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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(9): 1794-1799

www.thepharmajournal.com
Received: 20-06-2023
Accepted: 24-07-2023

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# Health benefits of kinnow (*Citrus reticulata* cv.) peel

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### Abstract
In this comprehensive review, we have delved into the multifaceted potential of Kinnow peel, an often-neglected by-product of the fruit processing industry. Kinnow peel has emerged as a valuable resource with a wide range of applications and utilizations that can significantly impact various sectors. From its transformation into delectable candies to its role as a source of biofuel and carbon nanofibers, Kinnow peel has showcased its versatility in addressing critical issues like food waste and sustainable energy production. Its incorporation as a functional ingredient in bread highlights its importance in enhancing the nutritional value of food products. Moreover, the broader utilization of fruit and vegetable waste, including Kinnow peel, in different food formulations signifies a promising path towards waste reduction and more sustainable food production. Additionally, the development of food-grade plastics from Kinnow peel extracts underscores its potential in environmentally friendly packaging solutions that also preserve food quality. Overall, this review underscores the significance of recognizing and harnessing the untapped potential of agricultural by-products like Kinnow peel. These diverse applications and utilizations not only contribute to waste reduction but also promote sustainability and innovation across multiple industries. As we move towards a more resource-efficient future, Kinnow peel stands out as a valuable ally in addressing complex global challenges.

**Keywords:** Kinnow peel, bioactives, health benefits

### Introduction
Kinnow (*Citrus reticulata cv.*) hybrid variety of king and willow mandarins (*Citrus nobilis Lour x C. deliciosa Tenore*) that has gained immense popularity for its exquisite taste and numerous health benefits which is first developed by Howard B. Frost, at the University of California. Kinnow is from Rutaceae family that belongs to class Magnoliopsida and order Sapindales [1]. It is major citrus fruit grown in a northern region of India, especially in Punjab, Haryana, Rajasthan, and Himachal Pradesh captivating the taste buds of millions and becoming a staple in kitchens, juice bars, and culinary experiments [2].

The interplay between the sharpness of its tang and the underlying sweetness creates a harmonious flavor profile that distinguishes Kinnow from other citrus varieties. This flavor balance lends itself to a wide array of culinary applications, ranging from fresh consumption to juices, desserts, salads, and even savory dishes, infusing a zesty twist into gastronomic creations.

Beyond its delectable taste, Kinnow boasts a rich nutritional profile that bolsters its status as a superfruit. Bursting with vitamin C, a powerful antioxidant, Kinnow contributes to immune system support, collagen synthesis, and overall well-being. The fruit also contains dietary fiber, aiding digestion and promoting a healthy gut. Potassium, a vital electrolyte, is present in Kinnow, helping regulate blood pressure and supporting heart health [1]. Additionally, the fruit contains B-vitamins, flavonoids, and other bioactive compounds that offer an array of health benefits, from anti-inflammatory properties to potential cancer-fighting abilities and underscored their antioxidant and anti-pathogenic properties. These findings illuminate Kinnow's potential role in food preservation and healthcare. Kinnow pulp residual trash is high in cellulose (40%), hemicellulose (10%), pectin (2%), and antioxidants (15%) [2].

The Kinnow fruit has not only enriched diets but also economies. Its adaptability to diverse climatic conditions and relatively low susceptibility to diseases have led to increased cultivation, generating livelihoods for numerous farmers around the world. An in-depth economic analysis conducted in 2016 in the Fazilka District of Punjab shed light on the cultivation and marketing of Kinnow. The study highlighted its economic significance as a major citrus crop in the region, contributing significantly to both local employment and revenue generation. The findings underscored the importance of Kinnow as a cash crop, supporting the livelihoods of numerous farming households [3].

Kinnow industry by products are such as Kinnow pomace includes peel and pulp residue [2]. Kinnow's potential extends beyond its consumption as a fresh fruit. Various studies have explored the industrial applications of different parts of the fruit, emphasizing the value addition that can be achieved. Additionally, the byproducts of the Kinnow industry, such as the peel and seeds, have been utilized for preparing fiber-enriched extruded products and bioactive compounds, broadening its utility and minimizing waste [2]. Similarly, in-depth analyses of citrus peel oils underscored their antioxidant and anti-pathogenic properties. These findings illuminate Kinnow's potential role in food preservation and healthcare.

