the wound and scar areas, and lipid peroxidation. These effects were attributed to the antioxidant property of the plantain [42].

3.7 Effect on atherosclerosis

Atherosclerosis is a disease characterized by accumulation of plaque inside the arteries. In a study, Ambon *(Musa paradisiaca)* peel was used to ascertain its effectiveness as anti-atherosclerotic agent by the inhibition of NF-κB (nuclear factor kappa beta) and increasing e-NOS (endothelial nitric oxide synthase) expression in atherogenic rats using immunohistochemical method. It was observed that the extract significantly decreases NF-κβ activity and increased e-NOS activity in a dose-dependent manner. Linear regression showed that the extract can lower NF-κβ activity by 82.1% and increase e-NOS expression by about 95.2%. Therefore, the extract of Ambon banana peel was proven to be effective in preventing

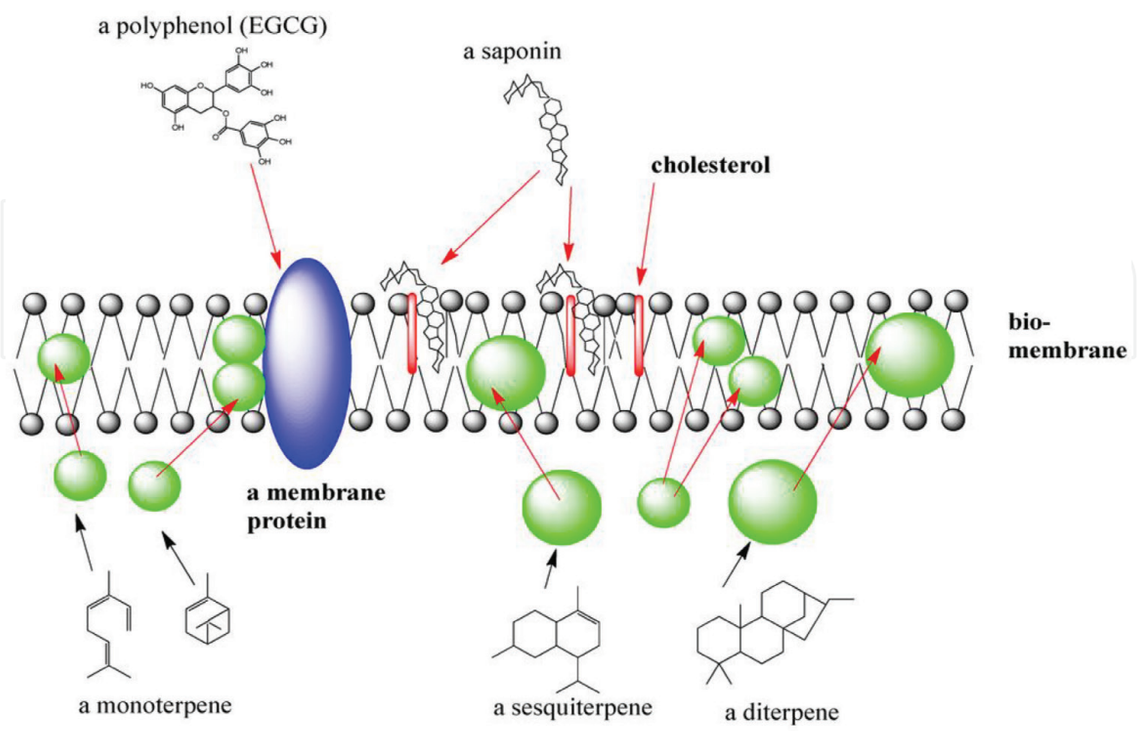


Figure 6.
The cholesterol-lowering activity of banana may be because of the phyto-constituents on cellular membranes. For example, saponins can form complex with membrane cholesterol; polyphenols influence 3D structure of membrane proteins like receptors, transporters, and ion channels); small lipophilic terpenoids assemble in the inner lipophilic core of the biological membrane [73].

