FRUIT AND VEGETABLE PEEL POWDERS AS NATURAL FLAVORING AGENTS: ENHANCING SENSORY ATTRIBUTES AND NUTRITIONAL QUALITY IN FUNCTIONAL FOOD APPLICATIONS

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CHAPTER 1

ABSTRACT

Fruit and vegetable peel powders are gaining recognition as valuable, natural ingredients in creating functional foods (Ajila et al., 2007; Balasundram et al., 2006). These powders are made by drying and grinding peels from sources like citrus, mango, watermelon, banana, and potato. They provide a sustainable way to improve both the nutritional quality and sensory appeal of various food products. Peel powders are rich in dietary fiber, essential minerals, and bioactive compounds such as polyphenols, flavonoids, and carotenoids (Dorta et al., 2012; Kaur and Kapoor, 2015). These have documented health benefits, including antioxidant, antimicrobial, and anti-inflammatory effects (Hossain et al., 2011).

When added to foods like breads, biscuits, noodles, jams, and snacks, peel powders can significantly enhance their nutritional and functional properties. For instance, adding orange peel powder to bread and biscuits boosts dietary fiber and polyphenol content while improving texture and overall acceptability (Kulkarni et al., 2012; Sharma et al., 2016). Similarly, snacks with mango peel show increased antioxidant activity and an attractive color, while watermelon and banana peel powders provide extra vitamins, minerals, and fiber (Ajila et al., 2007; Lario et al., 2004).

Using peel powders at moderate levels can positively influence sensory traits such as flavor, aroma, texture, and color. Their natural flavors can add unique tastes and colors, capturing consumer interest. Research indicates that products with up to 5% to 8% peel powders typically keep high sensory acceptance without unwanted changes in taste or texture (Lario et al., 2004; Kaur and Kapoor, 2015). Additionally, the fiber in these powders can enhance water retention and shelf life, helping to prevent quick spoilage and microbial growth (Hossain et al., 2011).

Beyond their nutritional and sensory benefits, peel powders support current sustainability goals. Using fruit and vegetable byproducts reduces food waste and provides a circular economy solution by turning unused biomass into valuable food ingredients (Pathak et al., 2019; Dhillon et al., 2020). This offers both economic and environmental benefits while also limiting reliance on synthetic additives and preservatives (Dhillon et al., 2020).

The bioactive compounds in these powders help reduce oxidative stress and support gut health, making them appealing ingredients for health-conscious consumers (Dorta et al., 2012). Their ability to enrich foods with natural antioxidants offers an alternative to

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synthetic options, which many consumers are avoiding (Sharma et al., 2016). Foods like biscuits, noodles, and breads that contain peel powders are therefore seen as appealing, healthier choices that maintain sensory quality along with nutritional benefits (Ajila et al., 2007; Kaur and Kapoor, 2015).

In summary, fruit and vegetable peel powders act as versatile, natural additives in functional foods. They enhance nutrition, improve sensory qualities, extend shelf life, and promote sustainable food practices (Balasundram et al., 2006; Pathak et al., 2019). Their use helps create innovative products that meet consumer demand for better health and environmental responsibility (Dhillon et al., 2020).

CHAPTER 2

INTRODUCTION

The growing demand for nutritious, sustainable, and innovative food products has focused considerable scientific and industrial attention on using underutilized natural resources, especially fruit and vegetable peel powders, as functional ingredients in food systems (Smith et al., 2020; Kumar et al., 2019). Each year, global fruit and vegetable processing generates millions of tons of byproducts, mainly peels, seeds, and pulp, which are often thrown away or not fully used (Chen et al., 2021; Lee et al., 2018). With a pressing need for value addition and waste reduction, using fruit and vegetable peels offers an eco-friendly, cost-effective solution that supports circular food systems and contributes to sustainable development goals (Patel et al., 2022; Singh et al., 2020).

Fruit and vegetable peels often have higher concentrations of beneficial nutrients than the edible parts (Garcia et al., 2017). Rich in dietary fiber, essential minerals, potent phytochemicals like polyphenols, flavonoids, and carotenoids, vitamins, and natural pigments, these peels provide many health benefits (Rao et al., 2019; Zhou et al., 2018). The nutritional advantages of peels from citrus, mango, pomegranate, watermelon, banana, potato, pumpkin, and various other fruits and vegetables have been recognized for their antioxidant, antimicrobial, anti-inflammatory, and immune-supporting effects (Martinez et al., 2020; Wong et al., 2021). Besides direct health benefits, peels enhance sensory qualities—flavor, aroma, color, and texture—that improve the overall eating experience of functional foods (Hussain et al., 2019).

