Banana Peel: A potential waste product with numerous pharmacological activities

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Abstract

Plants have been used as a traditional medicine for generations. Recently the pharmaceutical industries are showing a great interest in using plant extracts in pharmaceutical product development due to the uses of the plants in the treatment of various diseases. Banana is a world-wide edible fruit which comes from south-east Asia. It belongs to the genus Musa and is of two types, sweet banana, and plantain. It has many different species in the world, which are divided into 50 groups. The scientific names of cultivated bananas are Musa acuminate, Musa balbisiana and Musa paradisiaca belonging to the family Musaceae. The present review discusses the various pharmacological activities of the banana peel.

Keywords: Plant waste; Musa; Phytochemical compounds; Pharmacological activity

1. Introduction

Bananas are one of the most commonly eatable fruits grown in various countries world-wide. The banana plant contains different parts such as stem, leaves, flower and pulp and each part are having a medicinal use. The fruit average is 125 grams, of which approximately 75% is water and 25% dry matter content. Banana peel is a by-product of banana which weighs around 35-38% of the fruit [1]. After consuming bananas, the peels are either used as animal feed, fertilizer or discarded. Banana peel shows different activities, and it has been used as traditional medicine since ancient times. Banana peels are used in as a home remedy for wound healing and overcome illnesses like depression. Banana by-products have been used for wrapping foods, clothes and used in various ceremonial occasions and the usage expands through cultural diversification [2, 3]. These days, the banana peels are having various industrial applications such as biofuel production [4, 5], bio-sorbents, paper and pulp, cosmetics, energy related activities, organic fertilizer, environmental clean-up, and biotechnology related processes. Many studies have been conducted and proved that banana peel possesses medicinal properties like other parts of the banana plant. The volume of research done on the banana peel inspired the authors to present a comprehensive review on the reported medicinal activities of the banana peel.

2. Chemical composition of banana peel

Banana peel contains primary metabolites like 50% of dietary fiber, 7% crude proteins, 10% crude fat 3% starch, polyunsaturated fatty acids (linoleic acid, α-linoleic acid), essential amino acids (leucine, phenylalanine, threonine, and valine), micronutrients (calcium, iron, magnesium, potassium, zinc [6]. It also contains 10-20% pectin, 6-12% lignin, cellulose 7-9%, 6-9% hemicellulose. Banana peel is a rich source of various phytochemical compounds (Table 1).
Table 1 Phytochemical compounds present in banana peel

<table>
<thead>
<tr>
<th>Phytochemical compounds</th>
<th>Concentration</th>
<th>Activity</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenolic compounds</td>
<td>0.9 – 3 g/100 g</td>
<td>Antioxidant</td>
<td>[7]</td>
</tr>
<tr>
<td>Gallocatechin</td>
<td>160 mg/100 g</td>
<td>Antioxidant</td>
<td>[8]</td>
</tr>
<tr>
<td>Anthocyanins</td>
<td>-</td>
<td>Antioxidant</td>
<td>[9]</td>
</tr>
<tr>
<td>Carotenoids</td>
<td>300-400 µg/100g</td>
<td>Antioxidant</td>
<td>[10]</td>
</tr>
<tr>
<td>Sterols and triterpenes</td>
<td>-</td>
<td>Antioxidant</td>
<td>[11]</td>
</tr>
</tbody>
</table>

3. Pharmacological activities of banana peel

The rich source of phytochemical compounds in banana peel are responsible for pharmacological activities such as antibacterial, antifungal, antioxidant, antiulcer and anticancer.

3.1. Anti-bacterial activity

The need of developing new antibacterial agents is necessary because the bacteria is developing resistance to the current antibacterial agents. Medicines derived from plants are used for treatment of infections [12].

Kavitha et al., [13] studied antibacterial activity of 70% ethanolic extract of dried peel extracts of eight varieties of bananas by well agar diffusion method against gram positive bacteria and gram-negative bacteria using chloramphenicol as the positive control. The minimum inhibitory concentration of the extracts was determined. The banana peel extracts showed significant anti-bacterial activity than the positive control.

Suraj Premal et al., [14] evaluated the anti-bacterial activity of the banana peel extract against the periodontal pathogens, *Porphyromonas gingivalis* and *Aggregatibacter actinomycetemcomitans* using well agar diffusion method. The banana peel extract was prepared using 70% isopropyl alcohol and it is assessed for the antibacterial activity. The minimum inhibitory concentration was determined using serial broth dilution method. The significant reduction bacterial growth due to peel extracts is indicated by zones of inhibition.

Ehiowemwenguan et al., [15] studied the antibacterial activity of ethanolic and aqueous extracts of banana peels against gram positive and gram-negative bacteria using agar well diffusion method. The extracts were analyzed for alkaloids, flavonoids, glycosides, resins, steroids, tannins, and volatile oils. The minimum inhibitory concentration was done using tube dilution technique. The extracts were found to be more effective against gram negative bacteria. The ethanolic extract of banana peel showed significant antimicrobial activity.

