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Pharmaceutical Aspects of Banana peel: A Review

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Abstract:
Banana is the most common edible fruit which has numerous health benefits. The banana peel is the unutilized part of the banana, which is rich in bioactive compounds. The extract of the peel possess antioxidant, antibacterial, antifungal, and anticancer agents. These agents can be utilized effectively in treating various diseases. This review highlights the bioactive compounds which are responsible for their potential therapeutic actions and factors influencing in it. It also outlines the banana peel as a excipients in the formulation development. Hence, it will be a viable alternative option to synthetic drugs and excipients in pharmaceutical formulations.

Keywords: Antibacterial, Anticancer, Antioxidant, Banana peel, Pectin, Silver nanoparticle.

INTRODUCTION:

Plants are the source of medicine and nutrients since ancient times [1]. They remain the preferred source for treating various diseases as they provide safe and effective medication when compared to synthetic drugs [2]. The banana is a tropical fruit belonging to the family *Musaceae*. It is cultivated throughout the tropical and subtropical regions which spread over 122 countries in the world [3,4]. In international trade, the banana is a fifth agricultural crop [5]. India is the largest producer of the banana and contributes about 25.7% to the total production in the world [6].

The banana is a general term that comprises around 70 species in the genus *Musa* and it is scientifically known as *Musa sapientum.* The phytoconstituents present in the banana species are primarily accountable for their medicinal properties. The two diploid species are *Musa acuminata* (AA) and *Musa balbisiana* (BB), besides the triploid and tetraploid subspecies [7,8]. A and B genomes are the progenitors of *Musa acuminata* and *Musa balbisiana* respectively [5].

The edible and non-edible parts of the banana plant are rich in phytoconstituents, which can be utilized for medicinal purposes. Traditionally bananas are used for treating various ailments [9,10]. Banana leaves are used as a wound dressing material and on burns [11,12]. Flowers are used in treating diabetes and menstrual disorders [13,14,15]. Banana pulp acts as a natural fiber and can be utilized for treating GI disorders [16,17,18]. Banana stem is used in treating urinary disorders [19]. The root is used for anti-inflammatory property [20]. Likewise, the peel of the banana also holds a significant medicinal potential which is yet to be studied [9].

The peel occupies 40% of the total weight of the fresh banana and is generally considered as a waste in industry and everyday life [21,22,23]. Banana peel has a high source of total dietary fiber (43 - 49%), crude protein (6 - 9%), crude fat (3.8 - 11%), starch (3%), and polyunsaturated fatty acids (PUFA) especially linoleic acid α linoleic acid. It includes essential amino acids such as leucine, valine, phenylalanine threonine, and micronutrients such as calcium, magnesium, potassium, and phosphorous. The rich micronutrients, iron and zinc are present more in the peel than the pulp. It is also a rich source of pectin (10-21%), lignin (6-12%), cellulose (7.6-9.6%), and hemicellulose (6.4-9.4%) [24]. Multiple pharmacological actions such as antioxidant, antibacterial, antifungal, anticancer, and antiulcer agents were reported due to the presence of phytoconstituents in the banana peel [9].

In the banana peel slight increase in protein and lipid content increases soluble sugar, thereby decreasing starch and hemicellulose indicates the maturation of fruits. Since in the ripening stage, starch is converted into reducing sugar [24,25]. But the ripening stage did not consistently affect the chemical elements present in it [7].

This review aims to explore the potential uses of the banana peel as an active ingredient and shed light on the possibility of utilizing this as an excipient in pharmaceutical formulation development.

BANANA PEEL AS AN ACTIVE INGREDIENT:

Antioxidant activity:

The agents which scavenge the free radicals are called antioxidants. Banana peel is one of the best sources of antioxidants. It is rich in bioactive compounds such as phenols, carotenoids, flavonoids, saponins, and tannins [26,2]. The antioxidant activity of the banana peel is mainly attributed to the presence of phenol which is evident from the correlation between total phenolic content (TPC) and antioxidant activity [27,28].

Jyotsna *et al*., have analyzed the bioactive components from the banana peel using the Gas chromatography and mass spectroscopy. It confirms the presence of estragole, hexadecanoic acid, ethyl ester, epicatechin, gallocatechin, and enzymes such as ascorbate peroxidase, catalase, peroxidase, superoxide dismutase which also contribute to its antioxidant property [29].

