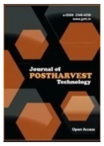

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REVIEW ARTICLE

A review on by-product utilization of plantain

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ABSTRACT

India is the world's largest banana producer, accounting for 27 percent of global banana production. It's also the world's second-most-produced fruit, behind citrus, accounting for around 16% of global fruit production. Plantains are the most well-known of the cooking bananas, accounting for almost one-third of total production. Since most edible bananas are grown primarily for their fruits, banana plantations generate a large amount of waste and by-products. Its vast by-products, which are recycled agricultural waste, offer a fantastic supply of incredibly important raw materials for other enterprises. The methodology of the study involved surveying primary and secondary information generated in the respective field of interest. The articles found most suited for the research problem and objective of the study were selected. The perspectives taken by different studies and researchers were synthesised to generate a solution to the research problems and to bridge the research gaps in the field. This review discusses the utilization of banana by-products such as peels, leaves, pseudostem, stalk, and inflorescence in various food and non-food applications acting as a thickening agent, colouring agent, and flavouring agent, as well as an alternative source of macro- and micronutrients, dietary supplements, animal feed, natural fibres, and organic bioactive substances and bio-fertilizers..

Keywords: Banana, agricultural waste, banana by-products, plantain, value added products.

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INTRODUCTION

Production of horticulture crops in India was estimated at a record 326.6 million metric tonnes (MMT) in the year 2020 as per third advance estimates, an increase of 5.81 million metric tonnes over the year 2020. India has the largest livestock population of around 535.78 million, which translates to around 31% of the world population. Area under horticulture is projected to rise by 2.7% in the year 2021(IBEF, 2021).

“Agricultural waste refers to the residue obtained from agricultural operations such as the processing and production of agricultural products like vegetables, crops, meat, poultry, fruits and dairy products. In general, agricultural wastes can be classified to four groups namely livestock wastes, agricultural industry - wastes, and, fruit, vegetable wastes and crop- residues (FVWs)” (Afolalu et al., 2021).

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The food-processing industry produces large volumes of wastes, both solids and liquids, generated from the production, preparation, and consumption of food. According to the Food and Agriculture Organization (FAO) data (FAO, 2013; Lipinski et al., 2013; Santana-Méridas et al., 2012), approximately one third of all food produced for human consumption in the world is lost or wasted. This corresponds to approximately 1.6 billion tons per year, 54% of which is lost during the production steps, postharvest handling and storage. The remaining 46% is further lost along the food chain, mainly during the retail distribution and domestic consumption (Ferrentino et al., 2018). These wastes are posing a growing amount of disposal and possible environmental issues, as well as a loss of important biomass and nutrients. For long-term industrial development, careful consideration of the proper utilisation and disposal of solid waste is essential. Source reduction through processing plant modifications, waste recovery, recycle, or waste treatment for value-added goods, and environmentally friendly detoxification or neutralisation of unwanted components are the three alternatives for industrial waste management. Waste management that is effective can reduce the cost of processed food production while also reducing pollution risks.

Reducing food loss and waste is widely seen as an important way to reduce production costs and increase the efficiency of the food system, improve food security and nutrition, and contribute towards environmental sustainability. Growing attention to food loss and waste is reflected in the Sustainable Development Goals (SDGs). SDG Target 12.3 calls for halving per capita global food waste at the retail and consumer levels and reducing food loss along production and supply chains (including post-harvest losses) by 2030 (FAO 2019).

By 2050 the world will need to feed an additional 2 billion people and require 70 percent more meat and milk. The increasing future demand for livestock products, driven by increases in income, population and urbanization will impose a huge demand on feed resources. Sustainability of feed production systems is being challenged due to bio- physical factors such as land, soil and water scarcity, food-fuel-feed competition, on-going global warming and frequent and drastic climatic vagaries, along with increased competition for arable land and non-renewable resources such as fossil carbon-sources, water and phosphorus. A key to sustainable livestock development is: efficient use of available feed resources including reduction in wastage, and enlargement of the feed resource base through a quest for novel feed resources, particularly those not competing with human food (Wadhwa and Bakshi, 2013).