atherosclerosis. This finding revealed the effectiveness of the peel extract in inhibiting the atherosclerotic process via suppressing the expression of chemo-attractant molecules and monocyte adhesion and thus the peel extract may be considered a novel therapeutic agent in preventing atherosclerosis [43]. A related study was conducted by [44], in which the effect of saponin, tannin, and flavonoid present in Kepok banana peel against total cholesterol level in obese male mice was measured. The researchers divided 20 obese male mice (*Mus musculus L.)* into four groups and treated them for 14 days. Total cholesterol level of each group was measured using spectrophotometer. It was observed that the Kepok banana peel lowered the total cholesterol level in the tested animals, with more effect in a group administered 8.4 mg/day of the peel extract than in the group administered 16.8 mg/day. It was thus concluded that banana peel extract is effective in lowering the total cholesterol level of obese mice reflecting its anti-atherosclerotic effect (**Figure 6**). The researchers obtained 8.4 and 16.8 mg/day based on the conversion of the effective doses of banana peel extract for rats. By this, 200 mg/kg body weight of banana peel extract can reduce total cholesterol level of rats.

4. Banana and pharmaceutical industries

Pharmaceutical industries demand for fast dissolving tablets [45] to facilitate drug onset of action, higher patient acceptance, and increased bioavailability [46, 47]. Banana, a natural superdisintegrant can be used as pharmaceutical excipient for oral drug delivery due to exhibition of faster drug dissolution which leads to improved bioavailability, effective therapy (therapeutic ratio), improved patient compliance, and satisfies all the standards of fast dissolving tablet. Various formulations were prepared by direct compression method using superdisintegrants like banana (2%), sodium starch glycolate (4%), and cross carmlose sodium (6%). The mixture was analyzed for different pre-compression parameters (angle of repose and tapped density) and post-compression parameters (thickness, drug constituents, weight variation, hardness, wetting time, friability, dissolution and disintegration time as well as drug release). It was concluded from the result that banana powder showed better disintegrating property over synthetic superdisintegrants such as SSG (sodium starch glycolate) and CCS (cross carmelose sodium) [45].

In another work by [48], dehydrated banana powder and potato starch were prepared and subjected to analysis. Physicochemical parameters, bulk and tape densities along with angle of repose, Hausner ratio, Carr's index, solubility, and melting point were assessed. FTIR spectroscopy was then performed to study the interaction between aceclofenac (a non-steroidal anti-inflammatory drug) and the excipients. Direct compression method was employed for the tablet preparation using the disintegrants, and the disintegration time of the tablet formulations was monitored. To depict the release mechanism from the tablet system dissolution, study was carried out and data were fitted to different kinetic models. The result revealed that tablets of banana powder *(M. acuminata)* and potato starch disintegrate more rapidly than that of microcrystalline cellulose. The prepared formulations passed the evaluation tests including weight variation, hardness, friability, and content uniformity. Therefore, banana powder and potato starch have better disintegrant property than the microcrystalline cellulose.

Fermentation is one of the processes used by pharmaceutical industries in drug manufacturing. Effect of banana fermentation product, obtained by subjecting banana pulp juice to a pre-fermentation in the presence of *Streptococcus thermophilus* (DSMZ 28121 strain) and yeast *(Saccharomyces cerevisiae* ATCC 4126T), and post-fermentation conducted in the presence of *Acetobacter* (*Acetobacter aceti,* DSMZ

3508), on antioxidation, probiotics, and pathogenic bacteria was compared to the unfermented banana pulp juice. The fermentation product was found to be effective in antioxidation (having higher superoxide dismutase (SOD) activity when compared to the commercial enzyme product) (**Figure 7**), increasing the number of probiotics (*Lactobacillus acidophilus*), by 4–8 fold (**Figure 8**), in the intestinal tract, reducing the number of pathogenic bacteria (*E coli*), by 4 fold (**Figure 9**), in the intestinal tract, and relieving constipation symptoms. Therefore, the product can be used as an edible or a pharmaceutical composite [49].

