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Review Article

Enhancing nutrition and value: Innovative uses of banana blossom in functional food products

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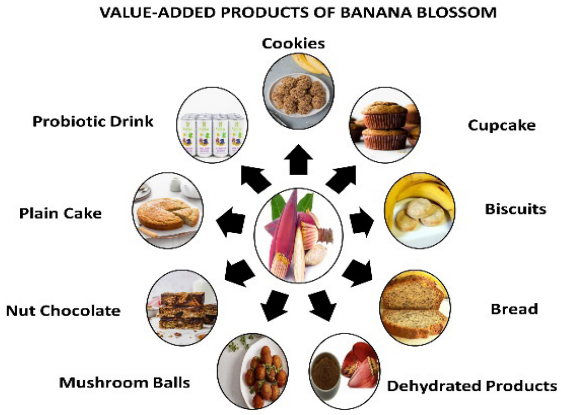
Abstract

The issue of food security has emerged as a significant concern, attributed to diminishing resources and extensive waste generation within the agricultural sector. An illustration of this is the fact that not all components of fruits and vegetables are utilized by consumers, resulting in substantial quantities of food wastage globally. Despite progress, a considerable quantity of agricultural remains of banana plant such as banana blossoms and leaves, are currently not fully utilized, presenting possibilities for the creation of effective goods. The health benefits of banana blossom make it often useful as a food additive. A noteworthy nutritional profile of banana blossoms is distinguished by elevated levels of fiber, starch, and bioactive substances, and thus highlighting their potential in promoting health-oriented product development. This scholarly review discussed various value-added products of banana blossoms and innovation of new functional foods through the incorporation of banana blossom as key constituents. Furthermore, the discussion comprises the nutritional profiles, advantages of value-added products, their acceptance by consumers.

Keywords: Antibacterial, Antioxidants, Banana blossom, Banana, Value-added products.



***G*raphical Abstract**

Introduction

The perpetual increase in the global population has led to a continuous rise in the demand for food on a yearly basis. The issue of food security has emerged as a significant concern, attributed to diminishing resources and extensive waste generation within the agricultural sector. An illustration of this is the fact that not all components of fruits and vegetables are utilized by consumers, resulting in substantial quantities of food wastage globally. Furthermore, unused agricultural by-products, such as seed coat, hull, husk, peels, seeds, and pomace, produce environmental challenges. Therefore, the effective utilization of food by products, particularly vegetables and fruits present itself as a potential possibility to enhance food sustainability, to achieve sustainable development goal (SDG) of the United Nations that aims to promote patterns of sustainable consumption and production. Additionally, some fruit by-products

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have been identified to possess nutritional value too, suggesting their potential utilization as functional ingredients in the food industry. Banana is the most common fruit and harvested on a large scale worldwide. Various parts of banana fruit are discarded as waste during postharvest processing. Banana blossom has been identified as a nutritious by-product and their utilization has been approved as an ingredient of functional food or value-added products. This scholarly review discussed various value-added products of banana blossoms and innovation of new functional foods through the incorporation of banana blossom as key constituents. Furthermore, the discussion comprises the nutritional profiles, advantages of value-added products, their acceptance by consumers. One effective way to tackle the issue of global food waste is by using agricultural by-products, such as banana blossoms. This approach not only promotes agricultural sustainability but also helps lessen the negative effects on the environment.

Agricultural sustainability and banana by-products

In recent years, there has been an increasing emphasis on the application of agricultural by-products owing to their potential benefits to human health post appropriate processing. Bananas belong to the group of climacteric fruits and encompass a variety of species within the *Musa* genus of the Musaceae family. Typically, they are categorized into two main groups, namely dessert bananas and cooking bananas or plantains. The edible varieties are the result of a cross between two species, specifically *Musa acuminata* Colla (AA) and *M. balbisiana* Colla (BB) (Figure 1). The banana plant is widely cultivated and consumed across the globe, ranking as the second most produced fruit worldwide, with India being a prominent producer.

Noteworthy for its abundant nutrients, banana serves as a valuable energy source and is highly palatable, contributing to its significant consumption, whether in its ripe form or as a culinary ingredient. Each part of the banana plant holds nutritional and therapeutic significance.

