

Review Article

Functional, nutritional and medicinal potential of banana peel

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Abstract

Banana, botanically called *Musa* spp. is among the most cultivated and consumed fruits, which generates a huge amount of waste (peel) annually. The current review was to combine the activities and beneficial aspects of banana peel. The organic composition of banana peel comprising lipids, fibers, carbohydrates and protein which results in presence of several bioactive molecules. The literature revealed that these bioactive compounds including alkaloids, flavonoids, phenolics, steroids (tannic acid, catechol, β -sitosterol, ferulic acid) help to perform different biological activities and cures antitumor, antiparasitic, antibacterial, antifungal, antiaging, antioxidant and antiviral activities. The mechanism of its bioactive compounds helps to cure infections and diseases. The study states that banana peel is a valuable byproduct which has several benefits and it can be used in different industries like pharmaceutical, cosmetics, food, lather, biodiesel and bioethanol.

Keywords: Amino acids; Anti-inflammatory; Antimicrobial; Antioxidant; Dermatological effect; Phytochemicals

Introduction

Banana (*Musa* spp.) is one of the most commonly eaten fruits with considerable nutritional value [1]. In tropical and subtropical zone, this crop is widely grown and consumed. Most of this fruit is consumed fresh, but it can also be processed into a variety of products at large scale, including dried fruit, chips, smoothies, ice cream, bread, flour, wine, and ingredients for functional cuisine [2-4]. Literature indicated, Southern Asian tropical regions are where bananas were first domesticated; today, 130 nations grow bananas. Banana production has significantly expanded globally over the last 20 years. The average annual output of bananas worldwide has increased from 69 million tons in 2000-2002 to 116 million tons in 2017-2019, in which India stands first with a production of 32 million metric tons annually (Fig. 1) [5]. Pakistan has produced

154,800 tons of bananas from 34,800 hectares on average. Sindh province of Pakistan has the major share with 87 % of total area followed by Khyber Pakhtunkhwa (KPK), Punjab and Balochistan [6].

The genus *Musa* of the family *Musaceae* includes a wide range of hybrids. According to published reports, there are almost 30 different varieties of banana present all over the world [7]. Whereas the *Musa* spp. is further diversified into different four sections namely *Eumusa*, *Rhodochlamys*, *Australimusa* and *Callimusa*. Among these sections, the most widespread section geographically is *Eumusa* and it is followed by *Australimusa*. The edible class of bananas is solely from *Musa accuminata* [8]. Pakistan produce different varieties of bananas among which 95 % of area is under Basrai variety (Cavendish dwarf), whereas other common varieties are William Hybrid, Grand Nine (G-

9), Chinese varieties B-10, W-11 and Pashing [6].

Banana sector has low yield and is less profitable in Pakistan than that of other neighboring banana-growing countries. Pakistan's banana fruit yield is facing several challenges in which the most significant challenge is prevalence of banana pathogen epidemics and the lack of high yielding

varieties that are compatible with the changing climate. Conserving infected suckers, lack of healthy disease-free suckers, prevalence of single low yield variety, poor crop management, skills and technology, water scarcity, fertilizers and post-harvest losses are other challenges [9].