Dopamine, a strong antioxidant has an o-dihydroxy (catechol) structure which is responsible for its water solubility. It is present higher in banana peel comparing to a pulp [30]. High quantities of dopamine, L- dopa, and catecholamines in the banana peel facilitates antioxidant activity [31].

The antioxidant potential of isolated bio-components from the banana peel was determined by Gilson differential respirometer (measuring rate of oxygen utilization by cell) and DPPH assay. The antioxidant potential was comparable to gallocatechin and ascorbic acid. However, banana peel exhibits higher free radical scavenging activity than the catechins [30]. The Methanolic extract

gives the highest yield of dopamine over ethanol, acetone, and water [31].

The solvent composition used for the extraction of antioxidants from the peel plays a vital role. Maximum yield and activity also depends on the species of the plant, stage of maturation, extraction time, temperature, and concentration of the extract [31,32]. Table1. illustrates the solvents used and methods for determining the antioxidant potential.

Noor Azwani *et al.,* formulated a semisolid jelly to explore and evaluate the antioxidant activity of the banana peel using the *Musa acuminata colla* peels. The jelly was formulated without adding commercial pectin because the peel itself acts as the gelling agent. The jelly with a 7% concentration of banana peel exhibits 84% scavenging activity which is greater than the commercial jelly (65%) [27].

Table 1: Solvents and Methods for Antioxidant Activity

Solvents	Methods	Inference	Reference
Acetone 80%, Methanol 80%, Ethanol 80%, and Water	DPPH, Power reducing assay (PRA), ABTS assay, and Fe^{2+} Chelating assay	Acetone 80% Extraction – Good activity in DPPH, PRA, and ABTS assay Ethanol 80% Extraction – Good activity in Metal chelating assay	33
Ethanol 10%	DPPH, ABTS, Lipid peroxidation inhibition assay	Comparing nine varieties of banana, Rasthali - Maximum ABTS scavenging activity (High TPC) Provan – Maximum lipid peroxidation inhibition activity (High flavonoids)	34
Methanol, Ethanol and Water	DPPH, Total antioxidant activity, Reducing power	Methanol extract - Highest activity in *Pachabale* and *Yelakkibale* varieties Ethanol extract - Highest activity in *Nendranbale* variety.	21
Acetone, Methanol, Ethanol, and Water	DPPH, ABTS	Methanol extract – High yield of dopamine Acetone: Water (1:1) – High DPPH and ABTS scavenging activity	31
Ethanol 95%, Ethanol 80%, and Water	DPPH	Ethanol 95% - High yield Water – Maximum antioxidant activity	32
Methanol, Ethyl acetate and Water	DPPH, β carotene linoleate system and ferric thiocyanate assay	Water extract - High yield Methanol: Ethyl acetate (1:1) chromatograph – Highest activity	25

Table 2: Solvents for Antibacterial Activity

Solvents used	Inference	Reference
Ethyl acetate, Chloroform and Water.	Ethyl acetate extract - Maximum antibacterial activity.	25
Ethanol and Water.	Ethanol - Highest zone of inhibition.	4 and 40
Methanol, Ethanol, Ethyl acetate and Water.	Water extract shows best results over other solvent extracts.	38
Acetone 80% and Ethanol 80%.	Acteone extract shows good antibacterial activity.	33
Methanol	Significantly *Musa acuminata* were most susceptible than Musa sapientum	41 and 42

Table 3: Antibacterial Activity of Banana Peel with Standard Antibiotic [39].

Target organism	Standard antibiotic and its zone of inhibition	Banana peel and its zone of inhibition
Pseudomonas citrii.	Ciprofloxaxin (25 mm).	Red banana peel (27 mm)
Salmonella typhi.	Ampicillin (17 mm)	Green banana peel (19 mm)
Aeromonas hydrophila.	Gentamycin (18 mm)	Yellow banana peel (20 mm)

Antibacterial activity:

The need for developing a new antibacterial agents arise due to the resistance developing by the bacteria against the current antibacterial agents. The researchers are investigating plant materials to develop new antibacterial agents. The banana peel has a good antibacterial activity with fewer or no side effects.

