Article

Fruit leather as a functional snack: a review of antioxidant richness across fruit varieties

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Abstract

Fruits are part of a category of foods that are prone to damage due to their high moisture content, which makes them susceptible to microbial contamination. Additionally, fruits can spoil as they become overripe. To prolong the shelf life of fruits, one approach is to process them into fruit leather products. This review article aims to serve as a resource and theoretical basis for readers. The methodology involves a literature review, gathering data from various sources. Findings indicate that fruit leather made from different fruits exhibits significant antioxidant activity, offering substantial health benefits. Moreover, combining multiple fruit types in fruit leather can enhance antioxidant activity. Research on fruit leather production, whether involving single fruits, binary combinations, or hydrocolloids, generally demonstrates strong antioxidant activity. Although combining fruits can enhance this activity, a reduction is possible in some instances, potentially due to the degradation of bioactive compounds during processing. In summary, fruit leathers made from fruits like dragon fruit, banana, pineapple, guava, and strawberry show strong potential for development as antioxidant-rich healthy snacks that can provide significant benefits to consumers.

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1. Introduction

Fruit is a plant-based food with various nutrients, providing energy for the body while improving health due to its bioactive compounds. Fruits are rich with nutrients such as complex carbohydrates, protein, fat, fiber, minerals, and vitamins. According to 2024 Ministry of Agriculture data, Indonesia's fruit production reached 28,667,649 tons in 2023. The top fruit varieties by production volume include bananas (32.56%), mangoes (11.52%), pineapples (11.01%), citrus (9.8%), and durians (6.46%). The remaining 22 fruit varieties collectively contributed 28.57% of total production (1). Despite substantial output, however, some fruits suffer prolonged spoilage due to distribution losses and excessive ripening process (2).

Fruits are classified into two groups based on the ripening characteristics: climacteric and non-climacteric fruits. Climacteric fruits continue to undergo respiration and ripening after harvest. This process is characterized by increased ethylene production, which triggers changes in color, texture, aroma, flavor, and generally causes the fruit to become softer and sweeter (3). In contrast, non-climacteric fruits do not continue to ripen after harvest and therefore must be harvested at the appropriate maturity stage. Climacteric fruits include bananas, apples, and mangoes, whereas oranges, grapes, and pineapples are categorized as non-climacteric fruits (4). Improper post-harvest handling of both fruit types can negatively impact the quality and quantity. One common consequence is increased transpiration, which leads to moisture loss and subsequently reduces the freshness, texture, and shelf life

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of the fruit (5). Changes due to metabolism can cause food loss that is detrimental to both producers and consumers.

One approach to prevent food loss during storage is to process fruits to healthy food or snack products, such as fruit leather (6). Fruits commonly used for fruit leather production are dragon fruit, mango, papaya, grapes, and strawberries. These fruits generally highly perishable and susceptible to microbial spoilage due to the high moisture content (7). However, it also contain high and diverse levels of antioxidants that help strengthen the immune system by neutralizing free radicals in the body (8). Processing these fruits into fruit leather is considered more advantageous than other methods, as the drying process and the addition of sugar can extend shelf life without significantly reducing antioxidant activity. Moreover, the variety of dried fruit products continues to expand, as it can be made from a wide range of tropical fruits to berries. The potential of dried fruit as a healthy and modern snack is particularly strong, especially among young consumers who are increasingly concerned about health and environmental sustainability. This review article examines the potential of various fruits to be processed into antioxidant-rich dried fruit products as healthy snacks for improving overall health.

2. Materials and Methods

The search for articles (original or review) was performed using the Google Scholar and Scopus electronic databases. The main keywords used were: “fruit leather”; “fruit leather production”; “fruit leather antioxidant,”; “antioxidant activity”; “fruit leather antioxidant activity” and “antioxidant activity,” among others. All the included references were manually selected and reviewed by the authors.

3. Results and Discussion

3.1. Fruit Leather

Fruit leather is a processed fruit-based product with simple preparation method and favorable nutritional quality. It typically has a semi-moist to dry texture, depending on the drying method employed (9). Fruits, which are rich in complex nutrients and bioactive compounds, are primarily utilized in pulp form for leather production (10). Fruit leather is characterized by its soft texture, diverse flavor profiles, and high fibre content (11). Typically containing 10–20% moisture, fruit leather is classified as a semi-moist food (12). In addition to fruit, the formulation requires gelling agents (hydrocolloids), sugars, and acidulants. Common hydrocolloids used to improve texture include pectin, gum arabic, carrageenan, and alginate (13).