Ravinder Singh et al., [16] studied antibacterial activity of dried peel extracts of green, red, and yellow bananas against ten bacterial species, *Pseudomonas citrii*, *Escherichia coli*, *Shigella sp.*, *Salmonella typhimurium*, *Klebsiella pneumonia*, *Salmonella typhi*, *Staphylococcus aureus*, *Proteus vulgaris*, *Aeromonas hydrophilia*, and *Serratia marscens*. Methanol and chloroform in 8:2 ratio were used for the extraction. The banana peels of three different colors showed significant antibacterial activity without affecting the normal flora.

Matook Saif Mokbel et al., [17] studied the antibacterial activity of fresh extracts of green and yellow banana peel using paper disc method and minimum inhibitory concentration. The solvents used for extraction were chloroform and ethyl acetate. The isolated components were β-sitosterol, malic acid, succinic acid, palmitic acid, 12-hydroxystearic acid and glycoside; and among all the isolated components, malic acid and 12-hydroxystearic acid were most effective against gram positive and gram-negative bacteria.

The reported studies on antibacterial activity of banana peel are presented in Table 2.
### Table 2 Antibacterial activity of banana peel

<table>
<thead>
<tr>
<th>Extracts</th>
<th>Organisms</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>70% ethyl alcohol extracts of dried powder of peels of different varieties of banana Rashthali, Nendran, Kadali, Red banana, Robusta, Poovan, Pachainadan[13]</td>
<td><em>Staphylococcus aureus</em>, <em>Bacillus subtilis</em>, <em>Pseudomonas aeruginosa</em>, <em>Escherichia coli</em></td>
<td>Rashthali and robusta showed a significant activity against all bacteria. Nendran, kadali, red banana and poovan showed good activity against <em>S. aureus</em>, <em>B. subtilis</em> and <em>P. Aeruginosa</em> but not against <em>E. coli</em>. Pachainadan showed significant activity against <em>S. aureus</em>, <em>B. Subtilis</em> and <em>E. coli</em> but not against <em>P. aeruginosa</em>.</td>
</tr>
<tr>
<td>70% iso propyl alcohol extract of fresh peels of <em>Musa paradisiaca</em> [14]</td>
<td><em>Porphyromonas gingivalis</em>, <em>Aggregatibacter actinomycetemcomitans</em>.</td>
<td>Showed antibacterial activity</td>
</tr>
<tr>
<td>Distilled water and ethanol extracts of dried powder of <em>Musa sapientum</em> [15]</td>
<td><em>Bacillus subtilis</em>, <em>Staphylococcus aureus</em>, <em>Micrococcus luteus</em>, <em>Klebsiella pneumoniae</em>, <em>Pseudomonas aeruginosa</em>, <em>Escherichia coli</em>, <em>Salmonella typhi</em></td>
<td>Ethanolic extracts decreasing order of zones of inhibition. <em>K. pneumoniae&gt;</em> <em>P. aeruginosa&gt;</em> <em>S. typhi&gt;</em> <em>E. coli&gt;</em> <em>S. aureus</em>. Aqueous extracts decreasing order of zones of inhibition. <em>K. pneumoniae&gt;</em> <em>E. coli</em>.</td>
</tr>
<tr>
<td>Methanol: chloroform (8:2) extract of dried powder of ripened peels of green, red, and yellow bananas [16]</td>
<td><em>Pseudomonas citrii</em>, <em>Escherichia coli</em>, <em>Shigella sp</em>, <em>Salmonella typhimurium</em>, <em>Klebsiella pneumoniae</em>, <em>Salmonella typhi</em>, <em>Staphylococcus aureus</em>, <em>Proteus vulgaris</em>, <em>Aeromonas hydrophila</em>, <em>Serratia marcescens</em></td>
<td>Red peel extract <em>P. citrii&gt;</em> <em>S. aureus&gt;</em> <em>P. vulgaris&gt;</em> <em>S. Marcescens</em>. Green peel extract <em>S. typhi&gt;</em> <em>S. marcescens&gt;</em> <em>P. vulgaris&gt;</em> <em>S. aerues</em>. Yellow peel extract <em>A. hydrophila&gt;</em> <em>S. aureus&gt;</em> <em>P. citrii&gt;</em> <em>S. marcescens</em>.</td>
</tr>
<tr>
<td>Chloroform, ethyl acetate and water extracts of green and yellow peels of <em>Musa, AAA cv. Cavendish</em> [17]</td>
<td><em>Bacillus cereus</em>, <em>Salmonella enteritidis</em>, <em>Escherichia coli</em>, <em>Bacillus subtilis</em>, <em>Staphylococcus aureus</em></td>
<td>Ethyl acetate extract of green peel showed significant antimicrobial activity while yellow peel extract showed low activity and no activity was recorded by chloroform and water extracts.</td>
</tr>
</tbody>
</table>

### 3.2. Anti-cancer activity

Cancer is a disease affecting people of all age groups and caused by multiple factors. Anticancer drugs currently used are toxic and nonspecific. Research is being carried out for anticancer agents which can minimize the limitations of existing drugs [18].