A huge quantity of fruit and vegetable wastes (FVW) and by-products from the fruit and vegetable processing industry are available throughout the world. For example fruit and vegetable processing, packing, distribution and consumption in the organized sector in India, the Philippines, China and the United States of America generate a total of approximately 55 million tonnes of FVW. A large proportion of these wastes are dumped in landfills or rivers, causing environmental hazards. Alternatives to such disposal methods could be recycling through livestock as feed resources and/or further processing to extract or develop value-added products (Wadhwa and Bakshi, 2013).

The 4-R concept, that refers to Reduce, Reuse, Recycle, and Recover, is the ultimate goal of optimising solid waste utilisation while reducing environmental problems. Pectin extraction, essential oils from citrus peels, and whey protein concentrate from whey are some examples of food-processing sector by-product use. Fruit and vegetable by-products have also been revealed to be good sources of antioxidants and antibacterial compounds. Using whey, molasses, and other sugars, microbial production of single-cell protein, amino acids, and vitamins is also achievable. Zero discharge, zero emission, and zero pollution could be the ultimate goal of green productivity.

Banana, also known as the 'Apple of Paradise,' is an ancient fruit crop that belongs to the Musaceae family of the Zingiberales order (formerly Scitaminae). The banana plant is a herbaceous (non-woody) plant that grows to a height of 2-8 metres. The banana plant is perennial (it can survive for more than two years) and monocarpic, which means that each stalk can only flower once before dying after producing fruit. Bananas and plantains continue to grow at a phenomenal rate over the world. Its year-round availability, affordability, varietal range, flavour, medicinal and nutritional worth, and export potential make it a popular fruit among all kinds of people (Joseph et al., 2014). Plantains are the most well-known of the cooking bananas, accounting for almost one-third of global production (Nayar, 2010).

PRODUCTION OF BANANA AND PLANTAIN WORLDWIDE

Estimates from the FAO published in 2018 showed a total of 155.2 million tonnes, of which 115.7 million tonnes were bananas (75 percent),39.5 million tonnes of plantains (25%) as global production. In the year 2019, 116,781658 tonnes of bananas and 41,580022 tonnes of plantain were produced worldwide. Table 1 shows top 10 banana producing countries of the world in 2019 (FAOSTAT 2021). India, China, Indonesia, brazil and Ecuador are the top 5 countries in banana production. Democratic Republic of the Congo, Ghana, Cameroon, Uganda, and Nigeria are the top 5 countries of the world in plantain production (FAOSTAT 2021) (Table 2). Table 3 shows top 10 banana producing countries in 2019. India, China, Indonesia, Brazil, and Ecuador are the top 5 countries in banana production Internationally. Ghana, Democratic Republic of the Congo, Cameroon, Uganda, and Nigeria are the top 5 countries in plantain production in the year 2019 (FAO, APEDA 2019)(Table 4).

Table 1: Top ten world banana producers

Rank	Producers	Amount (Tonnes)
1	India	30634000
2	China, mainland	11438700
3	Indonesia	7272519
4	Brazil	6768149
5	Ecuador	6544556
6	Philippines	6096987.5
7	Guatemala	4274396.5
8	Angola	3995497.5
9	United Republic of Tanzania	3401217.5
10	Colombia	2740794

Source: FAOSTAT, 2021

Table 2: Top ten world Plantain producers

Rank	Producers	Amount (Tonnes)
1	Democratic Republic of the Congo	4844398.5
2	Ghana	4780261
3	Cameroon	4727149
4	Uganda	3436922
5	Nigeria	3163524.5
6	Philippines	3161243
7	Peru	2237489.5
8	Colombia	2045729
9	Côte d'Ivoire	1848356.5
10	Myanmar	1366080