3.2. Fruits Commonly Utilized for Fruit Leather

3.2.1. Dragon Fruit

Dragon fruit (*Hylocereus* spp.) is a subtropical fruit characterized by its rounded, flower-like shape, vibrant pink to purple rind, and purple flesh speckled with small black seeds (14). It contains a variety of important nutrients, including vitamins B (B1, B2, B3), vitamin C, Vitamin E, carotenoids, flavonoids, phosphorus, iron, and calcium (15). Furthermore, it is rich in antioxidant compounds, dietary fiber, and oligosaccharides. The oligosaccharides present in dragon fruit can serve as prebiotics, functioning as a food source for beneficial probiotic bacteria in the gut (16). Due to the high nutritional value and healthpromoting properties, dragon fruit is commonly processed into various functional food products. Its consumption has been associated with potential health benefits such as reducing the risk of cardiovascular diseases, alleviating diabetes symptoms, and lowering cancer risk (17).

3.2.2. Mango

Mango (*Mangifera indica*) is a climacteric fruit predominantly cultivated in tropical and subtropical regions (18). Its fruit morphology is diverse, typically exhibiting round to elongated shapes, a skin color ranging from green to yellow, and a soft, fleshy pulp (19). Mangoes contain various phytochemical compounds, particularly phenolic compounds and flavonoids. Specific constituents such as gallic acid, chlorogenic acid, ascorbic acid, and carotenoids are strongly associated with its antioxidant capacity (20). Consequently, mango consumption is linked to multiple health benefits, including antidiabetic, antidiarrheal, antihyperlipidemic, and anticancer effects (21).

3.2.3. Pineapple

Pineapple (*Ananas comosus* (L.) Merr.) is a non-climacteric fruit, meaning its ripening process does not continue after harvest (22). Its distinctive morphology features a crown-like shape, a scaly rind, and a sweet-tart flavor with soft flesh (23). Pineapple contains various phytochemicals derived from secondary metabolites, including flavonoids, alkaloids, saponins, and tannins (24). Notably, it is a natural source of the enzyme bromelain, found throughout the fruit (flesh, peel, and core), which is commonly utilized as a meat-tenderizing agent (25). Owing to its rich nutrient and antioxidant profile, pineapple is widely used as a primary ingredient or functional additive in food products. Its consumption is associated with health benefits such as immune support and anticarcinogenic effects, attributed to the ability of its bioactive compounds to neutralize free radicals in the body (26).

3.2.3. Banana

Banana (*Musa* spp.) is a climacteric fruit, which continues to ripen post-harvest and can therefore be harvested prior to full maturity (27). Morphologically, bananas are characterized by an elongated shape, a yellow peel, a sweet taste, and soft flesh (28). They are a source of various bioactive compounds, such as flavonoids, terpenoids, steroids, tannins, and phenolic compounds, in addition to essential minerals including calcium, phosphorus, and iron (29). Owing to these functional and nutritional attributes, bananas are widely processed into value-added food products, such as banana flour. Regular consumption is associated with health benefits, including improved digestive function and antioxidant activity (28).

3.3. Antioxidant

Antioxidants are natural compounds found in various substances and food products that function to inhibit the activity of free radicals (30). In food systems, antioxidants help prevent oxidative reactions that lead to spoilage, color changes, and off flavors. Naturally occurring antioxidants are abundant in pigmented fruits and vegetables, particularly those with red, orange, and purple hues (31) Key antioxidant compounds include carotenoids, thiols, ascorbic acid, and polyphenols (32). Antioxidants are widely incorporated into various food products due to their health benefits. In the human body, antioxidants play an essential role in neutralizing free radicals and reactive oxygen species (ROS) that can damage cells (33). By reducing oxidative stress, antioxidants help prevent chronic diseases such as cardiovascular disorders, cancer, inflammation, and premature aging, and they also function as anti-inflammatory and anti-aging agents (34).

The DPPH (1,1-diphenyl-2-picrylhydrazyl) assay is a common method for evaluating antioxidant activity, based on the ability of antioxidants to reduce the stable DPPH radical. This activity is often expressed as the IC_{50} value, which represents the concentration of antioxidant required to reduce 50% of DPPH radicals in the system(35). The assay procedure typically involves homogenization of the sample with reagents such as methanol to enhance compound extraction, followed by incubation in darkness due to the light-sensitive nature of DPPH (36,37). Homogenization ensures thorough mixing of the sample with chemical reagents , while the DPPH solution acts as the radical source that antioxidants neutralize (36,38).

