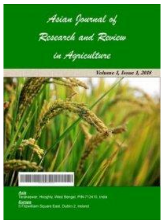

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Banana Peels as Possible Antioxidant and Antimicrobial Agents

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Authors' contributions

This work was carried out in collaboration between authors equally. All authors read and approved the final manuscript.

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ABSTRACT

The aim is to review the research on the antioxidant and antimicrobial activities of the banana peel and related research suggests that it may be used as good sources of natural antioxidants and for pharmaceutical purposes in treating of various deseases. Banana is an edible fruit and is herbaceous plant belonging to the genus *Musa* and Musaceae family. It is one of the world's most important fruit crops that is widely cultivated in tropical countries for its valuable applications in food industry and also banana peels are widely used as complementary feeds for cattle in the tropics. Its enormous by-products are an excellent source of highly valuable raw materials for other industries by recycling agricultural waste for preventing an ultimate loss of hugeamount of untapped biomass and environmental issues. Hence the utilization of banana by-products in various food and non-food applications and sources of natural bioactive compounds represents the desired goal that has been achieved and is still being explored. Future prospects and challenges are the important key factors in association to the sustainability and feasibility of utilizing these by-products. It can be concluded that banana peel can be used in food, pharmaceutical and other industries successfully. Therefore, the banana wastes may provide new horizons and areas of research for future.

Keywords: Antimicrobial activity; antioxidant activity; banan peel exracts.

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1. INTRODUCTION

Banana (*Musa* sp., Musaceae family) is one of the major fruit crops, cultivated in tropical and subtropical regions of Asia, America, Africa and Australia for food where its edible fruits. Banana peels and the vegetative parts of the plants are also used in animal feeding [1]. The world production of bananas in 2019 was 116.8 million tons. Globally, it is one of the major fruits, ranking in economic importance after grapes, tomatoes and apples [2]. The fruit can be eaten raw, dried, or cooked, and the fact that it can be obtained year round. The fruit of the common banana averages 125 grams, of which approximately 75 percent is water and 25 percent dry matter content. Bananas come in a variety of sizes and colors when ripe, including yellow, purple, and red. Although the wild species have fruits with numerous large, hard seeds, virtually all culinary bananas have seedless fruits [1]. Bananas fruites that are usually eaten raw are soft. It may also be dried and eaten as a snack food. Dried bananas are also ground into banana flour. It can be fried, boiled, baked, or chipped. Depending upon cultivar and ripeness, the flesh can vary in taste from starchy to sweet, and texture from firm to mushy. Unripe or green bananas and plantains are used for cooking various dishes and are the staple starch of many tropical populations [1]. Most production for local sale is of green cooking bananas and plantains, as ripe dessert bananas are easily damaged while being transported to market. Even when only transported within their country of origin, ripe bananas suffer a high rate of damage and loss [1].

Bananas are a valuable source of vitamin B6, vitamin C, and potassium. There are various species, hybrids, and cultivars of bananas. The most common bananas for eating (dessert bananas) belong to the species M. acuminata, or to the hybrid Musa x paradisiaca or M. sapientum (*M. acumianta* X *M. balbisiana*) [3]. Banana fruits are popular in part because being a non-seasonal crop they are available fresh year-round. In global commerce, by far the most important of these banana cultivars is "Cavendish," which accounts for the vast bulk of bananas exported from the tropics. There are two main groups of bananas: 1) bananas whose ripe fruit is eaten as dessert. They represent 56% of world banana production and 97% of exportations, and are mainly from the cavendish group. They have the highest yields (100 t/ha/year) [4-6]. 2) bananas used for cooking and include plantains and other sub-groups of varieties such as pisang awak in Asia, and represent 44% of world banana production [4, 5]. The ripe fruit is eaten fresh as dessert or baked, fried, dried or roasted. It can also be processed into vinegar, chips, starch or beer. The underground stem and male flowers can be eaten as a vegetable [6]. The leaves are used for wrapping food for cooking, making clothes and polishing floors. Ethno-medicinal uses of different parts of the banana are plentiful [6]. Young stalks and leaves, wasted fruits and banana peels are fed to livestock [6,7]. It has been estimated that 30% to 40% of total banana production are rejected for failing to meet quality standards, making them potentially available to livestock [8]. Banana wastes include small-sized, damaged or rotten fruits, banana peels, leaves, stalks and pseudostems. Fresh plantain and banana fruits may be ensiled with a wide range of crops and additives, including molasses, grass, legumes and rice bran. Green fruits are easier to ensile than ripe fruits. Bananas and plantains may also be dehydrated, chopped, milled or cooked, etc. [8]. Dehydrated or fresh green and ripe peels are used as feeds [8]. Banana and plantain leaves, stalks or pseudostems whole, fresh leaves, stalks and pseudostems can be chopped and directly fed or ensiled with molasses [8].