Source: FAOSTAT, 2021

Table 3: Top 10 International banana producers

International Production : Bananas Production in (000) MT 2019			
Sr. No.	**Country**	**Production**	**Share(%)**
1	India	30,460.00	26.08
2	China P Rp	11,655.70	9.98
3	Indonesia	7,280.66	6.23
4	Brazil	6,812.71	5.83
5	Ecuador	6,583.48	5.64
6	Philippines	6,049.60	5.18
7	Guatemala	4,341.56	3.72
8	Angola	4,036.96	3.46
9	Tanzania Rep	3,406.94	2.92
10	Colombia	2,914.42	2.5
	Total	**83,542.03**	

Source: FAO, APEDA, 2019

Table 4: Top 10 International Plantain and others producers

International Production : Plantains And Others Production in (000) MT 2019			
Sr. No.	**Country**	**Production**	**Share(%)**
1	Ghana	4,872.24	11.72
2	Congo D. Rep.	4,856.47	11.68
3	Cameroon	4,779.71	11.5
4	Uganda	3,423.84	8.23
5	Nigeria	3,182.87	7.65
6	Philippines	3,108.07	7.47
7	Peru	2,280.10	5.48
8	Colombia	2,185.01	5.25
9	Cote D Ivoire	1,826.13	4.39
10	Myanmar	1,340.60	3.22
	Total	**31,855.04**	

Source: FAO, APEDA, 201

Table 5: Top ten India banana producers

Indian Production of Banana Production(000 Tonnes) 2017-2018			
Sr. No.	**State**	**Production**	**Share(%)**
1	Andhra Pradesh	5,003.07	16.27
2	Gujarat	4,472.32	14.54
3	Maharashtra	4,209.27	13.69
4	Tamil Nadu	3,205.04	10.42
5	Uttar Pradesh	3,172.33	10.31
6	Karnataka	2,328.90	7.57
7	Madhya Pradesh	1,834.03	5.96
8	Bihar	1,396.39	4.54
9	West Bengal	1,200.00	3.9
10	Kerala	1,119.16	3.64
	Total	**27,940.51**	

Source: National Horticulture Board, APEDA, 2017-2018

PRODUCTION OF BANANA IN INDIA

In 2019-2020, production of banana in India was 31504000 tonnes as per second Advance Estimate (NHB 2020). Table 5 shows top 10 banana producing states of India in 2017-2018. Andhra Pradesh, Gujarat, Maharashtra, Tamil Nadu and Uttar Pradesh are the top 5 states in banana production (NHB, APEDA 2018).

In the year 2018, India produced a banana or plantain waste of 6.16 million tonnes (FAO 2018). As the banana is an important crop worldwide, plantations produce tonnes of by-products after each harvest season, including the peel, leaves, pseudostem, stalk and inflorescence (Padam et al., 2014). In agriculture and cottage industries, nearly every part of the banana plant, including the fruit, peel, leaves, stem, stalk, and inflorescence (flower), can be used. They are employed in a variety of food- and non-food-related applications, including those requiring thickeners, colourants, flavourings, macro- and micronutrient supplies, livestock feed, fibres, sources of bioactive compounds, and organic fertilisers (Padam et al., 2014). Additionally, the banana plant has medicinal properties in all of its components. For instance, diabetic, pulmonary, dysentery, and ulcer sufferers can boil and consume the blossom. To treat stings and bites, the stem sap can be taken internally or externally. In some nations, the roots, ashy leaves, peels, and seeds are all employed medicinally. (Okoli, 2007). This review discusses the usefulness of various by-products of plantain crop which has great potential to be developed into useful nutraceuticals and functional foods.

USES OF BY-PRODUCTS OF PLANTAIN CROP

One of the largest herb families in the world is the banana (Ploetz et al., 2007). The plant, which has a fleshy rhizome (corm), pseudostem (leaf petioles), and oblong leaves grouped spirally, can reach a height of 5-7 m. The tip of the pseudostem, which is made up of deep purple waxy bracts that enclose the female (which fills the lower 5–15 rows) and male flowers, projects the long, oval-shaped inflorescence, which is supported by a stalk (upper rows). The female flowers eventually grow into "berry" fruits (hands), which have white or yellow meat and a horned form. Wild types often have seeds, but produced variants typically lack seeds and have tiny ovule spots in the middle instead (Arvanitoyannis and Mavromatis, 2009).