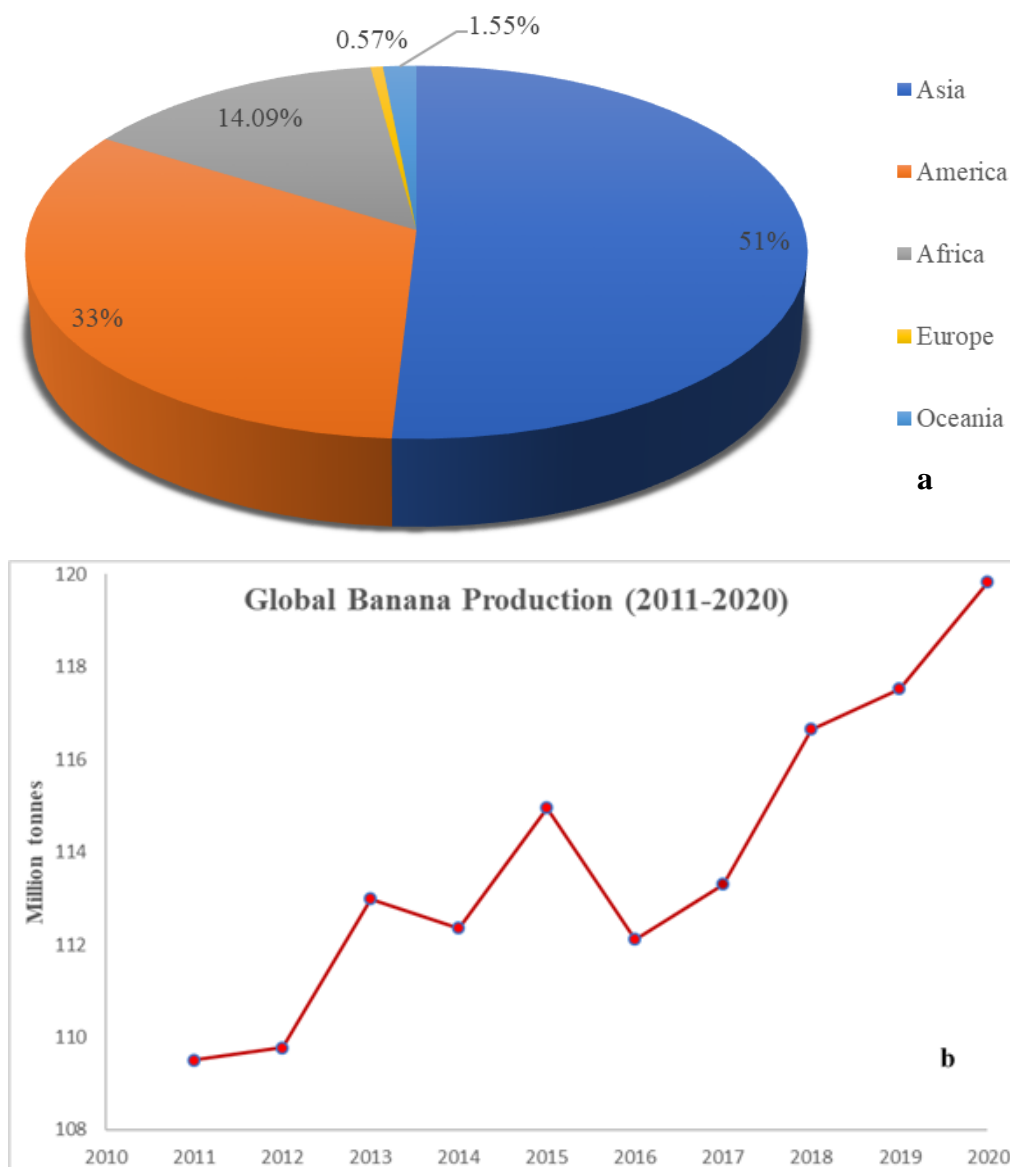


Figure 1: (a) Banana production region-wise (b) Top 10 largest banana-producing countries [5]

Approximately 220 tons of banana deposit produce per hectare comprised chiefly of lignocellulosic material. These deposit wastes are dumped largely into canals, waters

and roadsides origins grave environmental complications [10]. Leaves, peels, pseudostems, and stalks all contain a high level of lignocellulose which are the key

deposits of banana produce [11]. The outer coat of banana fruit accounts for up to 35 % of the total mass. Consequently, over 36 million tons of banana peel are produced annually and this is considered to be the potential material for further application. Still, a record percentage of banana peel is disposed of in landfills or with other junk [12]. As we all know that it has very high contents of micronutrients which attracts great attention to its nutritional and antioxidant properties, mainly due to the ascorbates, catechin, gallic acid and dopamine [13, 14].

Additionally, the banana peel also contains various bioactive elements namely terpenoids, alkaloids, flavonoids, tannins and phlobatannins [15]. It has been used as a therapeutic agent for antilithic, antiulcerogenic and anti-diarrheal, hypoglycemics, hypolipidemic and antivenom properties [16-19]. It is said to be very beneficial for maintaining the

cholesterol level [20]. Banana peel has a significant amount of carotenoid (64 µg/g) [21], which acts as a preventive strategy against several tumors, cardiovascular disease, diabetes, and age-related macular degeneration [22]. Banana residue has high phenolic content than avocado, pineapple, papaya, passion fruit, watermelon and melon [23].

Banana peel has high carbon content and can be used as an absorbent to remove various pollutants from sewage water [24, 25]. It constitutes hemicelluloses, cellulose and pectin having carboxyl, hydroxyl and amine as a functional group. Rhodamine- B (Rh-B) is said to be among the toxic dyes which cause carcinogenic and neurotoxic effects in humans. Agro-waste has been known for Rh-B removal with great efficiency. Whereas, the above functional group in banana peel has essential value for the binding of Rh-B on bio sorbent (Fig. 2) [26].