2. BANANA PEELS

Banana peel (banana skin) is the outer envelopes (covering) of banana fruit. They are the by-product of household consumption and banana processing [6]. Banana peels are used as food for animals, an ingredient in cooking, in water purification, for manufacturing of several biochemical products. Because of this removal of the banana peel, a significant amount of organic waste is generated [8, 9]. Banana peels are sometimes used as feedstock for cattle, goats, monkeys, poultry, rabbits, fish, zebras and several other species, typically on small farms in regions where bananas are grown [1]. There are some concerns over the impact of tannins contained in the peels on animals that consume them [10, 11].

3. NUTRITIONAL VALUE OF BANANA PEEL

The nutritional value of banana peel depends on the stage of maturity and the cultivar;for example plantain peels contain less fibre than dessert banana peels, and lignin content increases with ripening (from 7 to 15% dry matter). On average, banana peels contain 6-9% dry matter of protein and 20-30% fibre. Green plantain peels contain 40% starch that is transformed into sugars after ripening. Green banana peels contain much less starch (about 15%) when green than plantain peels, while ripe banana peels contain up to 30% free sugars [10] Banana peels are also used for water purification [12] to produce ethanol [13] cellulase [14] laccase [15] as fertilizer [16] and in composting [17]. Beside, culinary use with banana in Southeast Asian, Indian and Venezuelan cuisine [18-21].

4. BIOLOGICAL ACTIVITY OF BANANA PEEL

4.1 Antioxidant Activity

Banana peel is rich in phytochemical compounds, mainly antioxidants. The total amount of phenolic compounds in banana (*Musa acuminata* Colla AAA) peel ranges from 0.90 or 3.0 g/100 g dry weight [22, 23]. Someya et al. (2002) identified gallocatechin at a concentration of 160 mg/100 g dry weight. Ripe banana peel also contains other compounds, such as the anthocyanins delphinidin and cyanidin [24], and catecholamines [25]. Furthermore, carotenoids, such as β-carotene, α-carotene and different xanthophylls, have been identified in banana peel in the range of 300–400 μg lutein equivalents/100 g [26], as well as sterols and triterpenes, such as β-sitosterol, stigmasterol, campesterol, cycloeucalenol, cycloartenol, and 24-methylene cycloartanol [27]. To date, Someya et al. [23] have evaluated the antioxidant activity in banana peel, measured as the effect on lipid autoxidation, in relation to its gallocatechin content.

The antioxidant activity originates from the secondary metabolites contained in the banana peel extract, namely alkaloids, flavonoids, tannins, and saponins [28]. Flavonoids are strong antioxidants that can reduce free radicals and produce flavonoid compounds [29]. Free radicals are highly reactive and harmful substances that can damage the tissues of organs and cause various diseases. Since antioxidants can inhibit free radicals and increase endurance simultaneously, their presence are crucial in countering the effects of free radicals in the body [28].