The move from traditional food applications to including fruit and vegetable peel powders shows a change in food formulation strategies and consumer expectations (Kaur et al., 2021). When dried and ground into powder, peels can be easily added to various food products, including baked goods, snacks, jams, bread, cookies, noodles, and beverages, providing multiple advantages (Nair et al., 2022). Using them as natural flavoring agents not only introduces unique flavors and colors but also allows for products with higher dietary fiber, richer micronutrient content, and improved antioxidant activity (Patel et al., 2019). For instance, bread made with orange or banana peel powder maintains great sensory appeal and increased nutritional value, while cookies with pomegranate, jackfruit, or passion fruit peels offer more fiber, polyphenols, and better shelf stability (Das et al., 2020; Mehta et al., 2021).

From a sensory perspective, fruit and vegetable peel powders are highly adaptable. Including them at the right levels adds natural colors, better texture, and a mild flavor that can improve acceptance among both children and adults (Sharma et al., 2018). The dietary fiber in peel powders helps keep food moist and fresh (Gupta et al., 2020). Research indicates that products like noodles or snacks remain appealing and gain extra functional benefits when peels are added in suitable amounts (Singh et al., 2021).

One significant advantage of using fruit and vegetable peel powders is their effect on public health. Adding these powders to everyday foods provides a practical way to increase daily dietary fiber intake, naturally enrich foods with micronutrients, and reduce the need for synthetic preservatives and additives (Patel et al., 2019). The bioactive compounds in peels, like flavonoids and phenolic acids, are associated with a lower risk of chronic diseases, including heart problems, some cancers, and diabetes (Rao et al., 2019; Martinez et al., 2020). Their antimicrobial and antioxidant properties also help preserve food and extend shelf life, benefiting both producers and consumers by decreasing spoilage and the risk of foodborne illnesses (Wong et al., 2021; Kumar et al., 2019).

The environmental and economic benefits of this method are particularly persuasive. Turning what was once seen as waste from agriculture and industry into valuable food ingredients supports zero-waste initiatives and significantly lessens the overall environmental impact of food processing (Lee et al., 2018; Singh et al., 2020). By using peel powders in functional foods, manufacturers can cut production costs, reduce environmental pollution, and create innovative, clean-label products that appeal to health- and eco-conscious consumers (Patel et al., 2022).

Advancements in extraction and processing technologies further enhance the potential of fruit and vegetable peels. Modern methods, like ultrasound-assisted extraction, supercritical fluid extraction, and enzymatic techniques, make it possible to efficiently recover valuable phytochemicals while keeping their bioactivity intact (Gupta et al., 2020; Nair et al., 2022). This technological progress ensures that the resulting peel powders maintain both functional and nutritional properties when added to food products (Sharma et al., 2018).

In conclusion, fruit and vegetable peel powders sit at the intersection of nutrition, sustainability, and food innovation. Their use as natural flavoring agents and functional enhancers in the food industry boosts nutritional quality and sensory appeal while tackling important environmental and public health issues (Smith et al., 2020; Kaur et al., 2021). As food producers, researchers, and consumers increasingly embrace functional foods, the use of peel powders represents a new era of sustainable, wholesome, and attractive food choices that maximize nature's resources while reducing waste and enhancing health benefits (Patel et al., 2022; Singh et al., 2020).

CHAPTER 3

REVIEW OF LITERATURE

Fruit and Vegetable Peel-Enriched Functional Foods: Potential Avenues and Health Perspectives (Wiley, Journal of Food Quality, 2022):

Explores how fruit and vegetable peels can be transformed into valuable ingredients, looking at nutrition, bioactive compounds, and their potential health benefits. Useful for general background and scientific context.

Fruit Peels: Food Waste as a Valuable Source of Bioactive Compounds for Functional Foods (International Journal of Molecular Sciences, 2022, PMC9164088):

Focuses on the unique bioactive compounds found in fruit peels, linking food waste valorization with functional food product development. Great for sections on sustainability and food science innovation.

Nutritional and Functional Potential of Banana Peel Powder (Journal of Recent Trends in Dietetics and Nutrition, 2025):

Highlights banana peel powder's nutritional profile and its benefits when used in foods. Perfect for detailed examples of specific peel applications.

Development and Nutritional Evaluation of Pomegranate Peel Enriched Bars (PLOS ONE, 2025, DOI: 10.1371/journal.pone.0315830):

Presents research on pomegranate peel as a functional ingredient in healthy snack bars, with detailed results on sensory attributes and nutritional quality. Good for application-focused discussion.

Sustainable Valorization of Tropical Fruit Peels for Sustainable Food Products (RSC Food & Function, 2025):

Discusses the transformation of tropical fruit peels—like mango and banana—into nutritionally valuable and eco-friendly food ingredients, with practical insights on improving antioxidant content without sacrificing taste at moderate use levels.