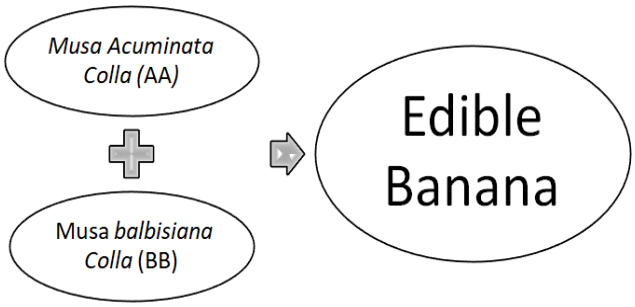

Figure 1: Edible banana: A cross between two varieties (Yadav, 2021)

The banana peel, constituting approximately 40% of the banana's weight, emerges as a significant by-product necessitating proper management. Various studies have featured banana's role as a source of phenolics, volatile compounds, phytosterols, carotenoids, flavonoids, biogenic amines, and dietary fiber, all crucial for promoting overall well-being (Mengstu *et al*., 2021). According to Garcia-Amezquita, L. E *et al*., banana peel contains a higher amount of dietary fiber compared to banana pulp (Garcia *et al*., 2018). Various components such as bracts, stems, and pseudo stems offer potential avenues for extracting valuable compounds. Begum, Y. A., & Deka demonstrated the encapsulation of anthocyanins extracted from culinary banana bracts through spray drying, showcasing diverse food applications (Begum *et al*., 2019). Khawas and Deka *et al.* conducted a similar investigation by encapsulating natural antioxidants derived from culinary bananas (P. Khawas *et al*., 2017). Furthermore, valuable phytochemicals evolve during the fruit's maturation process such as phenolic acids including gallic acid protocatechuic acid, caffeic acid, syringic acid, gentisic acid, vanillic acid, p-hydroxybenzoic acid, ferulic acid and vanillin, are found in banana inflorescence. Additionally, flavonoids such as quercetin, catechin, epicatechin, and rutin are present in the banana fruit. Phenolic compounds like epicatechin, catechin, gallocatechin, and anthocyanins are also present (Jiwan *et al*., 2018). Thus, banana and its parts are highly beneficial and sustainable but less utilized (Singh *et al*., 2017, Debabandya *et al*., 2010). Banana blossoms are unique among agricultural by-products because they are rich in dietary fiber and bioactive compounds. This makes them worth comparing to other options like jackfruit seeds and orange peels.

Banana blossoms or inflorescence

The major by-product of banana is the blossom of banana also known as the "Banana Heart" and "Banana flower", can be eaten raw or cooked. Despite progress, a considerable quantity of agricultural remains of banana plant, such as banana blossoms and leaves, are currently not fully utilized, presenting possibilities for the creation of effective goods. The tremendous health benefits of banana blossom make it often useful as a food additive in several Asian nations, including, Indonesia, Thailand, and Sri Lanka. It is consumed either raw and fresh, or used as pickles, dehydrated vegetables, as well as canned foods. In Sri Lanka, it is served as curry or as a boiled or fried salad (Salvador *et al*., 2018). The blossoms resulting from postharvest cultivation are a significant by-product abundant in dietary fiber, providing a valuable supplement to a variety of food and drink compositions. Through the incorporation of fiber-rich floral elements into a range of edibles, the generation of improved and practical food products is encouraged, aligning with the growing necessity for dietary fiber enhancement

(Begum *et al*., 2019). According to both the inner and outer bracts of culinary banana flowers include dietary fiber with functional features such as decreased bulk density, increased oil-holding capacity, water-holding capacity, and water swelling capacity, making it one of the greatest high-fiber components (Wickramarachchi *et al*.., 2005, B Burton *et al*., 2000). Banana blossoms are not only delicious, but they also offer significant health benefits that contribute greatly to overall wellness.