The antioxidant effects of crude extracts from green banana and yellow peel were investigated and the results indicated that the extract of green peel recorded more significant activities than that of yellow peel at other solvents extracts [30]. However, investigations for antimicrobial and antioxidant activities of the Mokbel and Hashinaga [30] study were focused in water and ethyl acetate extracts of green peel. Green banana peel displayed high antioxidant activity as measured by ß-carotene bleaching method, DPPH free radical and linoleic acid emulsion. The oxidative activity of linoleic acid was markedly inhibited by extracts. The BHA at 0.1 mg mL 1 as same as green banana extracts was included as positive control for the hydrophilic antioxidant. The results showed that the inhibitor activity of 70% acetone extracts of green banana peel using thiocyanate method at concentration of 0.5 mg mL 1 closed to the synthetic antioxidant reagent of BHA at 0.1 mg mL 1 [30]. The absorbance of control has increased in 6 days and decreased thereafter due to oxidation of linoleic acid generating linoleic acid hydroperoxides [30], which decompose too many secondary oxidation products in agreement with Jayaprakasha et al. [31]. These results of Tepe et al. [32] in all cases, the control without addition of antioxidant oxidized more rapidly, while the sample elicited inhibition of bleaching of ß-carotene. Free radical scavenging capacities of the extracts measured by DPPH assay. The free radical scavenging activity of aqueous acetone extract was superior to all other extracts, followed by ethyl acetate extracts and yellow banana peel showed low antioxidant activity.

The water extracts were eluted in silica gel column for fractionation and those fractions displayed significant antioxidant activity as measured by DPPH free radical [30]. Sundaram et al. [33] reported that raw, mature, and very mature banana (*Musa paradisica*) peels have the potential as antioxidants. The antioxidant activity of the peel was evaluated by red cell hemolysis test, free radical scavenging (1,1-diphenyl-2-picrillhidrazi), and superoxide dismutase activity. The results show that raw banana peels are the most active as compared to other banana peels. Determination of total flavonoids shows a correlation between total flavonoid content and its activity as an antioxidant. Alamsyah et al. [34] reported that banana peels (*Musa paradisica*) have potential as antioxidants with IC_{50} of 64.03 ppm.

Baskar et al. [35] investigated the antioxidant potential of 9 local banana peel varieties in Coimbatore, India. The results showed that the banana peel extract showed significant antioxidant activity. This study shows that the extract of this banana variety can be useful for treating free radical mediated diseases. Aboul-Enein et al. [36] reported that banana peel (*Musa paradaisica* L.) acetone extract showed the highest antimicrobial and antioxidant activity at 600 ppm. The main phenolic compounds from the extract was catchin, qurectein and chyrsin.

The ethanolic extract of the raw banana peel (*Musa paradisiaca* forma typica), originating from Jaro Village, Tabalong Regency, South Kalimantan, has very strong antioxidant activity with an IC50 value of 4.44 ppm. This study proves that banana peel extract can be used as an additional therapy or prevention in increasing the body's antioxidants, which play a significant role in free-radical scavenging [37].

The high phenolic and flavonoid content increased percentage of free radical scavenging activities [38]. Eight Malaysian banana cultivars showed a total phenolic content of 20.47 mg gallic acid equivalents (GAE)/100 g [39]. In 15 bananas cultivars that were grown in Viçosa, Minas Gerais, Brazil, the total phenolic content of the unripe peels ranged from 29.02 to 61.00 mg GAE/100 g and for ripe were between 60.39 to 115.70 mg GAE/100 g [40]. In addition, the total phenolic content was in an average of 88.31 mg tannic acid equivalents (TAE)/100 g peel (dry basis, d.b.) *M. paradisiaca* [41]. The tannin content was found to be 5800 mg TAE/100 g peel (d.b.) at the ripening stage and 1130 mg TAE/100 g peel (d.b.) at the maturation stage [42]. The flavonoid content that was found in the peel extract was 196 mg/g quercetin equivalent [43].

In the Behiry et al. [44] study, rutin was identified with a high amount (973.08 mg/100 g DE), and previously banana peel extract has been reported to contain naringinin, a flavanone glycoside, and rutin, a flavonol glycoside [25]. Other compounds, such as lutein, α- and β-carotene, auroxanthin, violaxanthin, neoxanthin, β-cryptoxanthin, isolutein, and α-cryptoxanthin have been identified in peel extracts [26]. Phenolic compounds, like ferulic acid (0.38%) and caffeic acid (0.06%), were identified in banana peel extract while using ultra-performance liquid chromatography with electrospray ionization [45].