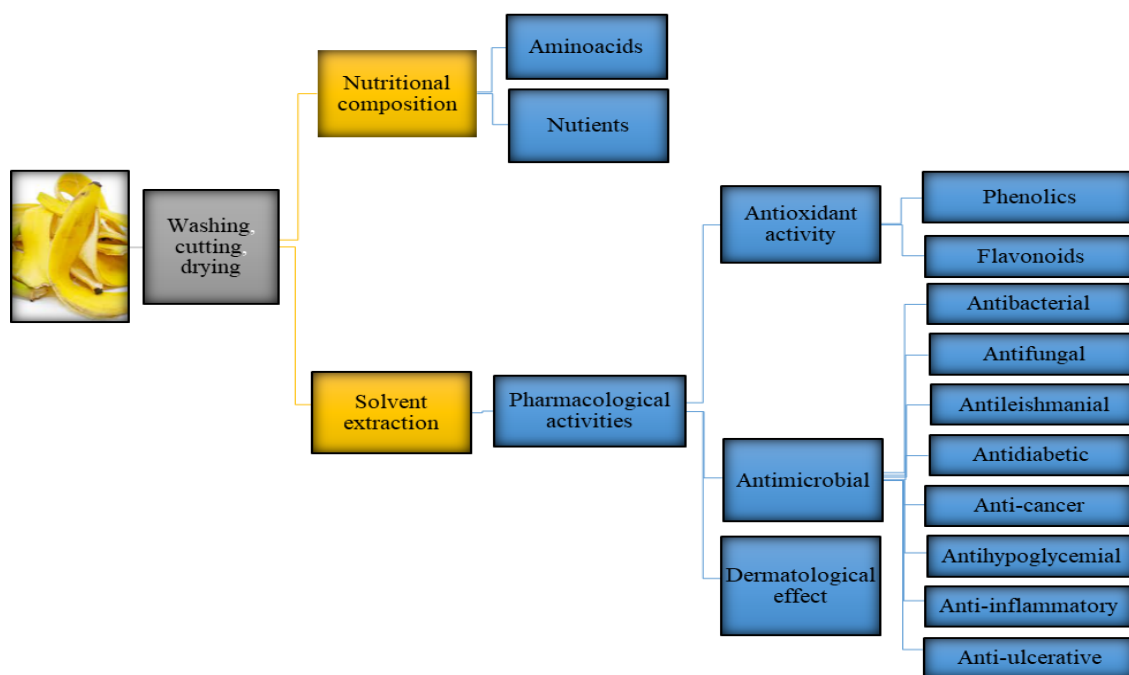


Figure 2: Valorization of banana peel

Nutritional composition of banana peel

Banana peel is a cheap source of starch, crude lipids, proteins, dietary fibers and polyunsaturated fatty acids, especially linoleic and alpha-linolenic acid, pectin, minerals and essential amino acids (Table 1).

It contains amino acids including lysine, leucine, valine, phenylalanine and threonine they are all approved to be higher than Food and Agricultural Organization (FAO) standard except lysine (Table 2) [27].

Table 1: Proximate composition of banana peel and pulp

Contents	Peel	Pulp	Reference
Moisture	75.3±3.2	62.0±2.87	[28-32]
Non-reducing sugar	3.4±0.19	5.4±0.09	
Protein	5.3±0.02	0.83±0.04	
Crude Fat	5.93±0.13	2.58±0.12	
Ash	15.29±0.05	1.54±0.07	
Carbohydrates	8.8±0.54	32.5±1.99	

Additionally, banana peel is a good source of cellulose (7.6-9.6 %), lignin (6-12 %), pectin (10-21 %), glucose, galactose, arabinose, rhamnose, xylose and hemicelluloses (6.4-9.4 %) [\[33\]](#). Micronutrients include calcium, iron, copper, manganese, sodium, potassium,

magnesium, zinc and phosphorus (Values are given below in Table 3) among which mopper, manganese, calcium, magnesium and potassium. Peel has a higher proportion of iron than pulp [\[34\]](#).

Table 2: Amino acids in banana peel and their applications

Amino acids		Banana peel (g/100g)	WHO (g/100g)	Application	References
Essential amino acids	Threonine	2.82	4.7	Substrate for protein synthesis	[35]
	Valine	2.01	6.6	Involve in muscle growth and energy production	[36]
	Histidine	4.61	-	Active site of enzymes	[37]
	Tyrosine	1.97	6.0	An essential component for the production of brain chemicals	[38]
	Lysine	7.16	7.0	Substrate for bones and connective tissues	[39]
	Methionine	2.52 6	6	Regulate metabolism and innate immune system	[40]
	Tryptophan	7.39	-	Role in metabolism	[41]
	Phenylalanine	9.56	9.3	Important in the nervous system	[42]
	Isoleucine	9.50	5.4	Role in maintaining the immune system	[43]
	Leucine	10.97	8.6	Stimulate protein synthesis	[44]
Non-essential amino acids	Asparagine	0	-	Role in nitrogen metabolism in plants	[45]
	Arginine	11.10	-	Potential role in dentistry	[46]
	Serine	8.26	-	Role in plant metabolism and development	[47]
	Glycine	7.32	-	As a biological modifier	[48]
	Alanine	8.51	-	In dye industry	[49]
	Cysteine	6.30	-	An important site of protein	[50]

Table 3: Mineral composition of banana and plantain peel [\[51\]](#)

Minerals	Peel (mg/100g)	Plantain (mg/100g)
Copper	1.35±0.05	0.59±0.83
Iron	5.06±0.07	7.89±0.79
Manganese	10.38±0.04	1.25±0.39
Zinc	11.60±0.03	13.30±0.57

Calcium	17.85±0.25	14.70±0.25
Magnesium	49.32±0.74	45.21±4.36
Sodium	58.16±2.73	76.88±0.89
Potassium	38.22±0.16	26.14±2.68
phosphorus	22.64±0.38	28.95±0.94