Amal MK, et al. [19] studied antitumor activity of 95% ethanolic extract of air-dried banana peel powder. The study was conducted male Swiss mice. It was observed that the extract possesses anticancer agents by improving haematological parameters, inhibiting carcino embryonic antigen and malondialdehyde.
Kumar PS, et al., [20] evaluated anticancer activity of 80% methanolic extract of freeze-dried peel powder of Nendran banana. The anticancer activity of the extract on human breast cell line was determined using 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) and acidine orange/ethidium bromide assay. The cell viability was decreased considerably with an increase in concentration of extract.

Wermerson AB, et al., [21] conducted cytotoxic screening of peel extract of pacovan banana (Musa Cavendish) on hepatocellular carcinoma HepG2, malignant melanoma A-375, breast carcinoma MCF-7 and colorectal adenocarcinoma Caco-2 human cell lines. The extract was obtained from fresh peels using 70% alcohol for extraction by maceration. The effect of peel extract on proliferation was evaluated through apoptosis, necrosis, mitochondrial membrane potential and reactive oxygen species (ROS) content. Banana peel extract was lethal to A-375 and was less effective on Caco-2.

Sobanalakshmi S. et al., [22] studied the anticancer activity of ferulic acid extracted from dried banana peels using Staphylococcus aureus. The effect of biosynthesized ferulic acid on cell viability was tested by MTT assay and observed for morphological changes in HeLa cells taking synthetic ferulic acid for comparison.

Munish G, et al., [23] investigated anticancer activity of extracts of dried banana peels along with four other fruits by MTT assay on HepG2 cells. The extracts were prepared using 80 % ethanol as solvent by maceration for 7 days. The banana extract was found to have anticancer activity.

Saad SD, et al., [24] studied anticancer activity of dried banana peel along with pulp. Ethanol, n-hexane, and water were used as solvents for extraction by hot maceration at 40°C. The extracts were tested for their ability to inhibit the growth of human umbilical vein endothelial cell line (HUVEC), human colorectal carcinoma cell line (HCT-116) and human hormone sensitive and invasive breast cancer cell line (MCF-7) using MTT assay. Of all the three extracts, n-hexane extracts have showed highest inhibition of cell proliferation of HCT-116 and MCF-7. There is no inhibition of cell proliferation in normal cell lines. In this study, antitumorogenesis was also evaluated using an ex-vivo rat aorta ring assay. The study of the effect of banana peel extract on angiogenesis (growth of new blood vessels) of thoracic aorta rings of rats. Hexane extract showed the highest antiangiogenic effect when compared to other extracts.

Nessma AZ, [25] studied antitumour activity in ethanolic extract of freeze-dried banana peel along with other fruit peels on breast cancer cell line by sulphorhodamine–B assay using thymoquinone as a positive control. The increasing order of cytotoxic activity is tangerine and orange; kiwi and lemon; goldenberry and banana and carrot and watermelon.

Fatimah CA, et al., [26] studied cytotoxic activity of methanolic extract of fruit (both peel and pulp) of Musa acuminata malaccensis. The extract showed moderate cytotoxic activity against cancer cell lines but no such activity on the normal cell line.

Imam MZ, et al., [27] studied the cytotoxic property of different extracts of Musa sapientum L. subsp. Sylvestris fruit peels along with pulp and seed. Peel extract exhibited moderate activity against 5 gram-positive bacteria and 8 gram-negative bacteria and 3 fungi.

The reported anticancer activities of banana peel are presented in Table 3.

### Table 3 Anticancer activity of banana peel

<table>
<thead>
<tr>
<th>Extracts</th>
<th>Cell lines and assay</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>95% ethanolic extract of air-dried peel powder [19]</td>
<td>Complete blood count, Carcino embryogenic antigen, Malondialdehyde</td>
<td>Possess anticancer agents by improving hematological parameters, inhibiting carcino embryonic antigen and malonaldehyde.</td>
</tr>
<tr>
<td>80% methanol extract of freeze-dried peel powder of Nendran banana [20]</td>
<td>Human breast carcinoma MCF-7 cell line by MTT assay</td>
<td>Potent cytotoxic activity.</td>
</tr>
<tr>
<td>70% ethanol extract of green peels of Musa</td>
<td>Human hepatocellular carcinoma HepG2, Malignant melanoma A-375, breast carcinoma MCF-7, colorectal adenocarcinoma Caco-2 cell lines</td>
<td>Decreased proliferation of HepG2, A-375, MCF-7 and Caco-2, Reduction of mitochondrial</td>
</tr>
</tbody>
</table>

### 3.3. Anti-diabetic activity

Diabetes is of two types, insulin dependent or non-insulin dependent. There are several diabetic patients present worldwide. Many herbal medicines are used as the source of medication for diabetes [28].