Flavonoid compounds have been identified in high amounts, and one previous study reported that plantain peel flour had a total phenol level of 7.71 mg GAE/g, mainly comprising flavonoid type [46]. There is a great deal of antioxidant activity in banana peel and it could be a very inexpensive source of extracts rich in bioactive compounds, as previously suggested by Someya et al. [23]. Extracting banana peel with acetone: water was not only very efficient but also produced extracts with high antioxidant capacity, as confirmed by various model systems. This may be due to variation in the quality and quantity of phenolic compounds and other bioactive compounds present in the different extracts, such as catecholamines and anthocyanins (ascorbic acid, tocopherols and phytosterols were not detected). The antioxidant activities of banana peel extracts obtained from different cultivars ("Grande Naine" and "Gruesa") were similar. However, the impact of other extraction conditions, such as time or temperature, should be studied in greater depth. Further work is also required for the isolation and characterisation of individual phenolic compounds present in various extracts, to determine the mechanisms involved in the antioxidant capacity of these by-product extracts [47].

4.2 Antimicrobial Activity

Several works have been done to evaluate the phytochemical compositions and antimicrobial activities of different parts of diverse plants, with the aim of using these plants for the treatment of microbial infection as possible alternatives to synthetic drugs to which many infectious microorganisms have developed resistance [48]. Effect of plant constituents can combat human and plant pathogenic bacteria, fungi and viruses without toxic side effects and environmental hazards [49]. Lino et al. [50] results indicated that the tannins are present but the flavanoids are absent in the extract of *Musa sapientum* L., Musaceae, epicarp, it is probable that the antimicrobial activity of the gel prepared from banana peel is related to tannins and not to flavanoids. In addition, it has astringent action, with ability to precipitate proteins, which may affect the bacterial peptidoglycan. The inhibitory effect of aqueous banana extracts to Gram-positive bacteria in our study was agreed with different studies. In the study of Mokbel and Hashinaga [30], ethyl acetate extract of green banana peel recorded significant antimicrobial activities, while yellow peel extracts recorded low activity and no activity was recorded to $CHCl_3$ and water extracts as measured by paper disk methods. The MIC was measured after 48 h of incubation at 36 °C. The MIC of ß-sitosterol, palmitic acid, malic acid and succinic acid was tested against *S. aureus, B. subtilis, B. cereus, S. enteritidis* and *E. coli*. ß-sitosterol, malic acid and succinic acid were active against all tested the Gram-negative and Gram-positive bacterial species, while palmitic acid was insignificant against all tested the bacteria species. The minimum inhibitor concentration (MIC) of ß-sitosterol, Malic acid and succinic acid varying between 140-750 ppm, respectively. These data indicated that malic acid exhibited strong antibacterial activity compared to ß-sitosterol, succinic acid and palmaitic acid. While, 12-hydroxystrearic acid recorded antimicrobial activity as measured by paper disk methods but didn't measure for MIC. This study clearly indicated that isolated compound inhibited the growth of food poisoning bacteria *in vivo* [30].

Ehiowemwenguan et al. [51] studied on antibacterial activity of organic extract and aqueous extract of banana peel, and they concluded that organic extract had least MIC value compared to the aqueous extract. The author in the same study also carried out phytochemical screening of both organic and aqueous extract of banana peel and found that the organic extract of banana peel contains glycosides, alkaloids, flavonoids, and tannins. While, the water extract contains only glycosides and alkaloids. This result indicated that organic solvents dissolve more active compound than water. Ehiowemwenguan et al. [52] reported that the ethanol extract of *Musa sapientum* peel inhibited 6 bacteria species with MIC (Minimum inhibitory concentration) of 16-512.5 mg/mL. Noor and Apriasari [53] reported that stems of Mauli banana (*Musa acuminata*) methanol extract was active as antibacterial against *Streptococcus mutans* with inhibitory zone of 15 mm at concentration of 80%. Antibacterial assay of *Musa acuminata* peel ethanol extract against *E. coli, S. aureus, P. aerginosa* resulted that the peels can inhibit the bacteria growth at a concentration of 20 mg/mL [54].

