Antimicrobial and Bioactive Components of Banana their Health Benefits and Applications in Dairy and Food Industry

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ABSTRACT

Bananas are the eldest fruits known for its medicinal value and are highly nutritious. India is the largest producer of bananas and contributes about 20% of world’s production. Karnataka occupies in 5th position after Andhra Pradesh, Maharashtra, Gujarat and Tamil Nadu, producing 3,713.79 metric tones. The bacterial resistance to antibiotics has led to the identification of novel and effective antimicrobial compounds. The demand for effective and cost efficient antimicrobial compounds has been increasing. This led to the introduction of banana which is a source of various antimicrobial compounds that are naturally present in it such as malic acid, ferulic acid, dopamine etc. Apart from these banana also contains certain bioactive compounds such as Tannic acid, Dopamine, Ferulic acid, p-Coumaric acid, Trans-β carotene, Serotonin etc. that provide numerous health benefits. It offers a potentially simple eco-friendly alternative to antibacterial and fungicidal agents rather than chemicals.

Keywords: Antimicrobial components, Bioactive components, Dairy Industry.

1. INTRODUCTION

A global staple and most important food after rice, wheat and maize is banana. These are herbaceous plant belonging to genus Musa and family Musaceae. It has been called as a “Poor man’s food”. It is derived from the Arabic word ‘Banan’ which means ‘Finger’. The flavour of banana is due to Isoamyl acetate. The fruit and tree has many names such as, Apple of paradise, Adams fig, Antique fruit crop, Plant of virtue, Tree of paradise, Tree of wisdom. India is the largest producer of bananas producing 32,454 million tones on 880 hectare of land. It contributes to about 20% of world’s production which was 125 million tonnes in 2021 — 22 and exports about 0.3%, stands in 21st position with a value of 90 million USD. The domestic consumption of bananas are about 24,991 kilo tones and about 6.5% wasted in wholesale level (physical injury, long travel and poor packing) (APEDA, 2022). Banana has its contribution in food, medicine and textile industry. In Food industry banana slivers are used to mimic fish in meen kuzhambu a fish curry and is called as Saiva meen kuzhambu or a vegetarian fish curry. In medicine, banana pulp and peel are used for the development of drugs (Mathew et al., 2017), in ayurveda banana flower and stem are used to treat diabetes, tree’s sap is used to cure leprosy, epilepsy and insect bites. In textile industry, banana waste and natural banana fibers are used to make eco friendly sarees. These are also used for ornamental purposes (Jiw et al., 2018). There are different varieties of banana which are commercially grown in India s i crop. Plant of virtue, Tree of paradise, Tree of wisdom (Heba, 2021). India is the largest producer of bananas, producing 32,454 metric tones on uch as Grand Nain (G9), Robusta, Dwarf Cavendish, Red Banana, Nendran and Yelakki.

1.1 Plant description

The banana plant has plants, flowers, and leaves that are 2.7 × 0.6 metres, flexible, and waterproof, with a height of up to 6-7.6 metres tall. Because of their wide waxy surface, the leaves are ideal for food packaging and serving, and they are also rich in fibre, flavonoids, polyphenols, and tannins. These have historically been used to treat a variety of skin conditions including eczema, cuts, irritation, rashes, dandruff, and sunburns because of their cooling properties. Fruits have an elliptical form by nature and come “prepacked,” with solid, creamy flesh encased in a thick peel. Because banana fruit is nutritious, containing significant amounts of pro vitamins A, B, C, sterols, minerals (including potassium), sugar derivatives, polyunsaturated fatty acids, and high quantities of bioactive substances (such glycosecs and acids like malic and oxalic acid). The pulp may be affected by thermal treatment (at 65°C for 30 min), as shown by a decrease in polyphenol oxidase activity, protecting total phenolic components from breaking down. The enormous, dark purple blooms, often referred to as the blossom or heart that emerges from each banana bunch, with a flavour that is slightly starchy and bitter. Rich in flavonoids (particularly quercetin), proteins, dietary fibre, vitamins (like C), and some biologically active substances (including tannin and α-tocopherol). Much of the plant biomass, which is typically burned and wasted or left on the plantation land, is made up of the pseudo-stem. Consuming
Fresh stem juice has been used to cure diarrhea, dysentery, and epilepsy as well as to cleanse the body and stop the formation of kidney stones. The GI tag is attached to the Nanjanagud rasbale and Kamalapur red banana cultivars among those cultivated in India. (Heba, 2021)