Source of bioactive compounds

Recovering bioactive substances from agricultural waste is an effective, affordable, and environmentally friendly strategy to reduce pollution. Numerous uses for these bioactive substances can be found in the food, cosmetics and pharmaceutical industries. Banana peel contains syringic acid, which has the potential to be used to treat abnormalities in glycoprotein components and has an antidiabetic effect in experimental diabetes [52], tannic acid which has been used as a burns treatment agent [53], catechol is used as an intermediary for in lubricating oil and rubber, developer for fur dyes, photographic developer, in polymerization inhibitors and in pharmaceuticals [54], while catechin has resistance of low density lipoprotein (LDL) to oxidation, brachial artery dilation increased plasma activity and fat oxidation [55], gallic acid have potential of hepatoprotective effects [56], cinnamic acid has been used as a precursor to the artificial sweetener aspartame by the means of enzyme catalyzed amino group to phenylalanine [57], p-coumaric acid has

antioxidant characteristics and may lower the chance of stomach cancer [58], while quercetin improves cardiovascular health by improving blood flow [59], ferulic acid is an antioxidant, antimicrobial, anti-inflammatory, antiallergic, anticarcinogenic, modulation of enzyme activity, antiviral and vasodilatory actions [60], trans- α carotene, a precursor to vitamin A and trans- β carotene lower the rate of cancer and cardiovascular diseases (CVD) [61]. Violaxanthin is a food colorant while neoxanthin is an intermediary in the generation of the plant hormone abscisic acid [62], cryptoxanthin is used as a food colorant and might reduce the risk of lung cancer [54]. Serotonin may play a role in sensations of happiness and well-being [63], dopamine decreases plasma oxidative stress and increases resistance to oxidative modification of low density lipoprotein (LDL) [20] and β -sitosterol able to lower blood cholesterol levels and the risk of benign prostatic hyperplasia [64], campesterol and stigmasterol control the level of cholesterol that is absorbed in human intestines [65], cycloartenol is the primary precursor in the synthesis of steroids (Table 4) [66].

Table 4: Bioactive compounds extracted from banana peel

Bioactive compounds	Sub-types	References
Flavan-3-ols	Gallic catechin Glutathione Norepinephrine Naringin Salsolinol L-Dopa	[67-69]
Flavanol	Rutin Quercetin-deoxyhexose hexoside Myricetin-deoxyhexose-hexoside Laricitrin-3-rutinoside Syringetin-3-rutinoside Kaempferol-7-rutinoside	[59, 69, 70]
Triterpenic	31-Norcyclolaudenone Cycloeucalenone	[71]
Carotenoids	Trans- α -carotene, Trans- β -carotene α -Cryptoxanthin	[54, 62, 72]

	β -Cryptoxanthin Violaxanthin Auroxanthin Neoxanthin	
Sterols	β -Sitosterol Stigmasterol Campesterol	[64, 65]
Triterpenes	Cycloeucalenol Cycloartenol 31-Norcyclolaudenone	[66, 71]
Cycloartane-type triterpenes	3-Epicycloeucalenol 3-Epicyclomusalenol 24-Methylenepollinastanone 28-Norcyclomusalenone	[71, 73]
Fatty acids	Methyl palmitate Methyl Linoleate Methyl petroselinat Methyl stearate 5-Cholene, 3, 24-dihydroxy 5-Dihydroergosterol 4,8,13-Duvatriene-1, 3-diol Henicosyl formate	[74]
Active amines	Serotonin Tyramine Norepinephrine	[63, 75, 76]
Polyamines	Putrescine Spermidine Spermine	[77, 78]

Antioxidant potential of banana peel

Antioxidants are substances that neutralize free radicals and can be obtained from food. Dietary antioxidants play a vital pharmacologically role in improving male reproductive health, reducing insulin resistance and lowering the risk of type II diabetes [79, 80]. Antioxidants promote normal biological functions including healthy cell proliferation, immunological support and molecular degeneration prevention, including the prevention of premature ageing [81]. The banana should be regarded as a useful dietary source against diseases and an excellent source of natural antioxidants for foods. These compounds predominate in the majority of the tissues in banana peel [82]. The banana peel extract was found to contain galocatechin which demonstrated significant antioxidant activity. Shinichi *et al.* [83] revealed in her study that peel contained higher galocatechin (158 mg/100g DW) than

pulp (29.6 mg/100g DW). It was also more potent than the banana pulp extract against lipid autoxidation. Catechins show strong antioxidant effects against lipid peroxidation [84] and protective effects against diseases such as cancer and CVD [85]. Antioxidant capacity depends on different solvents such as acetone, acetyl acetate, chloroform, ethanol, methanol and n-hexane by several antioxidant potential determining assays including diphenyle-1-picrylhydrazyl assay (DPPH), ferric reducing antioxidant power (FRAP), metal chelating activity, 2,2'-azino-bis (3-ethylebenzothiazoline-6-sulfonic acid assay (ABTS), superoxide anion scavenging activity (SOSA), nitric oxide radical scavenging activity (NORSA), hydroxyl radical (OH) scavenging activity, lipid peroxidation inhibition capacity (LPIC), total phenolic content (TPC) total flavonoid content (TFC), total carotenoid contents (TCC) and radical scavenging activity as mentioned in (Table 5).

