Bioactive profile and functional food applications of banana in food sectors and health: a review

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**ABSTRACT**
This review explores the nutritional and pharmacological aspects of banana, as well as their prospective applications in the food and pharmaceutical sectors. Banana is a widely consumed staple food in several countries and is popular for its pharmacological, nutritional and bioactive profile. Banana is ranked as the fifth most cultivated agricultural crop in terms of global trade. It is consumed in both raw and processed form. Banana comprises an immense amount of bioactive compounds including phytosterols, carotenoids, phenols, and biogenic amines that have a very effective role in health-promoting phenomena. Several bioactive compounds show antioxidant activities to reduce the disease risk. Banana has very effective pharmacological activities like anti-inflammatory, antioxidant, anti-cancer, and anti-diabetic. Banana has unique health-promoting aspects as well as used in the development of many food products like bread, pasta, confectionaries, and gluten-free products.

**Introduction**

Fruits are one of the most edible part of plants consumed in raw form, having fleshy structures. Fruits are considered the main source of sugars, vitamins and bioactive compounds involving phenolic compounds and fibers; and are beneficial to minimize the risk of various chronic ailments. [1] According to WHO, the consumption of approximately 400 g of fruits per day is recommended. [2] Banana is one of the widely consumed fruits that is a large herbaceous plant that belongs to the genus *Musa* from the family *Musaceae*. Banana is generally cultivated in the tropical and sub-tropical regions of the globe. Banana is the fifth agricultural crop than coffee, cereals, sugar, and cacao in terms of world trade and is a significant fruit crop after citrus fruits, grapes and apples. [3] Banana is one of the oldest cultivated crops of the globe because it is cultivated about 600 BC in India. [3] It is also described from various studies that the annual production of banana is about 145 million tons all over the world. The largest banana producing countries of the world are China, Ecuador, Philippines and India. Thus, USA is the largest banana importing country while Ecuador is the major exporter of the banana. [4] According to an estimation the demand of banana export reached to about 20.2 million tons in 2019. [5] Banana is a nutrient rich fruit and is the main source of many macronutrients, micronutrients and phytonutrients. It contains an immense amount of vitamins and phenolic compounds. [6,7] Banana is...
also a good source of minerals like sodium (Na), potassium (K), iron (Fe), copper (Cu), phosphorus (P), manganese (Mn) and zinc (Zn). Banana pulp contains various ingredients in different concentrations such as 72% moisture, 2.9% total fiber, 1.4% protein, 1.28% ash and other compounds like 14.4% sucrose, 8.5% vitamin C and 2.4% glucose.\textsuperscript{[6]} Banana is very useful for good health and well beings of people due to its highly nutritive values. Banana is used as a perishable food in several countries. It is also incorporated in many food products that is very effective for human health. Banana is a main source of various health promoting phytochemicals described by many studies.\textsuperscript{[9,10]} Both ripe and unripe bananas contains antiulcer, anti-diabetic as well as radical scavenging compounds.\textsuperscript{[11]} Banana is also used as vector for several vaccines because it is easily available and simply administered. Pectin obtained from banana is used in the capsule preparation as pharmaceutical excipient. Banana is consumed in raw as well as cooked form. Banana is used by human beings as well as green unpeeled banana is used as feed for animals. It is very important source of energy and generally consumed by athletes.\textsuperscript{[12]} It is the best source of energy for different sports activities described by food experts. Hence, banana is incorporated in various energizing drinks and bars which have beneficial effects to athletes. The use of banana enriched drinks as well as other food products reduce the risk of muscular contraction of athletes due to sufficient concentration of minerals (K and Mg) and vitamins.\textsuperscript{[6]} All the traditional plants are widely used for the treatment of various ailments all over the globe. Banana has many medicinal properties beyond its nutritional aspects such as wound healing, anticancer, anti-ulcerogenic, hypoglycemic, antioxidant, and anti-diarrheal activities.\textsuperscript{[13]} In recent years, the food industries are more interesting to increase healthy products, consumers interest in a healthy diet, as well as food manufacturers developing novel, sustainable food products.\textsuperscript{[14]} And with a rapid increase in the global population, it is mandatory to produce innovative and effective food manufactured through banana by-products like peel by using appropriate techniques. Therefore, the banana pulp and peel may be utilized in a variety of functional food products, including baked goods (bread, cookies, and pasta), confectionaries, and other gluten-free products. This review explores the nutritional composition, bioactive profile, potential health benefits, and auspicious food application of banana peel and pulp. The main goal of this review is to pay attention toward the key nutritional properties of bananas and their promising applications in food and pharmaceutical sectors.