Leaves

The weaving of baskets, mats, food wrappers for marketing and cooking, coverings for food, tablecloths, plates for eating, and cups for soup all make great use of leaves. To protect banana bunches from bats and birds, old leaves are utilised as "bunch covers." During the rainy season, rural people use the huge leaves of triploid bananas as umbrellas. The substrate and fuel for growing oyster mushrooms are dried banana leaves (Mohapatra et al., 2010). Banana leaves are used in India (Orissa, West Bengal, and Kerala) for traditional rituals and rites as well as the roasting or steaming of ingredients for particular cuisines. People traditionally eat off of banana leaves in Sri Lanka and India's banana-growing regions.

Recent study by Singh et al. (2018) also revealed that banana leaves are a good lignocellulosic source and have varieties of uses from feed to wrapping materials for specialised food product and even thatching material in banana growing places. According to Kuo et al. (2006), banana leaves (*Musa* sp. cv. Cavendish) contain a membrane-bound enzyme called 9-LOX that when pickedled or treated with soybean oil, linoleic acid, or linolenic acid, respectively, can produce flavours resembling those of oolong tea, melon, and fruity cucumbers. The enzyme's kinetic properties are similar to those of LOX derived from canola In order to continually produce natural tastes for use in the food business, banana leaves could be a viable target. Banana leaves (ashes) are used in eczema (Okoli, 2007), as cool dressings for blister and burns (Ghani, 2003), for a range of disorders from headaches to urinary tract infections (Frison and Sharrock, 1999).

Banana peel

Unsaturated fatty acids, antioxidants, and high-quality protein are abundant in banana peels (Emaga et al., 2007). These peels also include a significant amount of starch (35.4–39.3 percent DW), pectin, and dietary fibres (40–50 percent DW), particularly insoluble dietary fibres (Emaga et al., 2008a). Pectins from these banana peels have been characterised in a way that suggests they can be employed as therapeutic molecules for treating diabetes and cardiovascular disease because they lower blood sugar and cholesterol levels (Emaga et al., 2008b). Reduced stool volume, use of green banana peel as an intravenous fluid, and multiple vomiting and diarrheal issues have all been connected to it (Rabbani et al., 2001).

Banana flower

Large, dark purple-red blossoms called "banana flowers" appear at the end of a bunch of bananas. They can also go by the names banana male bud, banana blossom, or banana inflorescence. They are a by-product of agriculture that are frequently eaten as vegetables in several Asian nations, including Malaysia, Indonesia, Sri Lanka, the Philippines, and other South-East Asian nations (Wickramarachchi and Ranamukhaarachchi, 2005). Despite the fact that they are frequently eaten as vegetables, very few studies on their nutritional value and dietary fibre content have been done. Depending on their nutritional makeup, these banana blossoms may have many uses. Nevertheless, some studies have addressed their various therapeutic uses, including the prevention of intestinal cancer (Pari and Maheshwari, 2000; Wickramarachchi and Ranamukhaarachchi, 2005), the treatment of hyperglycemia and type II diabetes through the activation of GLU T1 and T4 carriers (Pasupuleti and Anderson, 2008; Bhaskar et al., 2011). Kumar et al. (2012) studied the traditional and medicinal uses of banana and found that flowers are used to treat dysentery, ulcers, and bronchitis. Cooked, flowers are considered a good food for diabetics. The chloroform extract of flowers of M. sapientum showed blood glucose and glycosylated haemoglobin reduction and total hemoglobin increase after oral administration in rats (Pari and Maheshwari, 1999). It also controls lipid peroxidation in diabetes (Pari and Maheshwari, 2000).