CHAPTER 4

MATERIALS AND INSTRUMENTS

The preparation of natural flavoring agents from fresh fruits or vegetables like carrots or bananas relies on these ingredients as the main raw materials due to their rich aroma, color, and nutrients (Ajila et al., 2007; Balasundram et al., 2006). The process starts with cleaning and slicing the chosen fruits or vegetables. Next, they are dried in a **tray drier** to remove moisture. This drying step helps keep the natural flavor and prevents spoilage from microbes (Hossain et al., 2011). Once fully dried, the materials are ground in a **pulverizer** to create a fine, uniform powder that acts as a stable and concentrated natural flavoring agent (Sharma et al., 2016). The powdered material is then placed in a **desiccator** to cool. This step protects it from absorbing moisture from the air or getting contaminated by bacteria, ensuring the flavoring powder stays dry and has a long shelf life (Lario et al., 2004).

To test the flavoring agent, a standard bakery product, like cake or biscuits, is made using **500 g of wheat flour or all-purpose flour**, **baking soda**, **baking powder**, **500 g of sugar**, **6 eggs**, **100 g of butter**, **½ liter of milk**, and **vanilla essence** (Kulkarni et al., 2012). The prepared fruit or vegetable peel powder is added in suitable amounts to the flour mixture to see how it affects the texture, color, aroma, and taste (Kaur and Kapoor, 2015). The batter is baked, and the final product is assessed for sensory qualities such as flavor, aroma, and overall acceptance (Lario et al., 2004; Sharma et al., 2016). This evaluation helps determine how effective the fruit or vegetable-based flavoring agent is as a natural substitute for synthetic additives, while also encouraging innovation and sustainability in food production (Pathak et al., 2019; Dhillon et al., 2020).

CHAPTER 5

METHODOLOGY

The preparation of natural flavoring powders from fruit and vegetable peels represents an efficient method for the utilization of agro-industrial by-products in functional food development (Bhardwaj et al., 2022). The process begins with the selection and preparation of raw materials, typically fresh fruits or vegetables such as carrots or bananas, chosen for their desirable aroma, color, and nutritional value (Lau et al., 2021). The raw materials are thoroughly washed under running water to eliminate surface dirt, dust, and microbial contaminants (Gupta et al., 2023). The peels are carefully separated from the edible portion, ensuring that only clean and unblemished sections are collected.

To facilitate uniform drying, the peels may be cut into smaller, evenly sized pieces (Ueda, 2023). The next stage involves the drying process, where the prepared peels are evenly spread on trays and placed in a tray drier. The drying temperature is maintained between 50°C and 60°C, which is optimal for moisture removal while preserving sensitive nutrients and volatile flavor compounds (Karam, 2016). The drying continues until the moisture content reduces to approximately 6–8%, a level sufficient to inhibit microbial growth and enzymatic activity (Gupta et al., 2023). This step plays a crucial role in maintaining the functional and sensory properties of the peels by preventing degradation of bioactive compounds.

Following drying, the samples are immediately transferred to a desiccator for cooling and equilibration under controlled, moisture-free conditions. This step prevents reabsorption of atmospheric moisture and minimizes the risk of microbial contamination, thereby ensuring the stability and safety of the dried material. Once cooled, the dried peels are subjected to pulverization using a pulverizer to obtain a fine, uniform powder. Particle size uniformity is essential for consistent blending, flavor distribution, and functional performance in food formulations (Ueda, 2023). The powder may be sieved to remove coarse particles and achieve a standardized texture suitable for application as a natural flavoring agent.

Finally, the packaging and storage stage involves sealing the prepared peel powder in airtight, moisture-proof containers to preserve its quality and prevent oxidative deterioration. The product is stored in a cool, dry environment away from direct sunlight to maintain its nutritional and sensory integrity during storage (VFD Food, n.d.).

Overall, this method ensures the production of a stable, high-quality fruit or vegetable peel powder that can be used as a natural flavoring and functional ingredient in various food products.

It not only enhances the nutritional and sensory attributes of foods but also contributes to sustainable food processing by converting agricultural waste into valuable products (Bhardwaj et al., 2022).

For cake preparation, the standard ingredients include 250g of refined wheat flour (maida), 180g of sugar, 3 eggs, milk, 100 ml butter or oil, 2 tsp of baking powder,half tsp of baking soda, a pinch of salt, 1 tsp of vanilla essence and 4 tsp flavoring agents. The recipe is modified by partially substituting the wheat flour with a measured quantity (typically 2–10%) of the prepared orange or carrot peel powder (Sharma et al., 2019). The process begins with creaming the butter and sugar together until the mixture becomes light and fluffy. Eggs are then added one at a time, beating well after each addition to ensure proper aeration. In a separate bowl, the dry ingredients—flour, baking powder, and the peel powders—are sifted together to ensure uniform mixing and to avoid lumps (Kumar & Thakur, 2020). The dry mixture is then gradually incorporated into the creamed mixture, alternating with milk to achieve a smooth, pourable batter (Singh et al., 2021).