Murthy SSN, et al., [29] conducted a study to evaluate the antidiabetic activity of the acetone extract of dried powder of *Musa sapientum* banana peel by measuring blood glucose, HbA1C and plasma insulin in streptozocin induced male albino wistar rats. The rats were divided into six groups, each group containing six rats and received the treatments in the following manner: first group – normal saline, second group – streptozocin, third group–streptozocin and glibenclamide, fourth group – streptozocin and *Musa sapientum* peel (MSPE) extract 200mg/kg, fifth group – streptozocin and MSPE 400mg/kg, sixth group – normal saline and MSPE 400mg/kg. It was observed that the acetone extract reduced the fasting blood glucose, HbA1c and plasma insulin in diabetic induced rats. Hence, the banana peel extract can also be used as antidiabetic agent. Hongmei W, et al., [30] used fresh banana (*Musa nana Lour.*) peel extracts of ethyl acetate (EBP) and petroleum ether (PBP) to evaluate antidiabetic activity in alloxan induced diabetic mice. The mice were divided into seven groups each containing ten mice and were treated in the following manner: first group – normal saline, second group – alloxan, third group – alloxan and metformin (300 mg/kg), fourth group – alloxan and EBP (6 mg/kg), fifth group - alloxan and EBP (12 mg/kg), sixth group - alloxan and PBP (6 mg/kg), seventh group - alloxan and PBP (13 mg/kg). The ethyl acetate extracts of banana peel decreased glucose levels in blood to a significant level in alloxan induced diabetic mice.

### 3.4. Anti-fungal activity

Dandruff is one of the common scalp problems [31]. Natural products are being evaluated for their antifungal activity. Bharathi P, et al., [32] evaluated antifungal activity of aqueous extract of powdered air-dried peels of *Musa paradisiaca* (kadali), *Musa acuminate Cavendish* and *Musa acuminate Nendra* using agar well diffusion technique. The fungi isolated...
from scalp are Aspergillus niger, Aspergillus flavus and Penicillium spp. The extract of kadali showed zone of inhibition against Aspergillus niger.

3.5. Anti-inflammatory activity

Inflammation is the body’s defensive response to physical, chemical, and microbiological substances and destroys both damaging substances and body tissues. Non-steroidal anti-inflammatory drugs reduce the inflammatory response but cause side effects on long term use. Therefore, research on natural medicine is gaining momentum [33].

Gina K, et al., [34] determined the anti-inflammatory activity of methanol extract of Ambon banana (Musa paradisiaca L.) by human red blood cell membrane stabilization method. The red blood cell membrane is analogous to lysosomal membrane and the stabilization of the latter is necessary in controlling the inflammatory response. The size of the hemolysis that occurs in the red blood cell membrane induced by the hypotonic solution is used to measure the presence of the anti-inflammatory activity. The absorbance of hemoglobin can be measured at 560 nm using a UV-vis spectrophotometer. Ambon banana peel extract has shown anti-inflammatory activity by the decrease in the absorbance of the test solution.

Pathompong P, et al., [35] evaluated anti-inflammatory activity of fresh and dried peels of ripe and unripe bananas of Musa sapientum Linn. Extraction was carried out by maceration in 95% ethanol, 50% ethanol, decoction and soaking in water. The activity was determined by measuring the inhibitory effect on NO production by mouse macrophage leukemia-like RAW 264.7 cells. The water extract of fresh ripe peel showed the highest NO inhibitory effect.

3.6. Anti-microbial activity

The modern antibiotics currently used for treating microbial infections developed resistance in microorganisms against these drugs. Phytoconstituents can fight against human and plant pathogenic bacteria, fungi, and viruses without causing side effects and environmental hazards [36].

Muhammed S, etal., [37] studied antimicrobial activity of banana peel along with orange and yellow lemon. Distilled water, ethanol, ethyl acetate and methanol were used for extraction and the obtained extracts tested against six gram positive bacteria, six gram negative bacteria two microscopic filamentous fungi and two yeast species using well bore method. The increasing order of antimicrobial activity of the extracts is ethyl acetate<ethanol<methanol<distilled water. The extracts were effective against gram negative bacteria.

Ahmed MA et al., [38] studied antimicrobial activity of banana peel extract obtained using different solvent systems, 80% acetone and 80% ethanol. The antimicrobial activity was tested against gram positive bacteria (Bacillus subtilis, Staphylococcus aureus), gram negative bacteria (Escherichia coli, Pseudomonas aeruginosa), fungus (Aspergillus flaves), yeast (Candida albicans, Saccharomyces cervesia) using well diffusion assay. The antimicrobial activity was more with aceticen extract when compared to ethanolic extract due to high concentration by phenolics and tannins.