Nanoparticles are used to increase the surface-to-volume ratio of pharmaceutical agents. These particles can pass through biological barriers and are made from a wide array of biocompatible materials that can be used in food and pharmaceutical industries [50, 51]. Nanoparticles from native and acetylated banana starch were prepared and used as nanovehicles for curcumin encapsulation and release. Acetylation proved to be a powerful chemical alteration for encapsulation of hydrogen bond donor molecules like curcumin. A strong nanoparticle-curcumin interaction is formed due to increased number of hydrogen bond-accepting sites. This allows more curcumin molecules into the starch nanoparticles. Encapsulation does not affect properties such as particle size and polydispersity index, proving that it is possible to design nanoparticles from banana starch with sizes below 250 nm. This result showed that ABSNp (acetylated banana starch nanoparticle) allowed more controlled release of curcumin in gastric medium, which could be a defining factor in their potential use in drug and nutraceuticals delivery [52].

Banana peel is an abundant byproduct of agro waste which is under investigation as an economical and feasible alternative carbon source for the cultivation and the growth of probiotic *lactobacilli*. It was found that there was no significant difference in the growth of *lactobacilli* between banana peel medium and commercial De Man, Rogosa, and Sharpe (MRS) medium. Banana peel waste can therefore be used for probiotic*, lactobacilli* production. The tested strains of *lactobacillus* demonstrated extraordinary growth at 37°C and pH 6.0. It can be summed up from this work that using banana peel agro waste would be optimal both economically as well as environmentally for probiotics production [53]. It was observed that pectin extracted from banana exhibited a good flow property and can be used as pharmaceutical excipient to prepare the solid and semisolid dosage form [54]. Citric acid is extensively used in dairy, food, beverage, pharmaceutical, and biochemical industries. Current economic pressure and escalating cost of substrates for microbial growth and production necessitate the exploration of alternative organic substrates for microbial production by pharmaceutical industries. Banana peel can be utilized as a substrate for citric acid production by *Aspergillus niger* [55].

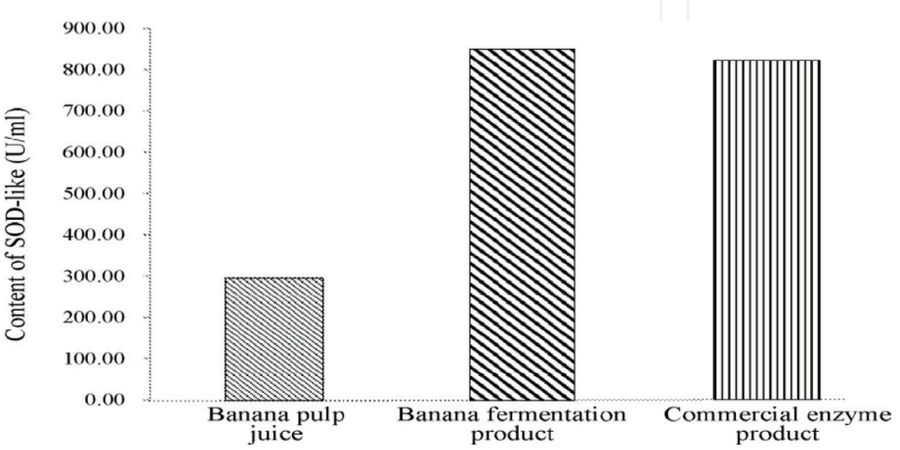


Figure 7.
Measurement of the content of SOD-like in the banana fermentation product [49].