**Nutritional composition of banana fruit**

Banana contains a high nutritional content, which aids in the absorption of a variety of nutrients while minimizing fat absorption. It helps to maintain blood glucose level as well as improve endurance workout performance.\textsuperscript{[15]} Banana is the main source of many phytochemicals and micro as well as macronutrients like carbohydrates, protein, unsaturated fatty acids, vitamins (A and C), and minerals. Several studies showed that banana contains different concentration of nutrients like vitamin C (12.7 mg/100 g), vitamin A (12.4 mg/100 g) and total soluble solids (17.9%).\textsuperscript{[16]} A medium size banana contains about 6 g of fiber. Banana is also good source of minerals with the medium size banana contains 450–467 mg of potassium.\textsuperscript{[16]}

**Carbohydrates**

Banana pulp is rich in sugars, fiber, cellulose, and starch contents. Higher amount of fiber is found in banana peel as compared to banana pulp. During development of banana fruit, a large amount of starch stored with nominal variations in major carbohydrates metabolites that generally noticed in the pre-climacteric phase of it.\textsuperscript{[17]} The starch in banana is later on converted into glucose, sucrose and fructose. The starch concentration during ripening of banana is usually decrease from 15 to 25% that is less than 5% of the ripened banana but in both conditions a significant increase occur in the sugar contents.\textsuperscript{[6,18]} Respiratory climacteric phase is a main factor that influence the concentration of sugar content in banana. There are two types of enzymes involved in the conversion of starch into sugar. Sucrose phosphate synthase is involved in the conversion of starch into sucrose while acid hydrolase is
responsible for the conversion of starch into non-reducing sugars from sucrose. The starch in the dessert banana is totally broken down in the ripening phase while in plantains it is not completely wrecked.\textsuperscript{19} Banana is also effective to alleviate the intestinal ailments due to presence of pectin. Diarrhea is considered as the vital cause of morbidity and mortality of children in underdeveloped countries; thus, the green banana provides a variety of antidiarrheal activity that is very effective to minimize the risk of diarrhea in children. A large amount of digestible starch found in the unripe phase of banana while resistant starch found in ripening state of it.\textsuperscript{20}

**Proteins and amino acids**

Banana is also considered as the good source of proteins and amino acids. Chitinase enzyme is an abundant protein commonly found in the unripe banana. Many enzymes such as malate dehydrogenase, starch phosphorylase and pectate lyase are accumulated during ripening of banana.\textsuperscript{21} Dopamine is a well-known water-soluble antioxidant as well as catecholamines which has ability to suppress oxygen, present in peel and pulp of various types of banana especially in Cavendish.\textsuperscript{22} Banana is rich in numerous bioactive amines like spermidine, serotonin and putrescine. It contains biogenic amines and nitrogenous compounds like norepinephrine, dopamine and serotonin;\textsuperscript{23} their concentration decreased with the ripening phase as reported by Borges et al.\textsuperscript{24} Banana has cultivar-dependent phytosterols, cycloeucalenone, cycloeucalenol, campesterol, β-sitosterol and cycloartenol. The use of banana is very useful in the cholesterol metabolism and cardiovascular disease risk.\textsuperscript{23}