It is active against Gram-positive bacteria such as *Staphylococcus aureus, Bacillus subtilis, Bacillus cereus*, and Gram-negative bacteria such as *Escherichia coli, Salmonella enteritidis, Pseudomonas aeruginosa* [25,26,33]. Ehiowemwenguan *et al.,* reported that peels also have activity against *Salmonella typhi, Micrococcus luteus, Klebsiella pneumonia* [4]. The banana peel has a good inhibiting activity against the periodontal pathogens such as *Porphyromonas gingivalis, Aggregatibacter actinomycetemcomitans* [35]. Fresh banana peels have the highest zone of inhibition against bacteria than the dried peels [36].

The antimicrobial activity of the banana peel extract is due to the presence of fatty acids present in it [37]. Lipophilic extraction of the banana peel contains fatty acids such as malic acid, β-sitosterol, succinic acid, and palmitic acid. Malic acid exhibits stronger antibacterial activity than other isolated components. But the antibacterial activity is less when compared to standard chloramphenicol [25]. Solvent screening and selection of the best solvent with high antibacterial activity is the crucial factor in extraction [38]. Researchers used different solvents in their study to examine the influence of solvent on the antibacterial activity which is represented in Table 2.

Chinnappan Ravinder singh *et al.,* studied the antimicrobial property of different coloured banana peels and compared them with the commercial antibiotics [39]. The extract of different coloured banana peels indicates higher antibacterial activity against specific organisms in comparison with standard antibiotics shown in Table 3.

Drying the peel plays a significant role to retain maximum bioactive components, thereby enhancing the antimicrobial activity. Youssef M.A *et al.,* evaluated various drying methods such as microwave irradiation, vacuum drying, hot air drying and dehumidified drying. They reported microwave irradiation was found to be the most effective process as it retained the highest amount of bioactive components which possess antimicrobial and antioxidant activities [22].

Antifungal activity

Even the synthetic antibiotic agent lags in the broad spectrum of antimicrobial activity in a wide range. So there is a need to develop natural antibiotic which has broad-spectrum activity. The banana peel has a wide range of inhibiting activity against both bacteria and fungi [26]. Bioactive components such as tannin, alkaloids, saponin, and flavonoids are contributed to the antifungal property of banana peel [43]. It is effective against fungi such as *Aspergillus niger, Aspergillus flavus, Penicillium digitatum, Fusarium oxysporum, Candida albicans, Saccharomyces cerevisiae* and *Penicillium citrinum* [26,33,38]. It can also used be as a preservative because it prevents spoilage by inhibiting fungi such as *Aspergillus oryzae* and *Rhizopus stolonifer* [43].

The antifungal activity of banana peel was compared to the ethanolic extracts of peels from other fruits such as carrot, goldenberry, kiwi, watermelon, tangerine, lemon, and orange. The banana peel shows the highest antifungal activity when compared to other peels [26]. In addition, the aqueous extract of banana peel exhibits a strongest activity when compared to orange, cashew and pineapple peels [44].

Solvent type, extraction time, temperature, and species are the most important factors affecting antifungal activity. The optimization of these influencing factors leads to a high yield with improved antifungal activity. Table 4 discusses the solvents for extraction of antifungal activity.

Table 4: Solvents for Antifungal Activity

Solvents used	Inference	Reference
Methanol and Ethanol	Methanol – Better antifungal activity	43
Methanol	The antifungal activity seems lower than banana pulp and seed	42
Ethanol and Water	Ethanolic extract was slightly better than aqueous extract	40
Ethanol	Among eight fruit peels banana peel exhibits highest antifungal activity	26
Ethanol, Ethyl acetate, Methanol and Water	Aqueous extract – Highest antifungal activity	38
Ethanol and Water	Aqueous extract – Highest antifungal activity	44
Acetone 80% and Ethanol 80%	Acetone – Maximum activity	33