It has also been shown that extracts from banana male flowers (Musa paradisiaca) have antibacterial characteristics that are comparable to commercial potassium sorbate and are able to decontaminate and reduce the growth of Listeria monocytogenes and Staphylococcus aureus in chicken breast flesh (Tin et al. 2010; Padam et al. 2012b)

In terms of nutritional content, the banana inflorescence is appreciated for its high dietary fibre content, which is important in facilitating digestion and preventing constipation. The banana inflorescence is indeed a good source of dietary fibre with a better soluble dietary fibre/insoluble dietary fibre ratio (SDF/IDF ratio) than many other sources of dietary fibre and other vegetables (Arun et al., 2017). As the banana is cultivated worldwide, its inflorescence can be exploited as a commercial source of dietary fibre (Bhaskar et al., 2012). In fact, Ramu et al. (2017) suggested that banana by-products, especially the banana inflorescence, have potential as an emerging alternative fibre-enriched food source comparable to oats and sorghum. Findings from various comparative studies have revealed that the banana inflorescence has greater potential to be developed as functional ingredients with regard to its nutritional attributes and composition of bioactive compounds (Lau et al., 2020)

A study on Preliminary phytochemical screening and in vitro antioxidant activity of Banana flower (*Musa paradisiaca* AAB Nendran variety) using six different extracts (Water, ethanol, methanol, chloroform, ethyl acetate and acetone) were done by Joseph J et al. (2017). Phytochemical screening of these extracts showed the presence of various phytoconstituents like carbohydrates, steroids and triterpenoids, tannins, proteins, flavonoids, phenolic com- pounds, fixed oils and fats. The results showed that ethanol extract having more amount of flavonoid (0.67%) and polyphenol content (1.92 mg Eq of GA) than other extracts. In addition, the ethanol extract exhibited more antioxidant activity with IC50value 63 μg/ml. This study indicated that ethanol extract of banana flower (*Musa paradisiaca* AAB Nendran variety) exhibited more antioxidant property due to the presence of high content of polyphenols and flavonoids.

The development of the banana inflorescence as a form of functional food or ingredient to be incorporated into one's daily food is feasible. For example, there has been an attempt to incorporate banana inflorescence flour into dark chocolate (Sharmila & Puraikalan, 2015). Another initiative was taken by Elaveniya and Jayamuthunagai (2014) who suggested the use of dried banana blossom (*M. paradisiaca*) as part of the recipe to produce biscuits with a better taste and texture while at the same time improving the dietary fibre, protein and mineral (Na, K, Mg, Cu and Fe) content. The biscuits produced from the banana blossom were suggested as a potent functional food for diabetic patients due to their low calorie and sugar content. On the other hand, Schmidt et al. (2016) reported that the addition of 2% (w/w) banana inflorescence extract together with (0.2%, w/w) sodium erythorbate into a pork burger was effective in delaying the lipid oxidation without affecting the physicochemical and sensory characteristics of the product. This implies that the extract of the banana inflorescence is a viable source of natural antioxidants to maintain the quality of food products during storage, thus, the dependence on synthetic antioxidants can be reduced.

The banana inflorescence was shown to have good water holding capacity, oil holding capacity, solubility and swelling capacity comparable to many dietary fibres of other origins. These results indicate that there is potential for the banana inflorescence to be used as an emulsion stabiliser (Ramu et al., 2017). It has also been shown that extracts from banana male flowers (*Musa paradisiaca*) have antibacterial characteristics that are comparable to commercial potassium sorbate and are able to decontaminate and reduce the growth of *Listeria monocytogenes* and *Staphylococcus aureus* in chicken breast flesh (Tin et al. 2010; Padam et al. 2012b)

Banana stem

The lignin and cellulose content in waste banana stems are about 83% and 15 ± 20%, respectively. This waste can yield biogas up to 271 l/kg of total solid (Saxena et al., 2011). Further, conversion of banana waste to ethanol can be obtained with a thermophilic, anaerobic bacterium (*Clostridium thermocellum* CT2 and *Clostridium thermosaccharolyticum* HG8) (Pappu et al., 2015). The core of the stem is believed to be useful in stomach upset and diabetes. The extract of core of the stem is considered to be useful in dissolving the stones in the kidney and urinary bladder and reducing the weight. The inflorescence mixed with coconut oil and spices is used for flushing the urinary blocks (Kumar et al., 2013). Banana stem juice has been used as a natural coagulant for treatment of spent coolant wastewater. It has been reported that chemical oxygen demand (COD), suspended solids (SSs), and turbidity of effluent were removed with an efficiency of 80.1%, 88.6%, and 98.5%, respectively, using banana stem juice. It was concluded from the study that banana juice stem exhibit high potential to be used as a natural coagulant for water treatment purposes (Pappu et al., 2015). Banana stem has also been used for the removal of Pb(II) metal ions from aqueous solution (Noeline et al., 2005).