**Vitamins**

Several types of vitamins are found in the cooking and dessert banana all over the globe. Vitamin C concentration varies from 2.1 to 18.7 mg/100 g in Cavendish banana estimated by high-performance liquid chromatography.\textsuperscript{16} While ‘Dwarf Brazilian’ variety of banana contains 4.5 mg/100 g to 12.7 mg/100 g of vitamin C reported by Nayak and Basak.\textsuperscript{25} Pro-vitamin commonly known as vitamin A is abundant in dessert banana\textsuperscript{26} although only a few cultivars with orange or yellow-colored pulp are known to have higher quantities of carotenoids.\textsuperscript{13} Globally, about 118 countries are the victim of vitamin A deficiency mainly in Africa as well as Asia which are usually involved in the consumption of cereals and tubers as compared to fruits. A mature banana contains carotenoids including lutein, α- and β-carotene. Banana pulp has high amount of carotenoids as compared to peel. It is evident from the studies that carotenoids concentration increased in the ripening phase of fruit. Different varieties of banana have distinct quantity of carotenoids. The banana with orange pulp has high amount of pro-vitamin. It was reported that a variety of banana (Karat) hold β-carotene of about 2230 µg/100 g.\textsuperscript{27}

**Minerals**

Banana contains enormous amount of variety of minerals including Magnesium (Mg), Copper (Cu), Iron (Fe), Potassium (K), Sodium (Na), Calcium (Ca), Zinc (Zn) and Manganese (Mn). Potassium is very effective for human blood pressure as well as good health of the heart.\textsuperscript{28} The banana and plantain contain a high amount of potassium. Different types of banana fruits have different concentration of minerals like potassium is 330.6 mg/100 g in Hawaii’s bananas and 509 mg/100 g in Tenerife cultivated banana. It is also evident from previous studies that the concentration of minerals dependent on area of cultivation of fruit. Tenerife banana contains Mg, P, Ca and K in a ratio of 0.38 mg, 0.59 mg, 0.38 mg and 5.09 mg per gram.\textsuperscript{16} Several studies showed that minerals like Cu, Zn, Ca and Mn are high in Ecuador cultivated banana while sodium, magnesium, iron and potassium are high in Tenerife’s banana. Mineral levels are also different in ripe and unripe bananas. Unripe bananas have 0.146% Mn and 0.68% Zn, while ripe bananas have 0.271% Mn and 0.80% Zn. The peel of banana
fruit is also rich in minerals; the Cameroon banana peel has a relatively high amount of minerals including Phosphorus 22.2 mg, calcium 18 mg, potassium 50.0 mg, and magnesium 11 mg in gram.\textsuperscript{[6]}

**Bioactive compound in banana**

**Phenolic compounds**

Phenolic compounds are very important bioactive ingredients with health-promoting as well as antioxidants properties, an immense amount of these compounds are present in banana. The most common phenols present in banana are catechin, epicatechin, anthocyanins, tannins and gallic acid. The phenolic compounds identified in banana by Sidhu and Zafar\textsuperscript{[29]} include salicylic, gallic, p-hydroxybenzoic, ferulic, sinapic, gentisic, and p-coumaric, syringic and vanillic. Banana peel is a major source of many phenolic compounds. Phenolic compounds have ability to donate hydrogen atom to a free radical due this it is considered as primary antioxidant in banana. The free radical scavengers’ activity of phenolic compounds show in Figure 1.

Different studies are conducted to analyze the efficacy of banana pulp and peel from plantain and dessert bananas.\textsuperscript{[31]} It was observed that plantain bananas contain a high content of ferulic acid-hexoside about 4.4–85.1 µg/g DW. Plantain banana peel contains 242.2–618.7 µg/g DW rutin which is a more abundant flavonol. These varieties of banana contain an immense amount of phenols such as myricetin, kaempferol, quercetin, and cyanidin, which have ability to scavenge reactive nitrogen species and reactive oxygen species.\textsuperscript{[29]} These phenolic compounds act as antiviral, antithrombotic, anti-inflammatory, antibacterial, and vasodilatory activities.\textsuperscript{[32]} It is concluded that banana peel contains more amount of phenolic compounds as well as antioxidant activities as compared to banana pulp. Tsamo et al.\textsuperscript{[31]} studied banana peel and pulp from two desserts and nine plantain banana cultivars. The findings exhibited that plantain pulp contains a high amount of hydroxycinnamic derivatives like ferulic acid-hexoside. A variety of phenolic compounds was analyzed in the experimental banana cultivars. The peel of plantain banana cultivars contains a high level of rutin.