Table 5: Total antioxidant activity of banana peel

Antioxidant activity	Solvents							References
	Water	Chloroform	Acetone	Methanol	Ethanol	Acetyl acetate	n-Hexane	
DPPH	9.8±0.2 ^a	8.7±0.3 ^a	72.83 ^c	28.50±1.30 ^e	19.10 ^c	43.7±0.5 ^a	171.6 ^c	[21, 82, 86-92]
FRAP	79.28 ^d	16.37±0.38 ^h	-	6.98±0.34 ^f	55.10 ^d	-	59.15 ^d	
Metal chelating activity	15.45±0.67 ^a	-	12.3±0.43 ^a	12.20±0.94 ^a	19.4±0.94 ^a	17.35±1.97 ^a	-	
ABTS	69±4.7 ^e	-	75.39±0.59 ^e	35.5±2.4 ^e	28.30±0.85 ^e	-	-	
SOSA	97±4.8 ^e	-	-	44.7±3.1 ^e	-	-	-	
NORSA	103±4.9 ^a	-	-	43±1.5 ^e	-	-	-	
OH radical scavenging	75.4±2.8 ^e	-	-	39.7±3.7 ^e	-	-	-	
LPIA	-	-	-	89.0 ^a	88.4 ^a	3.22±0.85 ^a	-	
TPC	371.74±3.82 ^g	17.85±2.45 ^g		0.54±0.02 ^b	12.58±0.04 ^c	630.14±2.85 ^g	68.83±3.32 ^g	
TFC	8.56±0.22 ^b	15.44±0.19 ^b	16.15±0.28 ^b	51.47±1.94 ^c	18.52±0.06 ^b	-	-	
TCC	-	-	-	64 ^c	-	-	-	

Note: a = %, b = mg/g, c = µg/g, d = µM Fe²⁺/mg, e = µg/ml, f = (mmol Fe²⁺/100g DW), g = GA mg/100 g, h = mg TE/g.

Phenolic compounds

Phenolic compounds are the most essential plant elements that exhibit antioxidant activity by neutralizing lipid free radicals or by preventing hydrogen peroxides from disintegration into free radicals [93, 94]. Vascular plants contain more than 4000 phenolic compounds [95]. Phenolic chemicals are well known for improving quality and nutritional value through modulating color, taste, aroma and flavor in addition to having beneficial impacts on health [96]. Banana peel contains phenolic chemicals, which have been the subject of extensive studies into the effects of dietary polyphenols on human health over the past 20 years. Compared to other fruits, the banana peel contains a high quantity of phenolic. These investigations firmly establish their significance in preventing degenerative disorders, including cancer and cardiovascular conditions. These investigations firmly establish their significance in preventing degenerative disorders, including cancer and cardiovascular conditions. Several studies have conducted antioxidant effects of polyphenols [97]. As bananas ripened, their overall phenolic content decreased [98]. Some of the health advantages associated with phenolic chemicals include the prevention of cardiovascular disease, cancer, diabetes and obesity [99, 100]. These compounds are effectively used as functional ingredients in the prevention of lipid oxidation [101] and inhibit microbial growth [102]. The phenolic content in green peel is greater up to 15-45 % than in ripe peel whereas it is 52 % higher than that of over-ripened peel [88]. Hang *et al.* [1] reported that total phenolic content in banana peel ranging from 4.95-47 mg gallic acid equivalent/g dry matter (mg GAE/g DM).

Flavonoid compounds

All plants include a variety of natural compounds called flavonoids, which make up the largest category of plant phenols and more than half of the eight thousand naturally occurring polyphenols [103-105].

Chalcones, isoflavonoids, flavonols, flavanones, flavones, flavanonols and anthocyanins are other subcategories of flavonoids. According to published research, phenolic and flavonoid concentrations are natural antioxidant sources [106]. Additionally, flavonoids affect the neurological system and may be used to treat cancer [107]. According to research, the banana peel contains flavones that have enormous potential in the food industry [108]. Banana peel extract contain flavonoid leucocyanidin that promote healing [109].

Antimicrobial activity

Herbal remedies have historically been used to treat a variety of infectious diseases and have been proven beneficial in many cases. Most herbal remedies come from plant components such as leaves, flowers, fruits and stems. To create novel antimicrobial compounds that will operate as a barrier against multidrug-resistant microbes, these extracts may be employed to create new chemical structures and mechanisms of action [110]. Banana peel has been found to contain flavonoids, alkaloids, saponins, triterpenes, and tannins. Flavonoid's antibacterial mechanisms of action prevent the production of nucleic acids, cytoplasmic membrane function, metabolic activity, adhesion and biofilm generation, altering membrane permeability which reduce the pathogenicity of microbes. Tannins prevent bacterial extracellular enzyme activity and interfere with bacterial metabolism by preventing oxidative phosphorylation [111]. Saponins increase the cell membrane permeability. This rise leads to the cell membrane being unstable and ultimately causing cell hemolysis. Similarly, alkaloids and triterpenoids break down lipid components and increase their permeability, causing the cell membrane to lyse or the cytoplasm of bacterial cells to coagulate (Fig. 3) [112]. As mentioned in (Table 6), previous studies found that banana peel's antibacterial capabilities were efficient against a variety of microbes.