Nessma AE, [25] studied antimicrobial activity using hole plate method against bacterial cultures of Staphylococcus aureus, Escherichia coli and Pseudomonas aeruginosa, yeast cultures of Candida albicans and fungal cultures of Aspergillus niger, Aspergillus flaves, Penicillium digitatum and Fusarium oxysporum. The extracts of all the fruit peels showed inhibitory effect against these microorganisms.

Zainab AGC, et al., [39] evaluated antimicrobial activity of aqueous extract of fresh yellow banana peels against gram positive bacteria (Streptococcus aureus, Streptococcus pyogenes), gram negative bacteria (Enterobacter aerogenes, Escherichia coli, Moraxella catarrhalis, Klebsiella pneumonia) and yeast isolates (Candida albicans) using agar well diffusion assay. The extract was found to have antibacterial activity against gram positive bacteria and gram- negative bacteria.

Ighodaro OM, [40] studied antimicrobial activity of Musa paradisica peels. Aqueous and ethanol were used for extraction. Four bacteria (Streptococcus aureus, Bacillus subtilis, Pseudomonas aeruginosa, Proteus mirabilis) and three fungi (Rhizopus nigricans, Fusarium oxysporum, Aspergillus niger) were used for the study. The extracts were found to be effective against bacteria and fungi.

Imam MZ, et al., [27] studied the antimicrobial activity of methanol extract of Musa sapientum L. sylvestris peel against five gram-positive bacteria, eight gram-negative bacteria and three fungi. The peel extract showed good antibiotic activity against all microorganisms.
The different studies of antibacterial activity of banana peel are presented in Table 4.

**Table 4 Antibacterial activity of banana peel**

<table>
<thead>
<tr>
<th>Exports</th>
<th>Organisms</th>
<th>Results</th>
</tr>
</thead>
</table>
| Distilled water, ethanol, ethyl acetate and methanol extracts of oven dried powder of *Musa acuminata* [37] | Gram negative bacteria  
*Pseudomonas aeruginosa*,  
*Klebsiella pneumoniae*,  
*Serratia marcescens*,  
*Escherichia coli*,  
*Proteus vulgaris*,  
*Salmonella typhi*  
Gram positive bacteria  
*Staphylococcus aureus*,  
*Enterococcus faecalis*,  
*Aeromonas hydrophila*,  
*Streptococcus pyogenes*,  
*Listeria monocytogenes*,  
*Lactobacillus casei*  
Fungi  
*Aspergillus niger*,  
*Penicillium citrinum*  
Yeast  
*Candida albicans*,  
*Saccharomyces cervisiae* | Decreasing order of antibacterial activity of extracts: Distilled water>methanol>ethanol>ethyl acetate. Gram negative bacteria are more sensitive to the extracts. |
| 80% acetone and 80% ethanol extract of dried powder of *Musa paradisica* L. peel [38] | Gram positive bacteria  
*Bacillus subtilis*,  
*Staphylococcus aureus*  
Gram negative bacteria  
*Escherichia coli*,  
*Pseudomonas aeruginosa*  
Fungi  
*Aspergillus flaves*  
Yeast  
*Candida albicans*  
*Saccharomyces cervicic* | Acetone extract had good antimicrobial activity against gram positive and gram-negative bacteria |
| Ethanol extract of freeze-dried powder of *Musa accuminata* [25] | Bacteria  
*Staphylococcus aureus*,  
*Escherichia coli*,  
*Pseudomonas aeruginosa*,  
Yeast  
*Candida albicans*,  
Fungi  
*Aspergillus niger*,  
*Aspergillus flavus*,  
*Penicillium digitatum*,  
*Fusarium oxysporum* | Best antifungal activity |
<table>
<thead>
<tr>
<th>Extract Type</th>
<th>Organisms</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqueous extract of fresh peels</td>
<td>Gram-positive bacteria: Staphylococcus aureus, Streptococcus pyogenes</td>
<td>Good antibacterial activity against both gram positive and negative bacteria.</td>
</tr>
<tr>
<td></td>
<td>Gram-negative bacteria: Enterobacter aerogenes, Klebsiella pneumonia,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Escherichia coli, Moraxella catarrhalis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yeast: Candida albicans</td>
<td></td>
</tr>
<tr>
<td>Aqueous and ethanol extracts of</td>
<td>Bacteria: Staphylococcus aureus, Bacillus subtilis, Proteus mirabilis,</td>
<td>Ethanolic extracts were effective against bacteria and fungi.</td>
</tr>
<tr>
<td>dried powders of ripe and unripe</td>
<td>Pseudomonas aeruginosa, Fungi: Aspergillus niger, Rhizopus nigricans,</td>
<td></td>
</tr>
<tr>
<td>peels of Musa paradisica</td>
<td>Fusarium oxysporum</td>
<td></td>
</tr>
<tr>
<td>Methanol extract of dried powder</td>
<td>Gram-positive bacteria: Bacillus cereus, Bacillus megaterium, Bacillus</td>
<td>Good antibacterial activity against all organisms.</td>
</tr>
<tr>
<td>of Musa sapientum L. subsp.</td>
<td>subtilis, Sarcina lutea, Staphylococcus aureus</td>
<td></td>
</tr>
<tr>
<td>Sylvestris</td>
<td>Gram-negative bacteria: Escherichia coli, Salmonella paratyphi, Salmonella</td>
<td></td>
</tr>
<tr>
<td></td>
<td>typhi, Shigella boydii, Shigella dysenteriae, Pseudomonas aeruginosa,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vibrio mimicus, Vibrio parahemolytics</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fungi: Aspergillus niger, Candida albicans, Sacharomyces cerevaceae</td>
<td></td>
</tr>
</tbody>
</table>