**Biogenic amines**

The nitrogenous compounds that are formed by the decarboxylation of amino acids or through aldehyde and ketone amination are known as biogenic amines.\textsuperscript{[33]} The common biogenic amines present in banana peel and pulp are dopamine, norepinephrine and serotonin. In banana pulp the concentration of serotonin was observed in a range of 8 to 50 µg/g. On the other hand, in the pulp of

![Figure 1. Free radical scavengers’ activity of phenolic compounds. Source: Rungratanawanich et al.\textsuperscript{[30]}](image-url)
plantain, red banana, and yellow banana the dopamine present in a range of 5.5, 54, and 42 µg/g, respectively. [34] Buckley[35] stated that L-DOPA, 3, 4-dihydroxyphenylalanine, C14-labeled phenylalanine, and tyramine can be used to make 3-hydroxytyramine from the peel of ripening bananas. During the ripening of banana peel, C14-tyrosine is converted into 3-hydroxytyramine which is indirectly the biosynthesis of dopamine through decarboxylation of tyrosine in the tyramine pathway.

It was also reported that dopamine is isolated from the banana pulp through hydroxylation of tyramine characterized by a suitable enzyme. The removal of the carboxyl group from L-DOPA formed a catecholamine known as dopamine having a lot of health-promoting aspects like regulating the neurotransmitter of the brain, impact on mood, enhancing the concentration ability and emotional constancy. Several studies depicted that during the ripening stage of banana the concentrations of tyramine and L-DOPA increased and the concentration of dopamine reduced in post-climacteric phase of banana peel and pulp but increased in the climacteric phase.

**Carotenoids**

Carotenoids are basically known as the precursors of vitamin A as well as contain antioxidant properties to scavenge reactive oxygen species. [36] Carotenoids is a major class of compounds that involve approximately 600 members. Banana contains carotenoids involving zeaxanthine, β-carotene and α-carotene. Chemical structures of selected common carotenoids show in Figure 2.

Lutein and lycopene also found in banana that are more strong antioxidants and very beneficial for human health to prevent risk of prostate cancer in men and antiaging agent respectively. [38] Davey et al. [38] studied 171 genotypes of *Musa* spp. For their levels of provitamin A carotenoids, and 47 different genotypes for their levels of two minerals zinc and iron. They observed vast variability in provitamin A carotenoids but low variability found in the minerals including iron and zinc, regardless of soil type or growth circumstances. It was also observed that high amount of Pro-vitamin A and low concentration of iron and zinc should be substantial approach to improve the problem associated with micronutrient deficiencies in banana consumption population. The orange and yellow fleshed banana contain higher amount of trans-β-carotene content observed by Dhandapani et al. [39] It was also evident from studies that the consumption of fruits rich in carotenoids content have many health benefits like improve immune system, lessen the risk of several ailments like CVDS, cancer and diabetes. [40] Banana is very beneficial to reduce the vitamin A deficiency generally found in poor

![Figure 2. Chemical structures of selected common carotenoids. Source: Lopes et al.[37].](image-url)
population that mainly consumed this type of banana rich in pro-vitamin A carotenoids. Carotenoids are major class of plant pigments such as xanthophylls and carotenes known as oxygenated derivatives of hydrocarbons and pure hydrocarbons respectively.\cite{41} Carotenoids play an important role as antioxidant as well as accessory pigments for light in harvesting of various plants, are basically the products of isoprenoid biosynthetic pathway.\cite{42} According to Mengstu\cite{34} it was observed that different varieties of banana contain different concentration of carotenoids like seven varieties of bananas contain 7760 to 10633 µg/100 g of these phytochemicals.

**Phytosterols**

Phytosterols impart an important role in reduction of serum low density lipoprotein cholesterol level by inhibiting the absorption of cholesterol from small intestine by increasing its excretion.\cite{43} These bioactive compounds also decrease the risk of different types of cancers like colon, prostate and breast cancer.\cite{44} Signal transduction trails including the regulation of membrane structure, immunity of host, tumor growth and apoptosis as well as inhibit the function of tumor cells. Thus consumption of banana shows health-promoting as well as protective effect in many circumstances. Different types of banana peel as well as pulp extracts are evaluated due to their anticancer and antiangiogenic activities reported by Dahham et al.\cite{45} The n-hexane extract of banana peel has highest anti-angiogenic activity which is more effective in preventing the growth of colon cancer cell lining. Thus, the more consumption of naturally occurring anti-angiogenic agents commonly found in fruits especially in banana shows an auspicious therapeutic approach to inhibit the tumor growth and metastasis.\cite{45} Villaverde et al.\cite{46} studies that the unripe banana contains phytosterols (2.8 to 12.4 g/kg DW). It was also noted that the ratio of phytosterols in *Musa balbisiana* cultivars was higher as compared to *M. acuminata* cultivars.