**Table 1 - State-wise production data of bananas (2021-22)**

<table>
<thead>
<tr>
<th>State</th>
<th>Production (metric tonnes)</th>
<th>% Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>5,838.88</td>
<td>17.99</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>4,628.04</td>
<td>14.26</td>
</tr>
<tr>
<td>Gujarat</td>
<td>3,907.21</td>
<td>12.04</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>3,895.64</td>
<td>12.00</td>
</tr>
<tr>
<td><strong>Karnataka</strong></td>
<td><strong>3,713.79</strong></td>
<td><strong>11.44</strong></td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>3,391.01</td>
<td>10.45</td>
</tr>
<tr>
<td>Bihar</td>
<td>1,968.21</td>
<td>6.06</td>
</tr>
<tr>
<td>West Bengal</td>
<td>1,147.79</td>
<td>3.54</td>
</tr>
<tr>
<td>Assam</td>
<td>1,108.00</td>
<td>3.41</td>
</tr>
<tr>
<td>Chhattisgarh</td>
<td>585.52</td>
<td>1.80</td>
</tr>
</tbody>
</table>

(APEDA, 2022)

**Table 2 - Export performance of All India (A I) and Karnataka (KTK)**

<table>
<thead>
<tr>
<th></th>
<th>2020-21 Value in Mn USD</th>
<th>2021-22 Value in Mn USD</th>
<th>Major Importing Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A I</td>
<td>KTK</td>
<td>A I</td>
</tr>
<tr>
<td>Bananas, Fresh</td>
<td>99.86</td>
<td>1.40</td>
<td>157.90</td>
</tr>
<tr>
<td>Curry Plantain</td>
<td>0.15</td>
<td>0.01</td>
<td>0.24</td>
</tr>
</tbody>
</table>

(APEDA, 2022)

**Fig 1 - Banana Exporting states of India (2021 – 22)**

![Value USD Mn](image)

(APEDA, 2022)

**Table 3 - Composition of Banana**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Content (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>371kJ (89 kcal)</td>
</tr>
<tr>
<td>Water</td>
<td>74.91</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>22.84</td>
</tr>
<tr>
<td>Sugars</td>
<td>12.23</td>
</tr>
<tr>
<td>Sucrose</td>
<td>66%</td>
</tr>
<tr>
<td>Glucose</td>
<td>20%</td>
</tr>
<tr>
<td>Fructose</td>
<td>14%</td>
</tr>
<tr>
<td>Dietary fibre</td>
<td>2.6g</td>
</tr>
<tr>
<td><strong>Vitamins</strong></td>
<td><strong>mg (daily value)</strong></td>
</tr>
<tr>
<td>Pantothenic acid (B₃)</td>
<td>0.334 (7%)</td>
</tr>
<tr>
<td>Pyridoxine (B₆)</td>
<td>0.4 (31%)</td>
</tr>
<tr>
<td>Choline</td>
<td>9.8 (2%)</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>8.7 (10%)</td>
</tr>
<tr>
<td><strong>Minerals</strong></td>
<td><strong>mg (daily value)</strong></td>
</tr>
</tbody>
</table>

(APEDA, 2022)
Table 4 - Bioactive components in banana (mg/100g)

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tannic acid (122.6-241.4)</td>
<td>Trans-α carotene</td>
</tr>
<tr>
<td>Gallic acid (56.1)</td>
<td>Violaxanthin</td>
</tr>
<tr>
<td>Cinnamic acid (1.93)</td>
<td>Cryptoxanthin (&lt; 10 to 30 µg)</td>
</tr>
<tr>
<td>p-Coumaric acid (2.09)</td>
<td>Dopamine (2.5-10)</td>
</tr>
<tr>
<td>Gallolechin gallate (29.6)</td>
<td>Campesterol and stigmasterol</td>
</tr>
<tr>
<td>Quercetin (1.51)</td>
<td>Serotonin (8.5-50µg)</td>
</tr>
</tbody>
</table>

Table 5 - Antimicrobial compounds in Banana

<table>
<thead>
<tr>
<th>Antimicrobial compounds</th>
<th>mg/100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malic acid</td>
<td>200.83</td>
</tr>
<tr>
<td>Dopamine</td>
<td>2.5-10</td>
</tr>
<tr>
<td>Feralic acid</td>
<td>16.6</td>
</tr>
<tr>
<td>Gallic acid</td>
<td>56.1</td>
</tr>
<tr>
<td>Chlorogenic acid</td>
<td>trace</td>
</tr>
<tr>
<td>Caffeic acid</td>
<td></td>
</tr>
<tr>
<td>3-carene</td>
<td></td>
</tr>
<tr>
<td>Limonene</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>27 (8%)</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>22 (3%)</td>
</tr>
<tr>
<td>Potassium</td>
<td>358 (8%)</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.15 (2%)</td>
</tr>
</tbody>
</table>

2. Antimicrobial activity of banana

Bananas are among the oldest therapeutic plants. The effectiveness of the naturally occurring active components in bananas, such as antimicrobial agents, has been the subject of numerous studies. It contains a variety of antimicrobial substances, including gallic acid, feluric acid, dopamine, and mallic acid. The discovery of new and potent antimicrobial compounds has become necessary due to the emergence of bacterial resistance to the antibiotics that are already in use. There is a need for antimicrobial substances that are both effective and affordable. Bananas possess antimicrobial, antioxidant, and anticholesterol properties.