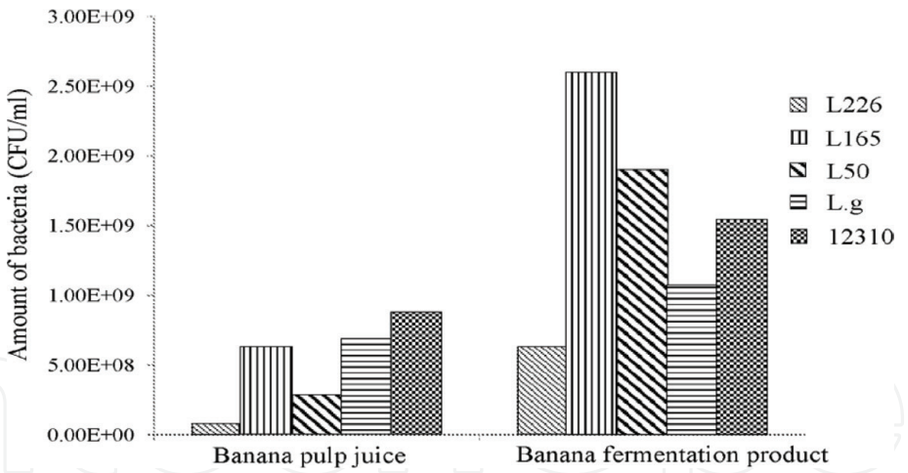


Figure 8.
Effect of banana fermentation product on increasing the number of probiotics [49]. L226 strain = Lactobacillus acidophilus, L165 strain = Lactobacillus rhamnosus, L50 strain = Lactobacillus plantarum, L.g strain = Lactobacillus gasseri, 12,310 strain = Lactobacillus brevis.

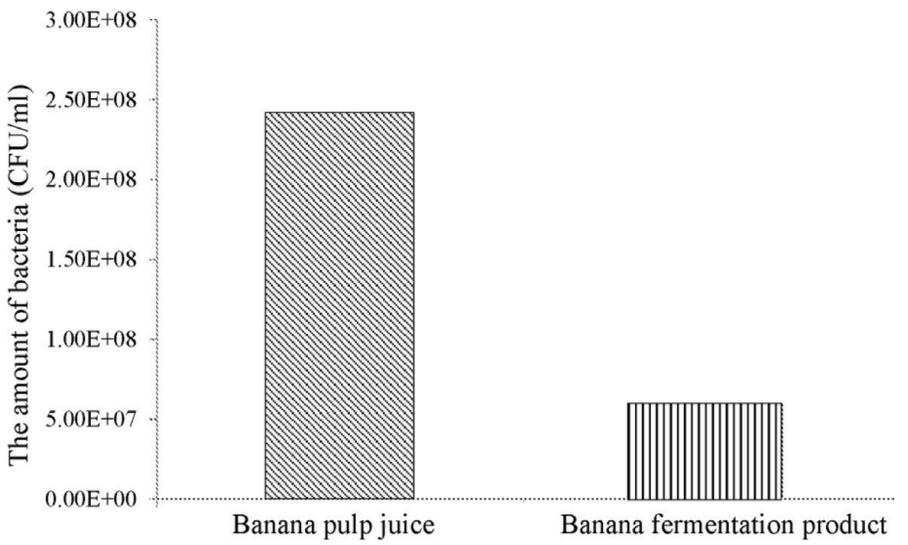


Figure 9.
Action of banana fermentation product on the number of pathogenic bacteria in the intestinal tract [49].

The shoot and callus cultures of banana (*Musa* sp.) were used to assess the accumulation of L-DOPA (L-3,4-dihydroxyphenylalanine), an important intermediate of plant secondary metabolism which is orally administered to relieve Parkinson's disease (a progressive disorder associated with a deficiency of dopamine in the brain). Treatment of the cultures with L-tyrosine and L-phenylalanine yielded higher levels of L-DOPA as compared to those in control cultures. Among the two amino acids, phenylalanine induced higher accumulation of L-DOPA. The study thus indicates that banana may be a potential resource to produce L-DOPA [56].

5. Banana in global traditional medicine and beliefs including geographical spread

5.1 Banana in global traditional medicine and beliefs

Parts of banana, which include roots, pseudostems, stems, leaves, and flowers, have long been utilized in local and traditional medicine in America, Asia, Oceania,