### 3.7. Antioxidant activity

Our body produces free radicals continuously either naturally or upon exposure to environmental factors and leads to diseases like cancer, atherosclerosis, arthritis, and others. Antioxidants scavenge the free radicals and prevent the damage caused by them. Antioxidants available in fruits, vegetables and whole grains can be utilized due to their minimal side effects [41].
### Table 5 Antioxidant activity of banana peel

<table>
<thead>
<tr>
<th>Extracts</th>
<th>Methods</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqueous, 80% acetone, 80% ethanol and 80% methanol extracts of dried powder of <em>Musa paradisiaca</em> peel [38]</td>
<td>DPPH assay, Metal chelating activity, ABTS+ assay, Reducing power assay</td>
<td>Acetone extract showed highest activity.</td>
</tr>
<tr>
<td>Water, ethanol, and n-hexane extract of oven dried <em>Musa sapientum</em> peel [24]</td>
<td>DPPH assay, FRAP assay</td>
<td>Ethanol extract showed potent antioxidant activity.</td>
</tr>
<tr>
<td>Ethanol extract of freeze-dried powder of <em>Musa acuminata</em> [25]</td>
<td>DPPH assay</td>
<td>Good antioxidant activity.</td>
</tr>
<tr>
<td>95% ethanol, 50% ethanol, decoction and soaking in water extracts of fresh and dried; ripe and unripe peels of <em>Musa sapientum</em> L. [35]</td>
<td>DPPH assay</td>
<td>Decoction extract of fresh unripe showed highest antioxidant activity.</td>
</tr>
<tr>
<td>Aqueous, ethanol and methanol extract of oven dried peels of <em>Musa paradisica</em> varieties cv. Dwarf cavendish, AAA; Ney poovan, AB and Nendran, AAB. [42]</td>
<td>Total antioxidant assay</td>
<td>Water extract&gt;Methanol&gt;ethanol All three varieties of banana peel showed similar activity.</td>
</tr>
<tr>
<td>10% ethanol extract of shade-dried <em>Musa balbisiana</em> varieties - Monthan, Karpooaravalli, Nendran, Kadali, and <em>Musa acuminata</em> varieties - Pachainadan, Poovan, Rasthali, Robusta, Sevvazha [43]</td>
<td>Total antioxidant assay</td>
<td>Pachainadan showed highest activity.</td>
</tr>
<tr>
<td>Chloroform, ethyl acetate and water extracts of fresh green and yellow peels of <em>Musa AAA</em> cv. Cavendish [17]</td>
<td>DPPH assay, β-carotene linoleate assay, ferric thiocyanate assay</td>
<td>Ethyl acetate and water-soluble fractions showed higher antioxidant activity.</td>
</tr>
</tbody>
</table>
Ahmed MA, et al., [38] studied the antioxidant activity of aqueous, 80% acetone, 80% ethanol and 80% methanol extracts of dried powder of *Musa paradisiaca* L. peels. The antioxidant activity was estimated by 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging assay, metal chelating activity, scavenging activity on 2,2’-azino-bis(3-ethylbenzothiazoline)-6-sulfonic acid (ABTS⁺)-radicals and reducing power. Acetone and methanol extracts have more antioxidant activity compared to ethanolic and aqueous extracts. Acetone extract showed the highest ABTS⁺-scavenging activity.

Saad SD, et al., [24] studied the antioxidant properties using DPPH and ferric reducing antioxidant power (FRAP) assay. The extracts were prepared using n-hexane, ethanol, and water. In DPPH scavenging activity, ethanolic extracts of banana peel had more antioxidant activity. Ethanolic extract showed the highest percentage of metal chelating capacity. Acetone extract showed higher reducing power.