Nutraceutical potential of banana blossoms

Banana blossoms, a nutritional food source present in the banana plant's tip, are also recognized for their medicinal properties (Salvador *et al*., 2018). Many Asian countries, including Malaysia Sri Lanka, the Philippines, and Indonesia consume the nutritious blossom as a vegetable. It is also eaten in curry and as a salad with rice and wheat bread (Sheng *et al*., 2010). Dietary fiber facilitates numerous health benefits, such as improved bowel function to slowed digestion and absorption of carbohydrates and fats and subsequent lower risk for certain diseases (Begum *et al*., 2019). Banana blossoms are high in antioxidant properties, making them a potential functional food with a wide range of nutraceutical values that are important in maintaining good health (Yadav *et al*., 2021, Thagunna *et al*., 2023, Sidhu & Zafar, 2018). The unique bioactive properties of banana blossoms have led to the development of various value-added products designed for health and therapeutic uses (Figure 2).

Value added products using banana blossom as an ingredient

Banana has been identified as raw material for use as an ingredient in processed products (Aurore *et al*., 2009). The most common product of banana is baked and fried banana (Abd Elmoneim *et al*., 2014) and the use of green banana (*M. balbisiana*) pulp and peel flour as an ingredient for tagliatelle pasta (Castelo-Branco 2017)

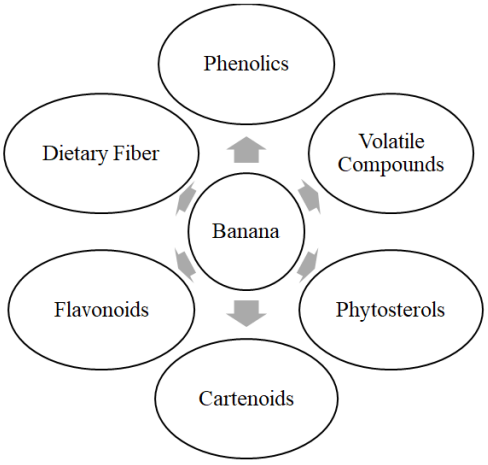

Figure 2: Nutritional significance of banana (Sidhu & Zafar, 2018)

has also been studied. Further, functional candy with banana, ginger and skim milk powder as a source of phenolics and antioxidants were also developed (Yadav *et al*., 2021). Studies have also been done on the chemical compositions, sensory properties and volatile compounds of banana wine (Chen Lihua *et al*., 2020). Now, some of the value-added products from banana blossom are discussed as shown in Table 1.

Ready to cook dehydrated product

A ready to cook product of dried banana blossom has been developed while retaining the quality and reducing the browning of enzymes. Briefly, banana flowers were cut into slices followed by immersing them in a 0.2% citric acid solution for 30 minutes and dried them drying them at 50°C for 6 hours. Results demonstrated that the banana flower could be treated to inhibit browning and provide a satisfactory product in terms of appearance, flavor, and overall quality (Wickramarachchi *et al*., 2005).

Biscuits

A pre-treated banana blossom powder with a citric acid solution and rice rinsed water to inhibit any browning enzymatic reactions before dehydration to make nutritionally dense and high fiber cookies. The stability, foaming capacity, bulk density, swell ability and solubility, least gelation concentration, water and oil holding capacity, pH and color analysis (radical scavenging assay and total phenol content) were tested for dried flour of banana flower. About 20 to 30% of the cases exhibited the best results in terms of mineral analysis, antioxidant properties and phenol content. It has also been discovered that more fiber to fortified banana blossom biscuits items increases dietary fiber consumption and lowers baked goods' caloric density (Elancheran *et al*., 2014).

Enriched plain cake

Pancakes were prepared using fortified banana blossom flour, treated with a composition of honey (15%), 2% of citric acid solution. Similarly with rice rinsed water to control the enzymatic browning. There is an improved color of flour and mineral retention has been observed on pretreatment of banana flower with (honey citric acid, citric acid solution, and rice rinsed water). Banana blossom flour supplementation with rice rinsed water significantly increased protein, moisture, fat, and ash content in the produced cakes (Tasnim *et al*., 2020).

Probiotic drink

Three variations of probiotic fermented drinks using banana flower or Ontong, banana leaf, and CO_2- free water were prepared. Product resulted in higher level of vitamin C and antioxidants which can be developed in healthy functional food options due to ability to increase immunity and anti-inflammatory properties.