3.4. Antioxidant and Bioactive Effect of Fruit Leather

Fruit leather is typically produced from a variety of fruits and vegetables (39). The fruits selected often exhibit bright colors, such as red, purple, yellow, or orange, which are indicative of high antioxidant content (40). The antioxidant activity in different fruits can vary significantly, primarily due to differences in the composition and concentration of bioactive compounds present in each fruit type (41).

Based on the data in Table 1, it can be observed that fruit leather formulations exhibit a wide range of antioxidant activities, influenced by fruit selection, combinations, and processing additives. As a foundational component, the antioxidant properties of individual fruits are significant; for instance, the flavonoids in oranges and apple puree's high phenolic content confer strong anti-aging and antioxidant effects (42–44). Various fruit combinations can significantly affect antioxidant properties of fruit leather. For example, combination of dragon fruit with watermelon increases total phenolic compounds, while banana and papaya enhance vitamin C and antioxidant levels (6,45). However, the impact varies, as seen with the moderate activity of guava-dragon fruit blends due to the higher complexity of guava’s antioxidant components compared to dragon fruit (8). Some fruits, like Murano and Malga strawberries, also exhibit a decrease in antioxidant activity after being processed into fruit leather compared to when they are fresh (34.45–35.21 mmol Trolox/100g) (46). Certain additives can also influence antioxidant capacity; for instance, incorporating carrageenan at a 50:50 ratio lowers the antioxidant activity of pineapple-based fruit leather from 68.10% to a moderate level of 27.37% (47). In contrast, combining mango with nata plum yields very strong antioxidant activity, with a correlation value of 40–45% (48). Siamese oranges contribute notable antioxidants through their flavonoids and vitamin C, as these secondary metabolites effectively neutralize free radicals by forming more stable molecules (49). However, the use of hydrocolloids in dragon fruit leather can decrease antioxidant activity by 2.295–7.847% due to the degradation of polyphenols, vitamins, and enzymes (13). In guava-banana fruit leather enriched with kappa carrageenan and gum arabic, the antioxidant activity remains moderate, influenced by banana’s naturally low antioxidant capacity (50). Finally, incorporating moringa leaf powder into pineapple fruit leather enhances antioxidant activity, with higher concentrations of moringa resulting in proportionally greater antioxidant potential (51).

Table 1. Antioxidant Activity of Various Types of Fruit

Type of Fruit Leather	Primary Antioxidant Compounds	Antioxidant Activity	Ref.
Orange	Ascorbic acid, flavonoid	87,93 mg /100 g	(42,43)
Mango	Ascorbic acid, β-carotene	147,06 mg /100 g	(42,52)
Dragon fruit + watermelon	Phenolic compounds (tannins, flavonoids, and phenols)	107,39 ppm IC50	(45)
Banana + pawpaw fruit	Flavonoid and total phenol	0,61 – 0,86 mg/ GAE g	(6)
Pure Apple	Phenolic compounds	321 mg GAE/100g	(44)
Pineapple + Dragon fruit peel	Flavonoid, ascorbic acid	73,93%	(53)
Guava + dragon fruit	Vitamin C, flavonoids, and polyphenol compounds	51,15 -94,63 IC50	(8)
Strawbery Murano and Malga	Vitamin C and Flavonoids	20,95 – 21,19 mmol rolox/100 g	(46)
Pineapple Cobs + Carrageenan	Vitamin C and Flavonoids	27,37%	(47)
Mango + Nata Plum	Flavonoids and phenolic compounds	40-45% 160 mg/g	(48)
Siam Orange	Ascorbic acid, flavonoid	74,89%	(49)
Dragon fruit	Polyphenols and vitamins	73,685-82,467%	(13)
Guava + Banana + Carrageenan + Gum arabic	Vitamin C, flavonoids, and polyphenolic compounds	48-57%	(50)
Pineapple + moringa leaves	Flavonoids and ascorbic acid	71,78%	(51)

4. Conclusions

Research on fruit leather production, whether involving single fruits, binary combinations, or hydrocolloids, generally demonstrates strong antioxidant activity. Although combining fruits can enhance this activity, a reduction is possible in some instances, potentially due to the degradation of bioactive compounds during processing. In summary, fruit leathers made from fruits like dragon fruit, banana, pineapple, guava, and strawberry show strong potential for development as antioxidant-rich healthy snacks that can provide significant benefits to consumers.

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Author Contributions

Conceptualization, Z.N.A.; methodology, Z.N.A.; validation, Z.N.A.; formal analysis, Z.N.A.; resources, Z.N.A.; data curation, Z.N.A.; and writing Z.N.A.

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Available data are presented in the manuscript.

Conflicts of Interest

The author declares no conflict of interest.

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