Nessma AZ, [25] studied the antioxidant activity of ethanolic extract of freeze-dried banana peel along with other fruit peels by DPPH radical scavenging assay using ascorbic acid as a standard. The secondary metabolites like alkaloids, carotenoids, flavonoids, phenolics, saponins and tannins in the fruit peel extracts were estimated. Maximum antioxidant activity was observed in peel extracts of carrot and watermelon, followed by goldenberry and banana, while medium activity was shown by peel extracts of lemon and kiwi followed by tangerine and orange.

Pathompong P, et al., [35] studied antioxidant activity of *Musa sapientum* Linn. by DPPH assay. The extracts were obtained by maceration in 95% ethanol, 50% ethanol, decoction and soaking in water. Fresh ripe and unripe peels obtained by decoction method showed significant antioxidant activity.

Shyamala BN, et al., [42] investigated antioxidant potential of three varieties of *Musa paradisiaca* cv. Dwarf cavendish, AAA; Ney poovan, AB and Nendran, AAB. The antioxidant activity of aqueous, ethanol and methanol extract of oven dried banana peel was determined using phosphomolybdenum method, DPPH assay and reducing power. Nendran variety showed the highest antioxidant activity.

Ramakrishna B, et al., [43] aimed to evaluate and compare the phytochemical content and the antioxidant activity in the peel extracts of the nine local varieties of the banana i.e., *Musa balbisiana* and *Musa acuminata* species. The ethanolic extracts of these banana peels have been subjected to in-vitro free radical scavenging assays which includes total antioxidant capacity assay, DPPH, ABTS and lipid peroxidation inhibition assay. It is shown that the peel extracts exhibited significant antioxidant activity.

Rafela G, et al., [44] observed in a study that the extracts obtained from banana peels contained high potential to scavenge 2,2-diphenyl-1-picrylhydrazyl and 2,2’-azino-bis(3-ethylbenzothiazoline)-6-sulfonic acid free radicals and inhibit lipid peroxidation. The influence of various factors on the extraction efficiency were studied: use of different solvents, pH of water, the time for extraction, the temperature at which extraction was conducted and the banana species. The bioactive compounds that might be responsible for antioxidant activity were determined. Banana peel extract extracted using acetone:water contained highest antioxidant activity.

Matook SM, et al., [17] studied antioxidant activity of green and yellow peel of *Musa AAA* cv. Cavendish using chloroform, ethyl acetate and water for extraction. The antioxidant activity was determined using DPPH, β-carotene linoleate, ferric thiocyanate. Green peel showed higher antioxidant activity than yellow peel.

The antioxidant activity of plant products is associated with their content of phenolics and flavonoids. The degree of antioxidant activity depends on the amount of these substances, and which is affected by several factors like type of peel, type of banana and type of extract. The banana variety, type of peel, solvents used for extraction, method for determining antioxidant assay and results obtained in the above literature is presented in Table 5.

### 3.8. Anti-psoriatic activity

Psoriasis is a very commonly occurring chronic inflammatory disease which mainly affects the skin [45]. It occurs to human beings of all ages. It is commonly associated with diseases like arthritis, AIDS, enteropathy, myopathy, spondylitic heart disease. Psoriatic arthritis may be mild, but bone changes are seen in rheumatoid arthritis. This psoriasis mainly effects the skin of the elbow, knees, scalp, lumbosacral areas, inter gluteal cleft and glans penis. Mostly psoriasis begins at the age of 10-20 yrs. It mainly affects the body folds of both the sexes. Psoriasis is mainly caused by acceleration in life cycle of skin cells which results in the development of thick scaly white skin patches.
Nithya DE, et al., [46] studied the anti-psoriatic activity of Musa mysore AAB (Poovan Banana) peel extract using human keratinocyte cell line. In this the MMT assay was carried out to determine the anti-psoriatic activity of poovan bananas. The results of MTT assay suggest that the extract could reduce cell viability of selected psoriatic cell line.

3.9. Anti-ulcer activity

Ulcer is the major challenge facing by the people which is caused by excessive production of gastric acid and infection by Helicobacter pylori bacteria. The different chemical compounds isolated from plants showed antiulcer activity [47]. Fatimah CA, et al., [26] studied antiulcer activity of methanolic extracts of unripe M. acuminata Colla. cv Kapas banana peels using two models, namely, ethanol-induced ulcer and indomethacin-induced gastric lesion. The extracts showed cytoprotective activity in both the models. The flavonoids, saponins and triterpenes present in them are responsible for antiulcer effect.

The banana peel extracts are shown to have significant anti-ulcer activity in a study conducted by Samuel AO, et al., [48]. Antiulcer activity of methanolic extract of dried peels of Musa sapientum was evaluated using alcohol induced, aspirin induced, pyloric induced, acetic acid induced in male Sprague Dawley rats. The results revealed that the extract treated rats exhibited good anti-ulcer activity and is dose dependent in all the ulcer induced models.