Table 1: List of value-added products using banana blossoms as ingredients

S. No.	*Name of product*	*Composition*	*References*
1.	Biscuits	Banana blossom powder	(Elancheran *et al.*, 2014)
2.	Ready to cook dehydrated product	Banana blossom powder	(Wickramarachchi *et al.*, 2005)
3.	Probiotic drink	Fermented drinks using banana flower or Ontong, banana leaf, and CO_2-free water	(Rompies *et al.*, 2021)
4.	Nut chocolate	Incorporation of banana blossom powder in nut chocolate	(Komal *et al.*, 2019)
5.	Enriched plain cake	Banana blossom powder with honey	(Tasnim *et al.*, 2020)
6	Mushroom balls	Fresh banana blossoms	(Chaiwongsa *et al.*, 2021)
7	Tuna shredded	Fortified with banana blossoms	(Hardoko *et al.*, 2022) (Djamaludin *et al.*, 2022)
8	Cupcake	Banana blossoms fortified with honey	(Tariga *et al.*, 2022)
9	Lacto cookies	With fish flour	(Nopriantini *et al.*, 2023)

Furthermore, the presence of prebiotics and probiotics make it beneficial to the immune system, as they improve the microbiome in the gut (Rompies *et al.*, 2021).

Mushroom balls

A plant-based shiitake mushroom balls were prepared using chopped fresh banana blossom chopped pieces were soaked in a 0.5% citric acid solution for about 30 minutes to eliminate discoloration followed by blanching method in boiling water for 3, 5, and 10 minutes and then immediately immersed in cold water. Finally, plant-based mushroom balls were made at the ratio of 100:0, 75:25, 50:50, and 25:75. The composition of mushroom and banana flowers with a ratio of 50:50 achieved the overall score in appearance as revealed by sensory analysis (Chaiwongsa *et al.*, 2021).

Nut chocolate

Nut chocolates were prepared using incorporation of banana blossom to develop a sound nutritional nut chocolate snack. Small pieces of banana blossom were added into nut chocolate at levels of 10, 20, and 30% variations. The incorporation of 20% level was greater than the control as revealed by sensory analysis using a 9- point hedonic scale (Komal *et al.* 2019)

Banana blossom cupcake

As a bread innovation, honey fortified banana blossom cupcake is highly acceptable among the taster respondents, particularly on its appearance, color, texture, and aroma where it was rated as moderately high while its flavor was rated as highly acceptable (Tariga *et al.*, 2022).

Tuna (Thunnus sp.*) floss product*

A functional food for degenerative disease patients has been prepared to increase the food fiber in tuna *(Thunnus* sp.*)* floss product using banana blossom (Hardoko *et al.*, 2022). In another study the peroxide, organoleptic, and proximate content of *Thunnus* sp. shredded fortified with banana blossoms were also studied (Djamaludin *et al.*, 2022).

Lacto cookies

The acceptability of lacto cookies fortified with banana blossom (*M. paradisiaca* Linn.) and fish flour were studied, and it was found that regarding color, taste, and aroma, formula with 40% banana heart +10% seluang fish was significantly more acceptable with a mean $p < 0.001$ (3.06 ± 0.97). While other formula having 40% banana heart +10% seluang fish in 100 g contains 110.03/100 g alkaloids, 25.79% protein, and 21.06% crude fiber (Nopriantini *et al.*, 2023).

Impact on human health profile

A strong correlation between banana inflorescence bioactive compounds and their associated biological activities has been shown by (Lau *et al.*, 2019). Banana flower powder (BFPs) with different physicochemical properties were obtained by different extraction methods. Bioactivities of BFPs were correlated to molecular weight, monosaccharide composition and chemical composition and are helpful for choosing appropriate extraction methods to obtain selected bioactive banana blossom powder (Chen *et al.*, 2019). Several studies reported the excellent antioxidant potential of banana blossom (Kumar *et al.*, 2019; China *et al.*, 2011; Muhammad Suffi *et al.*, 2021) In another study, a protein was extracted using ultrasonic assisted alkaline extraction from banana flower and optimized using response surface methodology. The extracted proteins were also characterized, and it showed antibacterial effects against both gram-positive and gram-negative bacteria (Kewalee *et al.*, 2018). Hot