Banana psuedostem

All banana plants have starchy corms and pseudostem bases that were and still are used in times of famine on Pacific islands (mostly SW islands and New Guinea). This was evidently the original use of banana for human food (Langhe, 1995). The banana pseudostem is cooked in India as the dish khich khach, taken monthly to prevent constipation (Gopinath, 1995). The juice extracted from the male bud is considered good for stomach problems and stem juice was considered a remedy for gonorrhoea (Frison and Sharrock, 1999).

Central core of banana tree is the inner tenderest portion of the pseudostem which is safe to eat. Various edible products viz., candy, drinks and pickles are made from it (Aurore et al., 2009). According to a separate study conducted by Singh et al. (2007), oral administration of banana pseudostem juice (*Musa paradisiaca*) to normal and hyperdiabetic (high blood glucose level) rats results in a significant rise in blood glucose levels, suggesting a potential treatment for patients with hypoglycemia brought on by low insulin levels or medications that lower blood sugar. Banana sap extracted from pseudostem can be used as liquid fertilizer for banana, papaya, sugarcane, etc. Studies indicate that it may save 20-40% fertilizer. It also improves the yields of banana and sugarcane (Patil and Kolambe, 2011).

The banana pseudostem was successfully used by Saravanan and Aradhya (2011) to isolate entisic acid, (+)-catechin, protocatechuic acid, caffeic acid, ferulic acid, and cinnamic acid. The antimicrobial, antioxidant, neuroprotective, chemopreventive, anticancer, cinnamic acid, gallocatechin, and antiproliferative properties of polyphenolic compounds such as these have been established (Chanwitheesuk et al. 2005; Shan et al. 2008); they also have a role in chemoprevention (Raina et al. 2008; Artali et al. 2009), chemopre (Jagan et al., 2008).

Banana pith

In several regions of the world, including India, Sri Lanka, and Malaysia, banana pith from the pseudostem has traditionally been consumed as a vegetable (Kennedy 2009; Subbaraya 2006). Starch, carbohydrates, and minerals are present in significant amounts (Mohapatra et al., 2010). Banana pith have been further used for removal of heavy metals rich in electromagnetic waste (Low et al., 1995). Toxic metal ions of Cu (II) were successfully removed using the banana pith (Low et al., 1995). Banana pith can be used as adsorbent for diminishing the cost of wastewater treatment significantly (Sathishkumar et al., 2008). Acid treated banana pith is known to be bio sorbent for removal of most of the metals. Activated carbon prepared from banana pith has been found to be an adsorbent for the removal of dyes and metals. Rhodamine, congo red, methylene blue, malachite green, and methyl violet were found to be removed to varying degrees, with clearance rates of 82.65, 76.55, 93.35, 48.20, and 37.45 percent, respectively. The pseudostem pith and the green banana that are removed during fruit selection and processing are two banana by-products that can be turned into edible starches (Abdul Aziz et al. 2011; Da Mota et al. 2000; Zhang et al. 2005).

Banana bracts

After bananas have been harvested, the purple outer bracts of the banana bloom are discarded as waste (Preethi and Balakrishnamurthy 2011). However, due to the appealing colour of the pigments, it exhibits significant potential as a cheap source of natural pigments (Pazmino-Duran et al. 2001; Begum and Deka 2017). About 300 kg of coloured bracts per hectare are disposed as residues during harvesting of banana and is an excellent source of anthocyanin. The anthocyanin content of outer bract of culinary banana flower is 56.98 mg/100 g (Begum and Deka 2017). While the presence of dietary fibre has been acknowledged by many, the few empirical studies which have been conducted in this field valorise this fact. Dietary Fiber is present in culinary banana flower's outer and inner bracts in proportions of 61.13 and 66.22 percent, respectively (Begum and Deka 2019). Additionally, a variety of phytochemicals and antioxidants that are favourable for human health can be found in it.