2.1 Antibacterial activity

*Bacillus subtilis*, *Bacillus cereus*, *Streptococcus mutans*, *Streptococcus faecalis*, and *Staphylococcus aureus* are among the gram positive bacteria that bananas are effective against. Gram negative bacteria include *Pseudomonas aeruginosa*, *Escherichia coli*, *Salmonella enteritidis*, *Shigella dysenteriae*, and *Vibrio cholera*. The G-positive bacteria (*Bacillus subtilis* and *Staphylococcus aureus*) exhibited maximum inhibitory zones.

2.1.1 Mallic acid

The pathogens *Listeria monocytogenes*, *Escherichia coli*, and *Salmonella enteritidis* are disrupted cytoplasmically by mallic acid, leading to an increase in permeability and cytoplasmic leakage. (Raybaudi *et al.*, 2009)
Dopamine can induce drastic changes to the cell structure i.e. changes in fluidity of *E. coli* by formation of kinks in the cell membrane.

**2.1.3. Ferulic acid**

Ferulic acid treatment alters the hydrophobicity, reduces the negative surface charges and causes pore formation that enables essential cellular components to leak out, the properties of the cell membrane (intra and extracellular permeability, charge, and physicochemical attributes) were permanently altered. It works well against *S. aureus, E. coli* and *P. aeruginosa*. (Borges *et al.*, 2013)

**2.1.4. Gallic acid**

Gallic acid caused the bacterial intima to significantly shrink and changes in shape in a dose-dependent manner (Lu *et al.*, 2016). By interacting with the lipid bilayers of G-positive and G-negative bacteria, it increases permeability within the cell and disrupts adhesion, motility, spreading, and sporulation. (Rasooly *et al.*, 2019)

**2.2. Antifungal activity**

When ferulic acid and gallic acid were tested against the pathogenic bacteria, it was discovered that there were irreversible changes in the membrane's physicochemical properties, extra/intracellular permeability, decrease in negative surface charge, and localised occurrences of rupture or pore formation. Potential antifungal action against four investigated yeasts of *Candida spp.* was identified for gallic acid. It has been discovered that bananas work well against *Penicillium, Candida*, and *Alternaria spp.* (Heba, 2021)

**3. Antioxidant Property of Banana**

Oxidation is the process of loss of electrons i.e., during oxidation an electron can be knocked out of the chemical bond resulting in a highly reactive free radical where an unshared electron occurs. This free radical can capture electrons from normal healthy molecules and create free radicals that damage the healthy molecules. The damaged cell can release free radicals and continue the effects of oxidative stress to surrounding cells. To prevent these destructive processes, the body constantly needs a reservoir of antioxidant molecules. Antioxidant is essentially the exact opposite of oxidation, in that antioxidant molecules have electrons to spare. Once an antioxidant and a free radical come in to contact, the antioxidant will supply the free radical with an electron. These antioxidants travel through the blood vessels to reach the damaged cells, repairs and stabilizes the chemical bond. In supplying electrons the antioxidant molecules do not themselves become free radicals. The frequent intake of these antioxidants will minimize the oxidative stress and repairs damaged cells. (Kyle, 2012)

**4. Anti – cholesterol Property**

Cholesterol, a waxy fat like substance. These are of two kinds HDL (High density lipoprotein) and LDL (Low density lipoprotein). HDL is regarded as the good cholesterol whereas LDL as a bad one. Many cardiovascular diseases are caused due to higher LDL levels. The deposition of LDL on the walls of blood vessels causes shrinkage of veins and blocks the flow of blood to other parts of the body leading to death. As banana contains soluble fibers (0.7g/100g), these mixes with the water and forms a gel like structure. This gel binds to the cholesterol and helps in removing it from the body through stools. Thereby reducing the bad cholesterol and preventing cardiovascular diseases.
5. Health benefits of Bioactive compounds in Banana