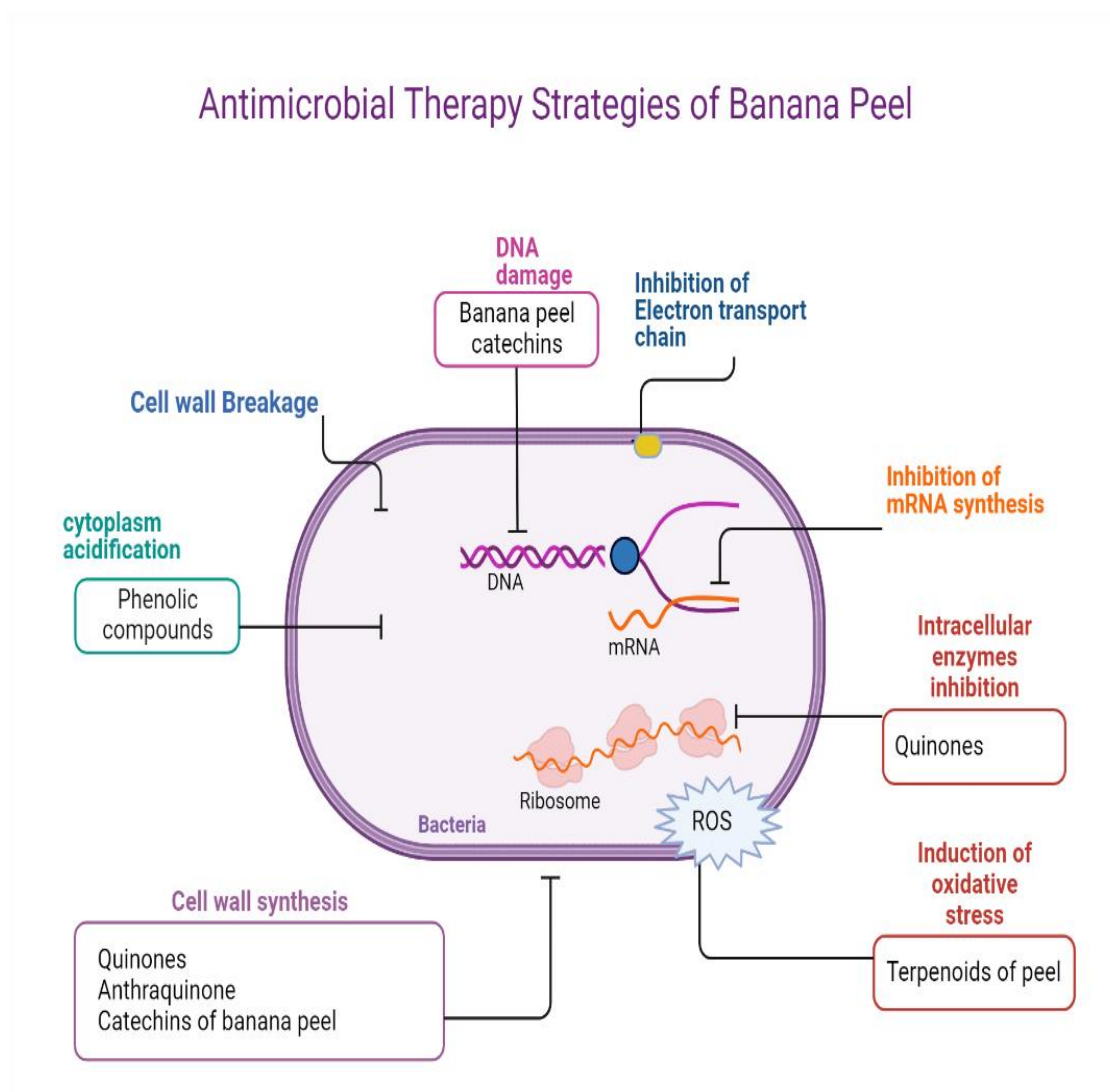


Figure 3: Antimicrobial strategy of banana peel

Table 6: Antibacterial potential of banana peel

Microorganisms	Extraction solvents Zone of inhibition (mm±standard deviation)						References
	Methanol	Ethyl acetate	Ethanol	Distilled water	Methanol-chloroform	Acetone	
Gram negative							
<i>Pseudomonas aeruginosa</i>	9±0.4	12±0.7	15.86	14±0.9	-	19.57	
<i>Klebsiella pneumoniae</i>	12±0.4	14±0.6	12±0.5	16±0.5	-	-	
<i>Serratia marcescens</i>	–	12±0.4	-	9±0.2	11	-	
<i>Escherichia coli</i>	9±0.3	10±0.3	15.23	12±0.4	-	18.15	
<i>Shigella</i> spp.	-	-	-	-	0	-	
<i>Salmonella typhi</i>	–	12±0.4	10±0.2	9±0.2	-	-	
<i>Salmonella enteritidis</i>	-	10±0.2	-	-	-	-	
<i>Proteus vulgaris</i>	14±0.3	15±0.3	12±0.2	16±0.4	8	-	
Gram positive							
<i>Staphylococcus aureus</i>	–	12±0.4	10±0.2	13±0.3	13	19.57	
<i>Enterococcus faecalis</i>	–	11±0.2	-	12±0.3	-	-	
<i>Aeromonas hydrophila</i>	12±0.3	13±0.3	11±0.2	14±0.3	20	-	
<i>Streptococcus pyogenes</i>	-	10±0.2	-	12±0.3	-	-	
<i>Listeria monocytogenes</i>	9±0.2	10±0.2	10±0.2	12±0.2	-	-	
<i>Lactobacillus casei</i>	10±0.2	10±0.2	-	12±0.2	-	-	
<i>Bacillus cereus</i>	-	14.17	11.01	-	19.57	-	
<i>Bacillus subtilis</i>	-	10±0.3	15.32	-	-	20.6	
Fungi							
<i>Aspergillus flavus</i>	-	-	11.76	-	-	17.81	
<i>Aspergillus niger</i>	10±0.2	9±0.2	-	10±0.2	-	-	
<i>Saccharomyces cerevisiae</i>	12±0.2	12±0.2	15.6	20±0.5	-	16.87	
<i>Penicillium citrinum</i>	-	8±0.2	-	9±0.2	-	-	
<i>Candida albicans</i>	-	9±0.2	15.6	14±0.3	-	17.61	
<i>Alternaria alternata.</i>	-	-	1.37±0.67	-	-	-	

[82, 90, 113, 114,115]

Dermatologist effect

There are different skincare benefits of bananas. There is a certain antimicrobial activity in fruit peels which acts against *Staphylococcus* and *Pseudomonas* species [116] as well as high potassium (K) content which is making it the ideal treatment against acne prone-skin. This peel acts as a healing agent by reducing the spread of bacterial skin cells and promoting the healing of pimples and other skin imperfections. It contains antioxidants such as dopamine, ascorbic acid and flavonoids and has anti-ageing benefits [20, 117]. Additionally, it contains vitamin C, which is reported to prevent melanin synthesis, a pigment that causes the skin to darken when exposed to sunlight. Thus, the skin-lightening and soothing properties of banana peel can be associated with anti-melanin synthesis and/or degradation because of its anti-inflammatory properties [118]. Potential skin protection, with a skin protection factor (SPF) value 10.67 was demonstrated by the banana peel ethanol extract with bisulphite immersion [119].

Anti-hyperglycemic activity