Table 2: Comparative analysis of banana blossom with other by-products

S. No.	*By-product*	*Nutritional potential*	*Economic viability*	*Applications*
1.	Banana blossom	High in dietary fiber, antioxidants, and bioactive compounds	Limited collection networks; moderate costs	Functional foods, dietary supplements (Yadav *et al*., 2021)
2.	Jackfruit seeds	Rich in protein, starch, and antioxidants	Low cost; readily available	Flours, snacks (Garcia-Amezquita *et al*., 2018) fermented products
3.	Orange peels	High in vitamin C, flavonoids, and pectin	Affordable due to abundant availability	Marmalades, beverages, and dietary fibers (Garcia-Amezquita *et al*., 2018)

water extraction and hot water-alkaline extraction are good potential methods for preparation of banana blossom powder (Wang *et al*., 2023). The presence of phenolic acids and flavonoids in the inflorescence are responsible for antioxidant and antidiabetic activity of inflorescence extracts. The inflorescence exhibited antidiabetic and anti-inflammatory activities due to the presence of phytosterols such as campesterol, β-sitosterol, and triterpenoids such as cycloartenol and lupeol. Whereas cardioprotective activities due to presence of fatty acids such as linoleic and linolenic acid extracts have been reported (Lau *et al*., 2019). Several studies have reported that banana is traditionally used in the treatment of diseases such as diabetes, hypertension, nephritis, dysentery, diarrhea, gout, inflammation and pain and thus it acts as antidiarrheal antihypertensive, anti-ulcerative, antimicrobial, hypoglycemic, antihypertensive, hypocholesterolaemic, role in atherosclerosis and antioxidant (Mohammad *et al*., 2011). Ash derived from banana leaves is used for treating eczema and as a dressing in case of burns and blisters. The flower of the plant is used for treating diabetes, dysentery and menorrhagia. Many recent studies on the pharmacological effects from different parts of banana have also been reported (Soni *et al*., 2020). Simultaneously, the banana blossom being as a rich source of minerals and antioxidants, it has been used in traditional medicine to treat constipation, bronchitis, and ulcer disorders (Soni *et al*., 2020). The antiviral activity of different parts of banana, i.e., leaf, pseudo stem and corm were tested against Chikungunya virus, enterovirus and yellow fever virus by (Panda *et al*., 2020). The antidiabetic effects of pseudo stem and flower extracts are established by studying their α-glucosidase inhibitory effects by (Patil *et al*., 2022). Nendran banana peels are reported to have bioactive compounds responsible for antitumor activity in breast cancer line (Muhammad Suffi *et al*., 2021).

Macrobrachium rosenbergii were shown a heightened percentage weight gain and percentage length gain when administered diets comprising banana blossom powder at levels of 10 and 20 g kg^{-1}, hot-banana blossom extract at concentrations of 10 and 20 g kg^{-1}, in addition to the basal diet over a period of 56 days. They also showed a marked elevation in total hemocyte count and different hemocyte count while phenol oxidase activity, respiratory and enhanced phagocytic activity and clearance efficiency. Concluding that a higher survival rate has been observed against *Lactococcus garvieae*, when compared to those fed with the basal diet (Mapanao *et al*., 2022). A modulated non-specific immune response and antioxidant enzyme activities of Nile tilapia (*Oreochromis niloticus*) has been observed using dietary banana blossom powder which has been perceived by receiving a high expression on immune-related genes (Phinyo *et al*., 2024). Banana flower is a popular galactagogue used for insufficient breast milk in Thailand. A study conducted among lactating mothers showed that mothers showed a higher milk production than those in control group on day 2 (48 ± 2 hours) and day 3 (72 ± 2 hours) of postpartum. Banana flower is a promising galactagogue in augmenting breast milk in mothers with preterm neonates with no adverse effects (Susanha *et al*., 2023). Similarly, for anemic adolescent girls a product has been developed from banana blossom powder and Indian gooseberry powder to supplement iron as well as fibers (Anand *et al*., 2019). The health benefits of banana blossoms are well-documented; however, to fully realize their potential, we must address the challenges associated with scaling and commercialization.