<table>
<thead>
<tr>
<th>Bioactive compounds</th>
<th>Health benefits</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catechin</td>
<td>Resistance to oxidation, brachial artery dilation increased plasma antioxidant activity, and fat oxidation</td>
<td>Williamson and Manach, 2005</td>
</tr>
<tr>
<td>Gallic acid</td>
<td>Antioxidant and potential hepatoprotective effects</td>
<td>Rasool et al., 2010</td>
</tr>
<tr>
<td>Cinnamic acid</td>
<td>Is a precursor to the sweetener aspartame by the means of enzyme catalysed amination to phenylalanine</td>
<td>Garbe, 2000</td>
</tr>
<tr>
<td>p-Coumaric acid</td>
<td>Antioxidant properties and potentially reduce the risk of stomach cancer</td>
<td>Ferguson et al., 2005</td>
</tr>
<tr>
<td>Galloocatechin gallate</td>
<td>Cholesterol reduction</td>
<td>Ikeda et al., 2003</td>
</tr>
<tr>
<td>Quercetin</td>
<td>Promotes overall cardiovascular health by encouraging blood flow</td>
<td>Perez-Vizcaino et al., 2010</td>
</tr>
<tr>
<td>Ferulic acid</td>
<td>Antioxidant, antimicrobial, anti-inflammatory, antiallergic, anticarcinogenic, modulation of enzyme activity, antiviral and vasodilatory action</td>
<td>Kumar et al., 2014</td>
</tr>
<tr>
<td>Serotonin</td>
<td>Might contribute to feelings of well-being and happiness</td>
<td>Young, 2007</td>
</tr>
<tr>
<td>Trans-α carotene</td>
<td>Precursor to vitamin A</td>
<td>Li et al., 2011</td>
</tr>
<tr>
<td>Trans-β carotene</td>
<td>Reduce the risk of CVD and cancer</td>
<td></td>
</tr>
<tr>
<td>Violaxanthin</td>
<td>Used as a food colourant</td>
<td>DeLorenze et al., 2010</td>
</tr>
<tr>
<td>Cryptoxanthin</td>
<td>Food colourant might reduce the risk of lung cancer</td>
<td></td>
</tr>
<tr>
<td>Dopamine</td>
<td>Reduce the plasma oxidative stress and enhance the resistance to oxidative modification of LDL</td>
<td>Yin et al., 2008</td>
</tr>
<tr>
<td>Campesterol and stigmasterol</td>
<td>Reduces the absorption of cholesterol in the human intestines</td>
<td>Choudhary et al., 2011</td>
</tr>
</tbody>
</table>

6. Applications of banana in the Dairy Industry

6.1. Fermented probiotic yoghurt

Cultures of *Lactobacillus acidophilus*, *Bifidobacterium bifidum*, *Streptococcus thermophilus*, and *Lactobacillus delbrueckii* were utilised to produce fermented yoghurt using green banana pulp (GBP) as a prebiotic. The concentrations of GBP used were 3, 5, and 10%. A maximum probiotic count of 21 × 10^8 CFU/ml was maintained, and a 3% level of GBP with an acidity of 0.93% was accepted. (Costa et al., 2017)

6.2. Probiotic blend

Apple juice and banana pulp puree (7 and 15%) were combined with *L. casei* to create a probiotic blend, and the blend’s viability was examined. For a 20-day storage period, a banana puree content of 7% worked well. (Mahdavi et al., 2018)

6.3. Coconut curd

A product containing probiotic bananas, which was created by blending coconut milk, banana fruit pulp (6%–9%), and skim milk powder (9%–12%), demonstrated acceptable firmness, appearance, texture, flavour, and colour. For every 100 g of coconut milk, the ideal formula (90 percent desirability) contained 6.98 g of pulp and 12 g of skim milk powder. The formula showed suitability as a vehicle for *L. acidophilus* and *L. fermentum* (10^7 Colony forming unit/g) probiotics after 20 days. (Kumar et al., 2018)

7. Applications of banana in the Food Industry

<table>
<thead>
<tr>
<th>Application</th>
<th>Banana</th>
<th>Food</th>
<th>Maximum accepted %</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat substitute</td>
<td>Whole green banana flour</td>
<td>Bread</td>
<td>20</td>
<td>Rajeswari et al., 2018</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural antioxidant</td>
<td>Banana flour</td>
<td>Indonesian meat ball</td>
<td>5</td>
<td>Suniati et al., 2019</td>
</tr>
<tr>
<td>Fat substitute</td>
<td>Green banana pulp</td>
<td>Pound cake</td>
<td>25</td>
<td>Desouza et al., 2018</td>
</tr>
<tr>
<td>Sucrose substitute</td>
<td>Banana flour</td>
<td>Sponge and layer cake</td>
<td>20</td>
<td>Segundo et al., 2017</td>
</tr>
</tbody>
</table>
8. References


Ikeda, I. et al. (2003). Heat-epimerized tea catechins rich in gallicatechin gallate and catechin gallate are more effective to inhibit cholesterol absorption than tea catechins rich in epigallocatechin gallate and epicatechin gallate. Journal of Agricultural and Food Chemistry, 51, 7303–7307


Kumar, N., Pruthi, V. (2014). Potential applications of ferulic acid from natural sources. Biotechnology Reports (Amsterdam, Netherlands), 4, 86–93