Defects in insulin secretion, insulin tolerance, or a combination of the following factors known as diabetes mellitus are the most prevalent endocrine diseases [120]. The leading causes of significant health issues in most of the nation [121]. According to a World Health Organization (WHO) report 2013, there are around 347 million diabetic patients worldwide, making it the third leading cause of mortalities [122, 123]. For the treatment of diabetes mellitus, several synthetic oral hypoglycemic drugs, such as biguanides and sulfonylurea, are in addition to insulin. In the prehistoric era of medicine, a variety of plants had been suggested as being beneficial in the identification and management of diabetes mellitus. The peel of different *Musa* spp. is used to treat and cure diabetes mellitus [124].

It is rich in antioxidants and can boost immunity and lower diabetes risk factors [125]. It has an anti-hyperglycemic effect, which is mostly attributable to the presence of phyto-constituents such as tannins, alkaloids, saponins and flavonoids [120, 126, 127]. Researchers found that anthocyanins, delphinidin, cyanidin and catecholamine are present in banana peel and may also have a role to produce insulin more efficiently from pancreatic beta cells, which in turn has an anti-diabetic impact [8, 128]. Peel has pectin which is one of the key ingredients that has been linked to antihyperglycemic effects. Gallic catechin, quercetin and rutin may have an anti-hyperglycemic effect that has been observed. Gallic catechin promotes peripheral glucose utilization and one of the potential mechanisms for anti-hyperglycemic activity could suppress intestinal glucose absorption or increase insulin generation by pancreatic beta cells. Furthermore, a significant concentration of potassium (K) and sodium (Na) has been linked to the glycemic effect [129]. Chromium (Cr) has been shown to increase glucose tolerance in diabetic elderly individuals and malnourished children. The antihyperglycemic activity was determined using an oral glucose tolerance test and [130] sucrose tolerance test [131].

Anti-ulcerative property

Ulcers are lesions that penetrate the mucosa of the gastrointestinal tract (GIT) [132]. Therefore, the development of the gastroduodenal (peptic) ulcer occurs when the aggressive factors-increased hydrochloric acid (HCl) and pepsin secretion, parietal cell mass and gastrin production-dominate the defensive components. These factors cause auto-digestion and breakdown of gastric mucous. Decreasing stomach acid production, neutralization of acid pepsin (aggressive factors) and stimulation of protective factors such as mucus and bicarbonate secretion, prostaglandins, mucosal blood flow and nitric oxide are the

major ideas for treating ulcers [133, 134]. Therefore, the main therapy recommendations focus on increasing the synthesis of substances that protect the stomach mucosa in addition to restricting acid secretion, thereby preventing epithelial erosion [135].