**Health benefits of banana-based food products**

Banana is one of the cost-effective fruit readily consumed by the people, impart major role to build good health because of its pharmacological as well as nutritional composition. Bioactive compounds including flavonoids and phenolic acids have high antioxidant activities as well as antitumor properties generally found in the banana pulp.\cite{37} Bioactive compounds in banana and their health benefits are discussed in Table 1.

Banana has a variety of health benefits due to its high nutritional as well as mineral profile. Banana is a rich source of potassium, which imparts a key role in the mechanism of muscle development. Mostly, banana is recommended for anemic patients due to the immense amount of iron. It is very

| Bioactive compound | Health benefits | Reference |
|-------------------|----------------|-----------|
| Biogenic amines   |                |           |
| Dopamine          | Increase the oxidative resistance of LDL | \cite{47} |
| Serotonin         | Decrease plasma oxidative stress | \cite{48} |
| Carotenoids       |                |           |
| Trans-α carotene  | Vitamin a precursor | \cite{49} |
| Trans-β carotene  | Limit the cancer and CVD risk | \cite{50} |
| Phenolic compounds|                |           |
| Gallic acid       | Antioxidant activity and hepatoprotective aspects | \cite{51} |
| Tannic acid       | Used as therapeutic agents for the treatment of burns | \cite{52} |
| Catechin          | Increase fatty acid oxidation, delay LDL to oxidation | \cite{53} |
| Quercetin         | Improve cardiovascular disease risk through proper blood flow | \cite{54} |
| Ferulic acid, Cinnamic acid, P-coumaric acid | Antioxidant, anti-carcinogenic, antiviral, antimicrobial, anti-allergic effects, precursor of aspartame, minimize the gastric cancer risk. | \cite{29,55,56} |
| Phytosterols      | B-sitosterol   | Cholesterol reduction | \cite{57} |
|                   | Campesterol and stigmasterol | Decrease risk of benign prostatic hyperplasia (BPH), decrease absorption of cholesterol in the intestine | \cite{58} |
effective in lowering blood pressure due to the high content of potassium and less amount of salt.\cite{59} Banana aids to avert depression by altering the attitude as well as relaxing the body because of high serotonin. Banana has a higher content of resistant starch that is effective in human intestine function as well as hypocholesterolemic action, mainly recommended for diabetic and heart patients.\cite{60} Plantains contain lower carbohydrate content and an immense amount of nutritional compounds, considered as a beneficial food for diabetic patients as compared to other foods like potatoes.\cite{61} Vitamin A deficiency disorders and chronic ailments are one of the most increasing issues in the world and can be minimized by the consumption of carotenoid-rich banana.\cite{62} Nowadays, people are more attracted to the choice of fresh fruits and vegetables that are rich in vitamins, minerals, dietary fibers, and antioxidants. Consumption of antioxidant-rich fruits are more beneficial for health such as minimizing the risk of neurodegenerative disorders, delaying the aging process as well as aids reducing the prevalence of degenerative ailments including inflammation, arthritis, heart disease, cancer, arteriosclerosis and brain dysfunction.\cite{5} It is evident from several studies that frequent use of bananas had health promoting benefits such as effectiveness in the treatment of gastrointestinal tract ailments. A variety of functional compounds including malic acid, 1, 2-hydroxystearic acid, ß-sitosterol, and succinic acid found in bananas show antimicrobial activities against many bacterial species like \textit{B. subtilis, E. coli, S. enteritidis and S. aureus}. The effect of palmitic acid was inconsequential against analyzed bacteria species, while the succinic acid, malic acid and ß-sitosterol showed significant effect against Gram-positive and Gram-negative bacteria. The malic acid showed high antibacterial activity than succinic acid and ß-sitosterol. The antimicrobial activity of 1,2-hydroxystearic acid was analyzed by using paper disk method instead of minimum inhibitory concentration.\cite{63} Many health care professionals recommend the use of banana for the treatment of bacterial infection due to its antimicrobial properties. Different varieties of bananas have different health-promoting benefits like banana consumed in Thailand show gastroprotective effects.\cite{64} Banana consumption decreases fasting blood glucose and the LDL/HDL cholesterol ratio. Rats fed dietary fiber from banana pulp had lower fasting blood glucose levels and liver glycogen concentrations. The dietary fructo-oligosaccharides are active ingredient of food, commonly obtain from banana that has many health benefits including aids to improve mineral absorption, reduce the serum cholesterol level and encourage the growth of intestinal microflora due to its prebiotic effects.\cite{65,66} Abdel Aziz et al.\cite{67} reported that diabetic rats who ate banana peel hydroethanolic extract every day for 4 weeks had better insulin sensitivity and lower cholesterol levels.