India, and Africa [57]. Based on the resources of Iranian traditional medicine, bananas are prescribed for depressed patients [58]. Iranian traditional medicine as a complementary and alternative medicine involves several non-pharmacological treatments, among which food therapy is the most notable. Data from an Arabic source indicate that *Musa* species is useful against heat in the chest, lungs, and the bladder, and softens the stomach [59]. Report by [60] confirmed that banana fruit from India have been used traditionally to fight off a large number of sicknesses. This attribute is due to the presence of various constituents present in the fruit. For example, the anti-depressive role, blood pressure control, and anti-anemic property may be due to the presence of banana's tryptophan, high potassium, and high iron contents, respectively. Banana also helps during body's recovery from nicotine withdrawal thereby helping people to quit smoking perhaps because banana is rich in not only potassium and sodium but also vitamins B6 and B12. The ability of banana to revamp normal bowel action, attributed to its high fiber content, made it a good candidate for treating constipation. It is also used in heartburns and ulcers due to natural antacid effects as well as in stress conditions ascribed to the presence of potassium. Topical application of banana peel has long been used in treating burn wounds in Brazilian local and traditional medicine [61]. Wounds were wrapped around with cataplasm prepared using peels of ripe bananas which can serve as an analgesic and also reduce swelling. In case of urgency, banana peel can be wrapped directly around an injury due to its antiseptic nature [62].

Banana peel contains anti-histamines, which works by subduing and blocking histamines such that the effect of the histamines is undone. Histamines are the chemical compounds released in body cells that cause allergic reactions. Hence, it is applied on bug bites, where anti-histamines in the banana peel sink into the skin and prevent further swelling and cure itching [63].

5.2 Banana geographical spread

Worldwide distribution of some banana cultivars according to their genomic group is summarized in **Table 1** below.

Genomic group	Cultivar	Fruit usage	Geographical distribution
AA	Frayssinette, Figue sucrée	Dessert banana	All continents
	Ouro	Dessert banana	Brazil
AAA	Gros Michel, Lacatan Poyo	Dessert banana	All continents
	Intuntu	Cooking	East African highland
	Caipira	Dessert banana	Brazil
	Yangambi-5	Dessert banana	Central and West Africa
	Grand Nain, Valery	Dessert banana	Egypt
	Mujuba	Cooking	East African highland
AAAA	Champa Nasik	Dessert banana	East African highland
AAAB	Goldfinger	Dessert banana	America and Australia
AB	Safet Velchi	Dessert banana	India and East Africa
	Sukari	Dessert banana	India and East Africa
AAB	Maca, Silk	Dessert banana	All continents
	Prata, Branca, Pacovan	Dessert banana	Brazil, India and Egypt
	French, Horn	Cooking	Africa Caribbean
	Corne	Cooking	Africa Caribbean
	Batard, Mbouroukou-1, Mbouroukou-3	Cooking	Belgium
	Terra, Pacovan, D'Angola	Dessert banana	Brazil

Genomic group	Cultivar	Fruit usage	Geographical distribution
ABB	Figo Vermelho or Figo Cinza	Dessert banana	Brazil
	Bluggoe	Cooking	Philippines and America
	Fougamou	Dessert banana	Philippines and America
AABB	Ouro da Mata	Dessert banana	Brazil
ABBB	Klue Terapod	Cooking	Philippines and America
BBB	Saba	Cooking	Indonesia and Malaysia

Note: Represents combinations of the Musa balbisiana Colla and M. acuminata Colla genomes. Cooking means plantain varieties.
Source: [64–68].

Table 1.
Banana geographical distribution showing genomic group, cultivar, and type.

6. Conclusion

Bananas are widely used all over the world as food staples and for medicinal purposes. This is for their interesting bioactive secondary metabolites. Phytochemical and pharmacological studies of bananas and plantain are expanding as it has been demonstrated that *Musa* species extracts possess numerous pharmacological activities, which are ascribed to their phyto-constituents like phenols, carotenoid, and amines. There is a growing interest in developing a banana-based phytomedicine for wound healing and treating Parkinson's disease, considering the ethnopharmacological data available on the potentials of banana fruit. To achieve that, issues such as modality, quality control, efficacy, safety, and toxicity need to be addressed at both preclinical and clinical levels. Finally, looking at the genetic diversity of banana species and its adaptation to different environmental conditions, ethnopharmacological investigations will provide the suitable support needed for clinical usage of secondary metabolites of banana species in modern medicine. Furthermore, thorough phytochemical screening needs to be undertaken to ascertain the active components in different types of extracts of banana parts. This will enrich the literature and provide a solid base for scientific arguments as against the current reliance on empirical and anecdotal assumptions.

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Conflict of interest

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