Peptic ulcer prevention or treatment is one of the most difficult medical issues since gastric ulcer therapy has downsides and the majority of medications on the market today have limited effectiveness against stomach disorders and are frequently linked to serious adverse effects. In particular, in the treatment of peptic ulcers in various experimental models for the evaluation of anti-ulcer medications, the research of natural products and medicinal plant extracts has emerged as one of the most fascinating and attractive sources of innovative therapy for various gastrointestinal problems. Additionally, they observed the protective effects of the banana peel on gastric mucosa due to its several bioactive ingredients including essential phytochemicals and micronutrients such as alkaloids, carotenoids, flavonoids, lignans, phenolics and tannins. Mechanistic characteristics of bioactive components may inhibit ulcer through a number of mechanisms, including antioxidant activity, repression of cell growth, activation of apoptosis, repression of cell invasion and intracellular signaling pathways [86].

The remarkable antiulcer activity and cytoprotective properties of the extract of banana peel (*Musa paradisiaca*) on the experimental organisms may be attributed to the phytochemicals such as flavonoids, tannins and saponins [136]. Leucocyanidin, a naturally occurring flavonoid, reportedly preserves the gastrointestinal mucosa from erosions [137]. Leucocyanidin and its synthetic derivatives, hydroxy ethylated leucocyanidin and tetraallyl leucocyanidin, were reported to protect the gastric mucosa in rat models of aspirin-induced erosions by

thickening gastric mucus [138]. Literature indicated that research has been done on laboratory animals (rats and mice). The peel extract has been tested on different acute ulcer models including Alcohol-induced gastric ulcer (AL) in rats [139], Aspirin-induced gastric ulcers (ASP) in rats [140] and Pyloric ligation-induced gastric ulcer (PL) in rats [141], Cold-Restrain Stress-Induced Ulcer (CRS) and chronic ulcer model such as Acetic acid-induced ulcer model [142]. Unripe plantain peel extract was found to have a protective effect against (ASP) of stomach mucosa [136]. The peel extract's greatest percentage of ulcer inhibition against ethanol-induced ulcers was 83.33 %, compared to 100 % against (ASP) and (CRS). Fatimah *et al.* [143] demonstrated the preventive effect of *Musa paradisiaca* tepal and skin methanol extracts by demonstrating how they significantly decreased the ulcers.

Anti-inflammatory potential

In response to infection, injury or irritation a certain biological process is called Inflammation [144]. The term "inflammation" refers to a complex immunological response that is connected to the gradual release of pro-inflammatory cytokines [145]. One of the main inflammatory mediators is nitric oxide (NO). In addition to NO, other inflammatory mediators such as cyclooxygenase-2 (COX-2), interleukin (IL)-1b, IL-6 and tumor necrosis factor-alpha (TNF-a) are also active and are predominantly expressed in inflammatory cell types such as macrophages and mast cells [146, 147]. Therefore, controlling the overproduction of inflammatory mediators, especially pro-inflammatory cytokines may help to prevent a variety of inflammatory infections [148]. Inflammation appears to be linked to a variety of illnesses, including cancer, allergies, atherosclerosis and even rheumatoid arthritis [149].

Numerous natural products rich in phytochemicals including antioxidants and phenolics in fruits and vegetables are the major bioactive components known to show various health benefits [8, 150]. The anti-inflammatory actions of numerous plant extract isolated mixtures have already been methodically confirmed, whereas banana peel has been conventionally used as a therapeutic substance for the handling of inflammation [1, 15]. Flavonoid, saponin and tannin contents of banana peel possess anti-inflammatory potential [107]. Pathompong *et al.* [151] indicated that NO inhibitory activity supported the use of *Musa* spp. peel as medicine for the treatment of inflammation. It indicated that water extract of fresh ripe banana peel exhibits high NO inhibitory activity ($IC_{50} = 6.68 \pm 0.34 \mu g$).

Conclusion and future prospects

Based on previous information, the banana peel has great biological potential. Concerning nutritional content, the peel can be considered a cheap viable source of dietary fiber because it contains a high amount, which promotes healthy digestion of food. Many studies have proved that banana peel contains high antioxidant and bioactive content that could help the pharmaceutical sector to prevent chronic diseases and increase interest in enhancing food quality. It might provide consumers with a better understanding of the production of value-added products. On the other hand, several molecular processes, such as metabolomics, genomics and proteomics, enable us in determining the mode of action of several bioactive chemicals to treat a wide range of unclear diseases or infections. Apart from excellent antioxidant sources and high nutritional values for preventing and treating chronic diseases, literature has shown that banana peel may also be used to produce cost-free energy in the form of bioethanol, biodiesel, organic acids, single-cell protein and various important industrial enzymes.

some studies have advocated that peel can be used for skin treatment because of its high antimicrobial potential, which may open a new site for the cosmetic industry. Raw banana peel can be transformed into edible food to avoid its unpleasant taste and increase its consumption.

Authors' contributions

Conceived and designed the experiments: A Akbar & M Hashim, Performed the experiments: M Hashim & Z Hamid, Analysed the data: M Hashim & Z Gul, Contributed materials/ analysis/ tools: A Akbar, Wrote the paper: M Hashim.

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