**Pharmacological applications**

**Antioxidant activity**

Banana contains a vast variety of bioactive compounds that are antioxidant in nature and involve to boost up the defensive system by scavenging free radicals. Bioactive compounds like carotenoids, phenols

| Banana Type | Part of banana used | Food product | Improvement | Reference |
|-------------|---------------------|--------------|-------------|-----------|
| Musa acuminata | Fresh banana peel | Extract used in tea | Antioxidants and gallicatechin content enhance | [62,63] |
| Williams Bananas | Dried pulp | Baked or fried products | Acclimatization of micropropagation | [94,95] |
| Cavendish Bananas | Banana flour | Confectionaries | Dietary fibers and gluten free food | [86] |
| Gros Michel banana | Banana piece | Banana juice | Pectinase enzyme liquefaction | [96] |
| Red banana | Banana pulp | Smoothies | High bioactive compounds content and high anthocyanin content | [97] |
and vitamin C are the most abundant antioxidants found in banana.\[^{29}\] Banana pulp is also rich in antioxidant containing ingredients like norepinephrine, dopamine, carotenones and vitamin C.\[^{29}\] A substance act as antioxidant by preventing the free radical oxidation and formation of stable radical after scavenging of it.\[^{68}\] Reactive oxygen species (ROS) produce in cells can damage proteins, lipids and nucleic acids during the oxidation process. Banana contains many compounds having antioxidant and chelating properties in it.\[^{69}\] It is also evident that banana is one of the frequently used fruits having significant antioxidant properties that are very effective to boost up immunity by retarding the free radical oxidation.\[^{70}\] These antioxidant properties of banana are very effective in the prevention of diseases that are caused by ROS like aging, CVDS, neurodegenerative diseases and cancer.\[^{71}\] Banana peel and pulp are also rich in antioxidant properties but it is observed that banana peel contains more antioxidant capacities as compared to its pulp. It is evident from previous studies that a single meal of banana is very effective to minimize the plasma oxidative stress in a heath individual due to presence of various bioactive compounds especially vitamin C and dopamine while norepinephrine and serotonin in involve in the elevation of blood pressure and inhibit gastric secretion.\[^{3}\] Different varieties of banana vary in antioxidant properties like banana peel is more liable in antioxidant activities which is 33–36% more than full green banana.\[^{72}\] The antioxidant activities of banana are evaluated by using several methods including β-carotene bleaching, ABTS radical scavenging, 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging, ferric reduction power and thiocyanate, evident from many assays. Banana is a rich source of total phenols and flavonols that are considered the best way to measure the antioxidant capacity of banana.\[^{72}\]

**Anti-inflammatory activities**

Banana shows anti-inflammatory effects due to presence of enormous amount of phytochemicals and minerals. Banana contains carbohydrate reserves that are involved to minimize the inflammatory cytokines, leukocyte counts, cytochrome P450 that produced oxylipins and plasma 9 and 13-hydroxyoctadecadienoic acid.\[^{73}\] The banana peel extract of Musa sapientum variety minimized the inflammatory response by increasing the endothelial expression in the endothelial cells of rats as well as suppressing the transcription factors such as NF-κB.\[^{8}\] The use of dried pulp of Musa balbisiana Colla shows excellent result associated with anti-inflammatory aspects like minimize the inflammatory gene expression by reducing the generation of myocardial inflammatory cytokines (IL-6 and IL-1β, TNF-α). It is also evident that oral consumption of Musa balbisiana pulp implies significant consequences such as the effect of overexpression of cardiac fibrosis markers and the infiltration of inflammatory cells into the muscle are reduced.\[^{74}\] The ethyl acetate fraction and n-butanol fraction in banana leaves shows significant anti-inflammatory activity other than the quercetin.\[^{75}\]