Table 5: Solvents and Cell Line in Anticancer Activity

Solvents used	Cell line	Cancer type	Reference
Ethanol	MCF- 7	Breast carcinoma	26
Ethyl acetate	HeLa	Cervical cancer	45
70% ethanol	HepG 2, A-375, MCF- 7 and Caco- 2.	Hepatocellular carcinoma, Malignant melanoma, Breast carcinoma and Colorectal adenocarcinoma	46
18% aqueous methanol	MCF- 7	Breast carcinoma	47
Ethanol: water (8:2)	HepG 2	Hepatocellular carcinoma	48

Anticancer activity

Cancer is the world's leading cause of death. The efficacy of commercially available antitumor agents is decreasing due to developing resistance and high cytotoxicity. New treatments to cure and avoid this life-threatening disease are continually in demand. The researchers are investigating secondary metabolites from plants for their anticancer activities which will contribute to the development of new drugs. Plant-derived anticancer agents have been identified which shows significant effects as synthetic drugs. Flavonoids and phenols are present in the plants which plays a major role in the cancer treatment [28].

The antioxidant potential of the banana peel has an added advantage in combating tumor in its initial stages [28]. But it is non-toxic to the normal healthy cells [2]. Ferulic acid is a phytoconstituent from the banana peel which was biosynthesized and isolated using the bacteria *Staphylococcus aureus*. The cytotoxicity of biosynthesized ferulic acid was compared with the synthetic ferulic acid. The IC_{50} (Inhibitory concentration) of synthetic ferulic acid (62.5 µg/ml) and biosynthesized ferulic acid (125 µg/ml) was determined by MTT assay. Biosynthesized ferulic acid shows a good cytotoxic effect and hence it can be utilized for cancer treatment [45]. Further, to compare the cytotoxic potential of the banana peel with the standard cell line, studies were conducted using MCF 7 (breast carcinoma) cell line. The result shows that ethanolic extract of banana peel extract (32% of cell viability) exhibits a moderate cytotoxic activity compared to the standard thymoquinone (23% of cell viability) [26].

The banana peel was rich in phytoconstituents which is responsible for the improvement in hematological parameters and enhanced hemoglobin production [28]. Amal M Kamal *et al.,* demonstrated the anticancer and radioprotective effects of the banana peel by biochemical studies such as complete blood count (CBC), carcinoembryonic antigen (CEA), molecular study, and malonaldehyde test. The data indicates that there is significant amelioration in red blood cells (RBC), white blood cells (WBC), haemoglobin (Hb), hematocrit, and mean corpuscular volume (MCV). Carcinoembryonic antigen (CEA) and malonaldehyde which are used as biomarkers in tumors and oxidative stress respectively. These markers show significant reduction when the banana peel extract was used, which indicates banana peel as a potent anticancer agent [28]. The details of the cell lines and solvent used in the study are listed in Table 5.

BANANA PEEL AS AN INACTIVE INGREDIENT:

Pectin extraction from Banana peel:

Natural substances as excipients in the formulation are preferred over synthetic substances because they are non-toxic, non-irritant, and low cost [49]. Pectin is a naturally occurring polysaccharide that contains α- 1, 4 linked D-galacturonic acid units. Pectin can interact with other cell components to provide mechanical strength and flexibility to the plants [50]. Pectin is most commonly used as a gelling agent, stabilizer and emulsifier [51]. Because of its excellent emulsifying and stabilizing properties, it is considered as a highly valuable inactive ingredient [50].

Banana peel pectin contains glucose, arabinose, galactose, xylose and rhamnose [24]. The chemical properties such as galacturonic acid content, methoxyl content, degree of esterification (DE), and acetyl value decides the suitability of pectin as a gelling agent [52]. The gelling nature of pectin was majorly dependent on the degree of esterification (DE). Pectin involving above 50% DE is known as high methyl ester pectin (HM) and below 50% DE is known as low methyl ester pectin (LM) [53]. LM pectin requires multivalent cations such as calcium ions for the gelling property, whereas HM pectin doesn't require multivalent cations [54]. From the literature review, it was found that the pectin extracted from the banana peel can be used as an inactive ingredient in the formulation development.

Acid extraction and ammonium oxalate extraction was the common method to isolate pectin from banana peel. But acid extraction would be the most efficient with a maximum yield of pectin [55].