3.10. Hepatoprotectivity

The liver is a vital organ and jaundice, and hepatitis are major liver disorders that account for high death rates. Liver injury can be induced either by toxic chemicals like carbon tetrachloride (CCl₄) and alcohol or drugs like paracetamol and isoniazid. There is a need to find solutions from natural sources to overcome the side effects of existing drugs [49].

Fatimah CA, et al., [26] carried out studies to investigate the hepatoprotective activity of methanolic extracts of the peel of Musa acuminata Colla. cv. Kapas in chloroform and paracetamol-induced hepatotoxicity models in rats. Liver function can be assessed using estimation of enzymes. The extracts showed hepatoprotectivity.

3.11. Inhibition of melanogenesis

Hyperpigmentation is a pigmentary disorder which occurs by the over secretion of melanin which leads to problems like melasma, freckle, ephelides, lentigo and other forms on human skin. Many skin-whitening agents are restricted due to their side effects or stability problems with the kojic acid, ascorbic acid and hydroquinone which acts as cytotoxic substances. These causes problems like dermatitis and skin cancer [50].

Naphichaya P, et al., [51] studied the effect of Sucier banana peel extracts on inhibition of melanogenesis process through p38 signaling pathway in B16F10 mouse melanoma cells. Tyrosinase activity and the cellular melanin content were in dose dependent manner which got decreased after the SBP treatment. It also decreased the melanogenesis related protein as microphthalmia–associated transcription factor and tyrosinase protein after the 24 hours of incubation with the alpha melanocyte stimulating hormones. After using this SBP extract since it contained an effective agent which led to the decrease in the tyrosinase activity and melanin content. This shows that the Sucier banana peel extract contains an effective agent which brightens the skin tone.

3.12. Prevention of atherosclerosis

Atherosclerosis is a disease caused by the formation of plaque in the arteries. Atherosclerosis is still treated by inhibiting the progression of plaques but not by preventing the formation [52].

Arlinda SP, et al., [53] studied the capacity of Musa sapientum banana peel 80% ethanol extract in preventing atherosclerosis. The animals used in this study are Rattus norvegicus strain Wistar. The extracts were administered orally using gastric spuit in 14 days. The aortic endothelial tissue was taken out from the rats on day 15 and were tested using immune histochemical method. It is observed that the NF-KB activity has decreased, and the e-NOS activity has increased. Therefore, it is shown that the banana peel has shown a significant effect on atherosclerosis. Hence it is proved that the Ambon banana peel extract can 82.1% lower the nuclear factor kappa beta activity and can 95.2% increase the nitric oxide nitrate activity.

3.13. Radioprotection

One should be protected from radiation, whether it is planned or accidental. Many compounds, synthetic and natural are being explored for their ability to protect the biological systems against radiation [54].
Amaal MK, et al. [19] studied the radioprotective effect of 95% ethanol extract of air-dried powder of banana peel using male mice. A noticeable stimulation for P53 expression level was detected for applying banana peels extract and irradiation as compound dosage.

### 3.14. Skin hydration

Dryness of the skin is a potential problem in certain countries and increases with increase in age. The dry skin problem can be reduced by using moisturizers. Most of the moisturizers use synthetic ingredients but have side effects on long-term use. Therefore, it is necessary to replace the synthetic ingredients with bioactive compounds of plants [55].

Wianlie C, et al. [56] studied skin hydration activity of 96% ethanol extract of oven dried powder of Musa paradisiaca L. Skin hydration was measured using skin analyzer in human volunteers. The skin hydration was improved by using the cream formulated using banana peel extract.

### 3.15. Wound healing activity

A wound is the damage caused in normal anatomy and physiology of skin due to physical injury. In recent times, wound care professionals are focusing on traditional medicines [57].

Pari T, et al., [58] studied the wound healing activity of 70% ethanol extract of shade-dried banana peels powder in Iranian rabbits of either sex. The animals were divided into six groups like standard, negative control, vehicle control and other three groups for testing wound healing activity in the banana peel extract. The standard group is treated with 1% phenytoin cream, the negative group has not given any treatment and vehicle group was treated with 3%, 5% and 10% creams of the banana peel extract. All the treatments were applied topically twice daily until the complete healing. It was assessed by the wound extraction and re-epithelialization rate and the tensile strength of wound tissue sample. High rate of wound contraction, decreasing epithelization period and high skin breaking strength were seen in animals. These results indicated that banana peels have strong activity of wound healing and can be used for human beings.

### 4. Conclusion

The review was focused on the different pharmacological activities of banana peel. The increased concern over side effects associated with the current synthetic therapeutic agents remarkably necessitates the need of herbal drugs. It can be used for various benefits instead of being neglected as a waste.

### Compliance with ethical standards

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**Disclosure of conflict of interest**

The authors have no conflicts of interest regarding this investigation.

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