Once the batter is ready, it is poured into a greased and lined baking tin. The cake is baked in a preheated oven at around 170–180°C for 25–35 minutes or until a toothpick inserted in the center comes out clean (Bhat & Hafiza, 2018). After baking, the cake is allowed to cool at room temperature before demolding. The incorporation of orange and carrot peel powders not only imparts a pleasant aroma, natural color, and mild fruity flavor to the cake but also enhances its fiber content, antioxidant properties, and overall nutritional value (Meena et al., 2022). This method offers an effective way to utilize fruit and vegetable processing by-products, reducing food waste while producing value-added functional bakery products (Ravindran et al., 2020).The cake was spongy, porous and exhibited a flavour of orange and carrot influenced in all four trials.

Formula to calculate moisture content in percentage :

Moisture content(%) = $\frac{weigh\ \ of\ sample\ before\ drying - wei\ \ \ \ of\ sample\ after\ drying}{weight\ of\ sample\ before\ drying} \times 100$

i) **CARROT POWDER:**

Moisture content(%) for carrot powder = $\frac{weig\ \ \ of\ sample\ before\ drying - weight\ of\ sample\ after\ drying}{wei\ \ \ \ of\ sample\ before\ drying} \times 100$

Where,

Weight of sample before drying = carrot weight = 248.6 g

Weight of sample after drying = carrot weight after drying = 24.3 g

Therefore ,

Moisture content(%) of carrot powder = $\frac{248.6 - 24.3}{248.6} \times 100$ = 90.22%

Hence, the moisture content of carrot powder in percentage is **90.22%**

ii) **ORANGE PEEL POWDER:**

Moisture content (%)of orange peel powder=$\frac{weigh\ \ of\ sample\ before\ drying - weigh\ \ of\ sample\ after\ drying}{weight\ of\ sample\ before\ drying}$ ×100

Where,

Weight of sample before drying = weight of orange peel = 114.7 g

Weight of sample after drying = weight of dried orange peel = 32.5 g

Therefore,

Moisture content(%) of orange peel powder = $\frac{114.7-32.5}{114.7} \times 100$ = 71.66%

Hence, the moisture content of orange peel powder is **71.66%**

iii) **CARROT CAKE TRIAL I :**

Moisture content(%) of carrot cake = $\frac{weight\ of\ sample\ before\ baking - weight\ of\ sample\ after\ baking}{weigh\ \ of\ sample\ before\ baking} \times 100$

Where,

Weight of sample before baking = weight of batter = 310 g

Weight of sample after baking = weight of the cake = 289.7 g

Therefore,

Moisture content(%) of carrot cake = $\frac{310 - 289.7}{310} \times 100 = 6.548\%$

Hence, the moisture content of carrot cake is **6.548%**

iv) **CARROT CAKE TRIAL II :**

Moisture content (%) of carrot cake = $\frac{weight\ of\ sample\ before\ baking - weigh\ \ of\ sample\ after\ baking}{weight\ of\ sample\ before\ baking} \times 100$

Where,

Weight of sample before baking = weight of batter = 352.7 g

Weight of sample after baking = weight of the cake = 306.4 g

Therefore,

Moisture content(%) of carrot cake = $\frac{352.7 - 306.4}{352.7} \times 100 = 13.127\%$

Hence, the moisture content of the carrot cake is **13.127%.**

v) **ORANGE CAKE TRIAL I :**

Moisture content (%) of orange cake = $\frac{weigh\ \ of\ sample\ before\ baking - weigh\ \ of\ sample\ after\ baking}{weig\ \ \ of\ sample\ before\ baking} \times 100$

Where,

Weight of sample before baking = weight of batter = 302.2 g

Weight of sample after baking = weight of the cake = 298.4 g

Therefore,

Moisture content(%) of orange cake = $\frac{302.2 - 298.4}{302.2} \times 100 = 1.257\ \%$

Hence, the moisture content of the orange cake is **1.257%.**

vi) **ORANGE CAKE TRIAL II:**

Moisture content (%) of orange cake = $\frac{weight\ of\ sample\ before\ baking - weigh\ \ of\ sample\ after\ baking}{weight\ of\ sample\ before\ baking} \times 100$

Where,

Weight of sample before baking = weight of batter = 315.9 g

Weight of sample after baking = weight of the cake = 284.3 g

Therefore,

Moisture content(%) of orange cake = $\frac{315.9 - 284.3}{315.9} \times 100 = 10.0031\ \%$

Hence, the moisture content of the orange cake is **10.0031%.**

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