Ananta et al. [55] revealed that the peels of milk, gold (lady finger), and wood banana have antibacterial activity against *E. coli* and *S. aureus*, where lady finger was the most active. Wahyuni et al. [56] reported that n-butanol extract of yellow kepok banana peels inhibited the growth of *S. aureus* and *E. coli* with MIC of 0.5 and 0.1% respectively. The total flavonoid and phenolic contents were 0.06 and 0.15%. According to Susanah et al. [57], between flavonoids or phenolic content and antibacterial activity, there was a positive correlation.

There are several studies showing the antimicrobial activity of banana peel. Ighodaro [48] evaluated antibacterial activity of banana peel extract (*M. paradisiaca*) against human pathogenic bacteria and found that banana peel extract showed inhibition against *S. aureus*, *Escherichia coli*, and *Proteus mirabilis*. Chabuck et al. [58], studied antimicrobial activity on clinical isolates of two Gram-positive (*S. aureus* and *Streptococcus pyogenes*), four Gram-negative (*Enterobacter aerogenes*, *Klebsiella pneumoniae*, *E. coli*, and *Moraxella catarrhalis*), and one yeast (*Candida albicans*). Banana extract showed highest antibacterial activity against both *M. catarrhalis* and *S. aureus* followed by *S. pyogenes*, *E. aerogenes*, and *K. pneumoniae* and no effect against *E. coli* and *C. albicans*.

In the *in vitro* study of Kapadia et al. [59], were focus on determining the antibacterial activity of alcoholic extract of banana peel against standard stains of Gram-negative anaerobes like *Porphyromonas gingivalis* and *Aggregatibacter actinomycetemcomitans* which are associated with periodontal diseases. *P. gingivalis* is a Gram-negative, anaerobic, nonmotile, saccharolytic rod that usually exhibits coccal to short rod morphologies [60]. It is mainly associated with adult periodontitis, acute periodontal abscess, and failure of the regenerative procedure [61]. *A. actinomycetemcomitans* is a small, nonmotile, Gram-negative, saccharolytic, capnophilic, round-ended rod [60]. It is associated with adult periodontitis, aggressive periodontitis, refractory periodontitis [61], and also associated with periodontitis lesion of Papillon-Lefèvre syndrome [62]. Both the bacterial strains showed sensitivity against an alcoholic extract of banana peel in the current study. In the study of Kapadia et al. [59], we carried out well diffusion assay and serial broth dilution method to detect the antibacterial activity of alcoholic extract of banana peel. In well diffusion assay, results have shown a 15 mm and 12 mm inhibition zone of *P. gingivalis* and *A. actinomycetem comitans*, respectively, against the alcoholic extract of banana peel. Whereas, in serial broth dilution method both *P. gingivalis* and *A. actinomycetemcomitans* have shown sensitivity until 31.25 µg/ml dilution against the same extract. In general, the presence of secondary metabolites in plants has been responsible for antibacterial activity [63].

Secondary metabolites such as flavonoids, tannins, phlobatannins, alkaloids, glycosides, and terpenoids were found in banana peel [64]. The presences of these phytochemicals/ secondary metabolites might be responsible for the antibacterial activity of banana peel.

Ighodaro [48] also reported the same result, and he found that organic solvent had higher antibacterial activity than aqueous solution. Therefore, in this study isopropyl alcohol was used to dissolve more active compounds from the banana peel. McDonnell and Russell [65] stated that alcohol has antimicrobial activity. Therefore, isopropyl alcohol was used as a negative control of the Kapadia et al. [59] study. In well diffusion assay of this study, 70% isopropyl alcohol has shown 8 mm and 10 mm zones of inhibition with *P. gingivalis* and *A. actinomycetemcomitans*, respectively. Whereas, the alcohol extract of banana peel have shown 15 mm and 12 mm of inhibition zones with *P. gingivalis* and *A. actinomycetemcomitans*, respectively. In MIC, 70% isopropyl alcohol has shown least sensitivity up to 31.25 µg/ml and 250 µg/ml against *P. gingivalis* and *A. actinomycetemcomitans*, respectively, whereas in alcoholic extract of banana peel showed sensitivity until 31.25 µg/ml against both strains. These results support the previous studies [30, 51, 58]. This also indicated that banana peel extract showed sensitivity against both strains, but it has no antibacterial activity against *P. gingivalis* at lower concentrations.