Emaga *et al.,* used an experimental design to identify the process parameters affecting pectin yield and its quality such as the effect of pH, temperature, and extraction time was studied using a full two-level factorial design. Decreasing the pH value increases galacturonic acid content. Based on the results from the experimental design pH 2.0 for 1 h at 90°c was found to be a favorable condition for extraction [55].

Pratik B. Kamble *et al.,* extracted pectin from the banana peel and characterized its nature. The solvent used for extraction was hydrochloric acid. DE of extracted pectin shows 80% which indicates its rapid-gelling property [53]. Banana peel pectin shows high yield and high DE when compared to commercial pectin obtained from citrus peel and apple pomace when 6% of citric acid was used as an extracting solvent [50].

High purification after extraction is required to get high-quality pectin for commercial use such as food additive and pharmaceutical purposes. The extract was purified to remove free sugars and salts using ethanol [50,53]. Anhydrouronic acid (AUA) content indicates the purity of pectin for commercial use. The purity of banana peel pectin seems slightly lower as it has anhyrouronic acid content less than 65% as per Food chemical codex monographs 1996 [53,56]. Among five varieties of banana in Thailand, Kluai Nam Wa pectin only shows 66.6% of AUA which is suitable for the commercial purpose [50]. Table 6 summarizes pectin in pharmaceutical formulations.

Table 6: Extracted Pectin in Formulations

Dosage form	Role of pectin	Solvent for extraction	Amount of pectin	Reference
Semi solid jelly	Gelling agent	Citric acid	5 to 7%	27
Tablet	Tablet excipient	Hot water	2 to 5 mg	49
Gastro retentive floating beads	Floating polymer	Citric acid	1.25 to 1.75%	54

Banana peel extract as a reducing agent in the formulation of Silver Nanoparticles (AgNP):

Silver is an inorganic antibacterial agent and it holds an important place in metallic nanoparticles [57]. Silver nanoparticles can be synthesized by several methods. The method of preparation includes thermal decomposition of silver compounds [58], sonochemical [59], facile method [60], electrochemical [61], green chemistry [62] and microwave-assisted process [63]. The most common and simple method for the synthesis of the silver nanoparticle is reducing the metal salts. Hydrazine, sodium citrate, sodium borohydride, ascorbic acid, ammonium formate, and dimethylformamide are the chemical reducing agents used to synthesize stable and different shaped silver nanoparticles in an aqueous solution [60].

These physical and chemical methods used for the synthesis of AgNP are expensive, laborious, require high energy, and involve hazardous chemicals [57,64]. So there is an unaddressed need to develop a viable alternative to prepare silver nanoparticles using plant extracts. Banana peel extract has the tendency to reduce silver ions (Ag^+ to Ag^0) which can be utilized as a reducing agent in silver nanoparticle preparation [65]. Banana peel extract was used to reduce silver nitrate ($AgNO_3$) in the preparation of silver nanoparticles. The surface plasmon resonance (SPR) band is an unique optical property seen in noble metals. Literature work reports that silver nanoparticles biosynthesized using banana peel extract shows a well defined characteristic SPR band [57,64,65]. The spectral, thermal, and microscopical study reveals that nanoparticles prepared using banana peel extract were spherical, monodispersed, and crystalline [57,64].

These biosynthesized nanoparticles exhibit good antibacterial activity against clinically isolated multidrug-resistant human pathogens. They are more effective against Gram-negative bacteria than Gram-positive bacteria [57,64]. The antibacterial activity of AgNP was comparable to levofloxacin and hence it can be used in the combination for better therapy [57]. Besides, Ashok Bankar *et al.,* have synthesized gold nanoparticles by reduction of chloroauric acid using banana peel extract. The synthesized gold nanoparticles also exhibit satisfactory antifungal and antibacterial activity [66].

CONCLUSION

This review details the information about bioactive components present in banana peels and the activity corresponding to it. If the banana peel was processed appropriately, it could be the most valuable product in pharmaceutical formulation applications. Extraction, isolation, and purification of bioactive components from banana peels to retain their properties pose a major challenge for the researchers. However, extensive clinical studies are required using the banana peel extract to prove the safety, efficacy, and toxicity. Therefore, banana peel would serve as a potential alternative to the commercial pharmaceutical ingredients.

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