**Anticancer effect**

Cancer is commonly known as the abnormal cell growth and it is one of major health concerns these days. It is an excellent approach to reduce the risk of cancer by using natural products. These natural products are rich source of antioxidants and phytochemicals that are useful to combat the risk of various diseases especially cancer. Banana is widely consumed fruit having a lot of health benefits like more effective to reduce the risk of lethal diseases. It was also observed by in vitro analysis that banana flower extract has also anticancer properties.\[^{76}\] The use of fruit juice against colorectal cancer should be very effective because it prevents the human colorectal adenocarcinoma cell line known as HT-29.\[^{77}\] It was evident from studies that plantain type of banana contains high amount of tannic acid that inhibit the tumor cell activity.\[^{44}\] Saponins is an anticancer substance, mainly found in banana peel that is significantly helpful for abnormal cell death show in Figure 3. The ripeness of fruit is considered as the key factor for the antioxidant activities. A variety of fruits including banana, watermelon, grapes, pineapple and apple are employed to examine their health benefits on human health under research conducted by Tokyo University.\[^{79}\] It was concluded that
banana is more liable fruit with respect to health benefits than others according to this study due to excellent concentration of white blood cells useful to enhance immunity as well as more concentration of anticancer agents.\cite{64}

**Wound healing attribute**

Banana peel is also more liable in the wound healing process because of its effectiveness against mucosal defensive mechanism through enhancing mucosal cell proliferation and DNA synthesis. The methanol, as well as the aqueous extract of plantain peel, was analyzed in the rat study by M. sapientum var. paradisiaca.\cite{80} It was observed that a significant increase occurs in the hexuronic acid, hydroxyproline, superoxide dismutase, hexosamine level and in the wound healing process. These extracts were also useful to minimize lipid peroxidation and diminish the scars created by the wound. This property was also considered as the antioxidant activity of plantain banana peel.\cite{80}

**Food application of banana**

Banana peels, both ripe and unripe, are widely used to optimize the nutritional as well as physicochemical properties of several food products including bakery, jelly, noodles and meat products. Banana peel has a sufficient amount of fat, dietary fiber, protein, and ash as compared to a banana pulp, due to which food products enriched with banana peel showed great functionalities.\cite{81,82} The incorporation of a high amount of banana peel in foodstuff enhances the antioxidant as well as physicochemical activity. To improve the physicochemical and organoleptic qualities of food products that contain banana peel, the appropriate amount of banana peel needs to be added (Table 2).
**Cookies and biscuits**

Arun et al.\textsuperscript{[83]} reported that functional cookies were made from banana peel powder with replacing wheat flour. These functional cookies contain high amount of ash, moisture and dietary fiber content. On the other hand, other parameters like breaking intensity, spread ratio and cookies index decrease with the high concentration of banana peel powder. The concentration of phenolic compounds also increased from 4.36 mg GAE to 5.28 mg GAE with the increase of banana peel powder than wheat flour. Banana peel powder makes the cookies more variable in flavor, texture, and color than other formulations. Xylitol is a bioactive compound obtained from the banana peel and is usually employed in the preparation of rusk.\textsuperscript{[84]} Xylitol also produced from banana peel which have a lot of advantages like reducing the water activity of rusk as well as enhancing the shelf stability of the product. It was evident from studies that rusk incorporated with sucrose and xylitol in a ratio of 0:100 and 25:75 showed excellent taste score.\textsuperscript{[84]}