A study on effect of processing on structural, thermal, and physicochemical properties of dietary fibre of culinary banana bracts were done by Begum and Deka (2019). Dietary fibre (DF) of culinary banana bract was extracted using alkaline extraction (alkaline extracted DF, AEDF) and ultrasound-assisted extraction in combination with alkaline extraction (ultrasound-assisted extracted DF, UEDF). The extracted DFs were compared for their composition, structural, thermal, and functional properties. The results revealed that Higher total DF (83.38 g/100 g) was detected in UEDF than AEDF. Higher crystallinity (25.86%), regular honeycomb structure, lesser particle size (<0.5 μm), and greater thermal stability was evident in UEDF, when compared to AEDF. Presence of 5-hydroxymethylfurfural and β-D-glucopyranose was detected in UEDF. Moreover, better water-holding capacity, oil-holding capacity, and water-swelling capacity with improved functional properties viz., α-amylase retardation index and glucose-absorption capacity were obtained in UEDF than AEDF. The results indicated that UEDF was better functional ingredient as compared to AEDF and can be used to develop low calorie and fiber-rich dietetic snacks.

In a different study, bread was fortified with anthocyanin-rich dietary fibre powder (ARDFP) by incorporating dietary fibre (DF) and anthocyanin formulation. The cytotoxicity of DF and anthocyanin extracts was evaluated prior to the integration of DF-anthocyanin formulation in bread manufacturing. It was investigated how varying levels of ARDFP incorporation with moisture affected the specific volume, texture, colour, sensory, and starch digestibility of bread. According to the findings, culinary banana bracts' extracted DF and anthocyanin were cytotoxic to the HT29 cancer cell line but harmless to peripheral blood mononuclear cells. With higher specific volume (5.50 cm3/g), improved textural features (high springiness and cohesiveness), anthocyanin content (9.08 mg/100g), colour characteristics, and sensory qualities, the incorporation of 2 percent ARDFP with 68 percent moisture was ranked as the best. The in vitro digestibility study suggested increased incorporation of ARDFP in bread flour reduced the rate of starch digestibility (0.0035 min-1) (Begum and Deka 2020)

Banana sap

Chemically, banana sap has astringent qualities. In traditional medicine, the sap is used to treat a wide variety of ailments, including leprosy, hysteria, fever, digestive disorders, hemorrhage, epilepsy, hemorrhoids, and insect bites (Kumar et al, 2012).

CONCLUSION

The waste from the food processing sector is not truly waste; it can be converted and used as food, feed, and fodder. Regulatory agencies and the food-processing industry can collaborate to create novel waste management and utilisation processes that are commercially viable. The effective and efficient use of fruit and vegetable wastes will lower the cost of animal feeding, enhancing farmer profitability, provide a variety of value-added products, and facilitate waste management and pollution reduction. Bananas, which come in a variety of well-known types and cultivars, have been studied, and by-products such as pseudostems, rhizomes, leaves, fruit stalks, and peels have been found to be possible raw materials in food and non-food industries, depending on the application. Banana by-products that have been evaluated and found to have potential applications for food additives, nutraceuticals, food supplements, feeds, renewable fuel, fibres, bioactive and other organic chemicals, fertilisers, and contaminant absorbers should be further addressed for their safety aspects to meet market demand. This indicates the banana's adaptability in terms of biomass potential. The requirement to appropriately utilise available and abundant resources, such as banana by-products, is deemed essential in order to reduce solid waste emissions and the loss of precious untapped biomass. Creating wealth from waste, such as banana by-products, should be considered one of the strategies to ensure an environmentally sustainable for future generations. There are endless opportunities for creatively using these renewable resources to meet the needs in the areas already stated, as well as identifying new areas that have yet to be explored. Keeping in mind that the immediate concern will always be research innovation in order to produce high-value and high-quality products with economic implications.

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