Comparative analysis of banana blossom with other by-products

To evaluate the potential of banana blossoms, it is beneficial to compare them with other agricultural by-products, including jackfruit seeds and orange peels. These by-products exhibit comparable nutritional and economic potential as shown in Table 2.

Banana blossoms are notable for their significant fiber content and distinctive bioactive compounds that contribute to cardiovascular health and the management of diabetes (Yadav *et al*., 2021). In contrast, jackfruit seeds and orange peels are more widely recognized by consumers and require less complex processing, thereby improving their economic feasibility (Garcia-Amezquita *et al*., 2018). Now that we have acknowledged the nutritional benefits of banana blossoms, it is essential to delve into their unique characteristics, culinary uses, and cultural significance.

Challenges and opportunities in commercialization

Turning banana blossoms into functional foods comes with its own set of challenges and exciting possibilities. One of the biggest hurdles is the cost involved. Processing banana blossoms into these products often requires special equipment, skilled workers, and advanced methods for extracting and preserving the nutrients. This can drive up production costs and make it hard to scale up operations. Another issue is the supply chain. Banana blossoms are frequently seen as waste and thrown away at farms. To create a dependable supply chain for collecting, transporting, and storing these blossoms, a lot of coordination and investment is needed. Plus, since banana blossoms spoil quickly, there are additional logistical challenges that require fast processing or effective storage methods to keep their nutritional benefits intact.

One major challenge is getting consumers to accept banana blossoms. Even though they are packed with nutrients, their unique taste and fibrous texture might not appeal to everyone. To attract more consumers, product developers should work on making these blossoms more appealing and come up with creative recipes (Salvador, 2018).

On the bright side, there are plenty of opportunities. With the growing interest in sustainable, plant-based foods, there's a great market for products made from banana blossoms. These items fit well with the global shift towards eco-friendly choices and reducing waste. Plus, new food technologies like freeze-drying and enzymatic treatments can help improve how long banana blossom products last and how easily they can be produced (Ranjha *et al*., 2020).

Working together, food producers, farmers, and researchers can explore new ways to bring these products to market. Raising public awareness about the health and environmental advantages of banana blossoms can also help them gain traction. Additionally, targeting specific markets, like vegan and health-conscious consumers, could be a smart way to start successfully selling these products. To address these challenges, effective teamwork and strategic planning are essential to encourage the use of products made from banana blossoms.

Recommendations

- Create affordable processing techniques to ensure that production is financially feasible.
- Form collaborations with banana farmers to build a smooth supply chain for blossoms.
- Emphasize the importance of informing consumers about the health and eco-friendly advantages of products made from banana blossoms.
- Look into ways to diversify products by mixing banana blossoms with other by-products, such as jackfruit seeds, to develop unique functional foods.

Conclusion

Banana blossoms, which have often been overlooked as a by-product of the banana plant, are now gaining attention as a key player in the search for sustainable and functional foods. Packed with dietary fiber, antioxidants, and various bioactive compounds, they show great promise as a flexible ingredient that can help tackle health issues like diabetes, heart disease, and oxidative stress. Studies indicate that banana blossoms are on par with other by-products, such as jackfruit seeds and orange peels, in terms of nutrition and economic value, but their distinct fiber content and bioactive features make them a standout option for innovative functional foods.

The potential for creating a variety of value-added products, ranging from probiotic drinks to high-fiber baked goods, highlights the creative uses of banana blossoms in crafting foods that are both nutritious and culturally significant. These developments not only meet the rising interest in plant-based diets but also open doors for incorporating banana blossoms into everyday food markets.

Research on their health benefits supports their role as nutraceuticals, showing that they possess antioxidant, antidiabetic, and antimicrobial properties, along with uses in both traditional medicine and modern diets. However, there are hurdles to commercialization, including costs, supply chain issues, and how consumers perceive them, which points to the importance of collaboration among researchers, farmers, and food manufacturers.

By tackling these obstacles through innovative technology, educational initiatives, and diversifying markets, banana blossoms can be effectively promoted as a sustainable and health-enhancing food ingredient. Their inclusion in global food systems could help minimize agricultural waste, ensure nutritional security, and support sustainable development.

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