Singh et al. [66] evaluated the antibacterial activity of three different color banana such as red, green, and yellow against ten clinical pathogens. The red banana showed a maximum zone of inhibition of 27 mm against *Planococcus citri* and 18 mm against *S. aureus*. The green banana peel showed inhibition zone of 19 mm against *Salmonella typhi* and *Aeromonas hydrophila*. The yellow banana peel exhibited 20 mm against *A. hydrophila* followed by 13 mm against S. aureus. This study enlightens a new line of approach for further study of different types of banana peels against different periodontal pathogens.

The methanol extract of *M. paradisiaca* peels showed a greater antibacterial activity than that of ethanol, water, and chloroform extracts against the human pathogenic bacteria *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Salmonella typhi* [67].

Peel extracts from three varieties of banana in powder and ash showed the presence of some phytochemicals, such as phenols, terpenoids, and saponins, and they exhibited antifungal activity against *A. niger*, but did not inhibit the growth of *A. flavus* or *Penicillium* spp. [68]. Galic acid (GA) had observed potential antifungal activity against four studied yeast of *Candida* spp. [69]. GA were observed considerable antimicrobial effects against different bacterial and fungal species [70, 71]. Ferulic (FA) and GA had antimicrobial activity against some pathogenic bacteria according to measured minimum inhibitory concentration MIC values [72]. The GA showed good antifungal activity against different strains of *Candida* [73, 74]. Additionally, Lino et al. [50], banana peel gel inhibited the growth of enterobacteria and pyogenic bacteria. Aldean et al. [75], showed that aqueous extraction of banana skin exhibited a variable degree of antibacterial activity against Gram positive and negative bacterial isolates causing gingivitis including streptococcus species. Sumathy [76] studied the antifungal and antimicrobial properties of yellow banana fruit peel and found that it is effective against different Gram positive and negative bacteria. As well as it can be of great significance in therapeutic treatments. Thus, more studies can be taken up in the future pertaining to the use of plant extracts as therapeutic agents especially those related to the control of antibiotic resistant microbes. High susceptibility of *K. pneumoniae, E. aerogenes* and resistance of *E. coli* to banana peel extract were found [77, 78] respectively. Some workers said that banana should be considered to be a good source of natural antioxidant and antibacterial and these criteria can be used to produce natural dyes extracted from banana peel to color cotton fabrics and protect them from bacterial effects [79]. In addition to that banana peel extract not only inhibit the non-spore forming bacteria but also certain studies conclude that unidentified substance extracted from banana skin has been shown to inhibit *Clostridium sporogenes* and other gram negative spore forming bacteria by using plate biological assay, the unknown substance demonstrate inhibitory effects at pH values as high as 7.5 [75].

5. CONCLUSIONS

Nowadays, The culinary banana peel, which is an agricultural waste available in abundance, has been able to draw much attention in terms of its utilization. In addition to being an abundant source of functionaland nutritional compounds, it also deserves to be utilized in a proper and/or better way. This work identified the potential suitability and use of banana peel for antiocidant and antimicrobial activities. The results of the banana peels showed that the banana peels extracts encouraging potentials for biological activities as antioxidant and antimicrobial activities. we suggestions for future work on banana waste, especially on the biological activities. Further studies should investigate how to identify of biologically active compounds present in banana peel and other plant residues to which biological activity is due. The above reports brings out the importance of consuming banana fruits for obtaining various health benefits. It is not only the banana fruit pulp, but also the peel of this fruit is known to contain many important phytochemicals and offers many health benefits. More research is needed to be carried out to find ways of using banana fruit peel in the development of many new func-tional foods.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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