**Pasta**

Pasta products have a significant role in dietary attributes due to their numerous characteristics including easier to prepare, longer shelf life, and lower glycemic index as compared to white bread.\textsuperscript{[85]} Subsequently, the incorporation of various Dietary fiber (DF) enriched flours and micronutrients into pasta products has been examined in the recent decade. It is evident from the studies that the incorporation of different ratio of banana flour as well as semolina flour reduces the protein content, and crude fat in spaghetti. Though, the release of amylose from starch showed increased adhesiveness and chewiness than control. It was also observed that the incorporation of banana in pasta products increased the cooking loss. Thus, semolina, as well as banana flour-based pasta products, are acceptable with less than 8% cooking loss. Banana flour was incorporated for the preparation of pasta products with wheat flour instead of semolina flour. It was observed that there was no darker color in pasta due to banana flour and it showed a high concentration of phenols, increase total dietary fat and ash content than the control product. Similarly, that product showed excellent sensory scores by a panel of the jury. It was a little bit hard to examine the effect of banana flour on the quality of pasta products. Further studies are mandatory to evaluate the physiochemical assay of these functional products.\textsuperscript{[86]}

**Confectionaries**

The food industry has increased the use of banana flour (BF) in confectionaries, particularly cereal-based, because of its high sugar content. Premixed cakes produced with 60% banana peel flour instead of wheat flour were tested for the development of pathogens for four months. Despite the high sugar content, the pre-

**Gluten-free products**

Gluten-related ailments including celiac disease and dermatitis herpetiformis are increasingly day by day due to which it is mandatory to expand the gluten-free (GF) food products in the market. Furthermore, untreated celiac disease is associated with intestinal cancer, vitamin deficiency, and oxidative stress, it is essential to produce GF goods that contain sufficient nutritional qualities.\textsuperscript{[88]} Banana peel flour may also be used to make gluten-free bread. The incorporation of green plantain flour enhanced crumb hardness by 15%, although baking at a lower temperature for a longer period of time increased bread volume by 25%,\textsuperscript{[86]}
Higher water-binding capacity and less starch retrogradation were achieved by increasing the amount of green plantain flour in grain flour bread. Addition of only 5% of darker crumb resulted in a 2.5% rise in RS over the control sample. Green and yellow banana GF bread had smaller volume, a lower height, and darker color when baked with 20% black banana pulp flour; nevertheless, these characteristics improved significantly when 20% black banana pulp flour was included in the recipe.[89]

**Bread**

In several countries bread is widely consumed staple diet and consumers are more conscious about the quality, safety and sensory evaluation of that product. Bread is mainly prepared from refined wheat flour, which contains small amount of minerals as well as vitamins, fiber and phytochemicals that are helpful to minimize the progression of many diseases.[90] Bread is widely consumed product all over the globe, thus it is mandatory to enhance the fortification of bread with sufficient functional compounds as well as dietary fibers to achieve maximum health-promoting benefits that is a dominating trend among the researcher.[91] It was observed that different concentrations of banana peel in the replacement of wheat flour has significant effects on sensory as well as physicochemical properties of Egyptian baladi flatbread. Thus, it was concluded that ash, protein and fat content of Egyptian baladi flatbread increased as compared to wheat flour bread.[82]

**Conclusion and future perspectives**

Banana is more consumed fruit as raw food and medicinal perspective around the globe and it is a rich source of bioactive secondary metabolites. Banana gain attention due to its phytochemical as well as pharmacological properties due to the presence of amine, carotenoids, phenolics, and bioactive ingredients. Banana contains micronutrients like magnesium, potassium, and vitamin C that can be utilized as a component in therapeutic foods. The variety of phytochemicals in banana plant sections may be responsible for their health benefits and traditional therapy against different types of disorders. Flower, fruit, inner core, inner trunk, stem, pseudo-stem, leaf, and roots of banana has been used medicinally by numerous tribes and ethnic groups around the globe for centuries. *Musa acuminata* extracts have already been used to treat diabetes, hypertension, and other respiratory infections. Both biological and environmental pressures pose serious problems for the banana industry. Bananas need to improve food security by increasing yields and maximizing production efficiency, and improving genetic disease resistance is essential. Increasing exports depends critically on the quality of fruit production and postharvest management. Therefore, the rapid development of in vitro cultures and all other methods of production must be considered. Studies are needed in the future to identify the additional bioactive constituents of both banana peel and pulp, validate nutritional and pharmacological claims to investigate their potential usage in food sector as well as in pharmacological industry.

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