Kinnow peel is a rich source of bioactive compounds that hold immense nutritional and medicinal value. Notably, gallic acid found in Kinnow peel exhibits antiviral, antifungal, antioxidative, and antidiabetic properties [4]. Chlorogenic acid contributes to regulating blood pressure, fat metabolism, and enhancing endothelial functionality. Other compounds like ferulic acid, p-coumaric acid, and caffeic acid possess antimicrobial, antioxidant, and anti-inflammatory properties, promoting overall health. Kinnow peel also contains catechin, hesperidin, naringin, quercetin, kaempferol, and limonin, each offering distinct health benefits, including antioxidant effects, blood pressure regulation, anti-inflammatory properties, and potential anticancer [5-7]. These bioactive compounds hold promise in managing cardiovascular health, diabetes, inflammation, and cancer prevention. As researchers delve deeper into their potential, Kinnow peel emerges as a valuable resource for functional foods, dietary supplements, and pharmaceutical applications, contributing significantly to human well-being. Its diverse range of bioactive compounds positions Kinnow peel as a potent player in the pursuit of enhanced health and wellness.

**Fig 1:** A whole Kinnow

**Fig 2:** Kinnow Pulp

**Fig 3:** Kinnow Peel

## Nutritional composition

The nutritional composition of kinnow (*Citrus reticulata* cv.) on both a fresh and dry basis consists of the following components per 100 grams: moisture (85 g), protein (0.66 g), fat (6 g), dietary fiber (11.33 g), calcium (4.66 mg), phosphorus (0.67 mg), iron (1.73 mg), thiamine (0.13 mg), riboflavin (0.067 mg), niacin (0.067 mg), vitamin C (2.6 mg), and zinc (0.046 mg). Additionally, it provides 380 kcal of energy per 100 grams of fruit, making it a nutritionally balanced and healthful choice. Kinnow (*Citrus reticulata cv.*) also contains dietary fibre and polysaccharides such as pectin and heteropolysaccharides, which are heteropolysaccharides made up of sugars such as arabinose, galactose, glucose, rhamnose, and xylose in a molar ratio. Alkaloids, flavonoids, steroids, phenols, and carbohydrates are abundant in the peels. Phytochemical properties of peel contain Alkaloids, flavonoids, steroids, phenols, carbohydrates, limonene.

Citrus fruit pulp and peel are both good sources of macro- and micronutrients. Because the amount in the peel of most of the fruits studied greatly outnumbers the amount in the pulp, particular consideration should be given to its potential use as a component of a functional food or in the pharmaceutical business. Citrus fruit peel may be utilised to make mineral preparations with varied compositions and qualities, as well as extruded morning cereals with high potassium, phosphorus, and calcium content [8].

**Table 1:** Mineral content in Kinnow Peel in 100 g [8]

| Minerals | Amount |
|---|---|
| Potassium (mg) | 154 |
| Sodium (mg) | 0.54 |
| Calcium (mg) | 41.9 |
| Phosphorus (mg) | 25.3 |
| Magnesium (mg) | 13.2 |
| Iron (mg) | 0.51 |
| Zinc (mg) | 0.25 |
| Copper (mg) | 0.15 |
| Manganese (mg) | 0.13 |
| Selinium (µg) | 2.35 |

## Bioactive compounds present in kinnow peel and their health benefits

Citrus peels are a rich source of bioactive compounds that offer a myriad of health benefits. These compounds have gained considerable attention from researchers and health enthusiasts due to their potential to promote well-being and prevent various chronic diseases. The bioactive constituents found in citrus peels include gallic acid, chlorogenic acid, ferulic acid, p-coumaric acid, caffeic acid, catechins, hesperidin, naringin, quercetin, kaempferol, and limonin. Gallic acid, present in citrus peel, exhibits antiviral, antifungal, astringent, and antioxidant properties, making it a potential tool against various diseases [4]. Studies have shown that gallic acid can significantly reduce blood glucose levels, offering potential benefits for individuals with diabetes [9]. Chlorogenic acid is another bioactive compound found in citrus peel. It plays a crucial role in regulating blood pressure, maintaining fat metabolism, and improving endothelial functionality. These properties make it beneficial for heart health [9]. Ferulic acid, with its antimicrobial properties, helps maintain membrane functionality and regulates glucose levels. It has been observed to decrease blood glucose levels in diabetic rats and may have potential applications in diabetes management [10]. P-Coumaric acid, present in citrus peel, acts as an antimicrobial compound with a broad spectrum of activity. It forms pores in microbial membranes and enhances membrane permeability, making it effective against various pathogens.

Caffeic acid is known for its antioxidant, anti-inflammatory, and anticancer properties. It has been studied for its role in protecting DNA from oxidative stress and is used in skincare formulations and pharmaceuticals [11]. Catechins, such as epigallocatechin, found in citrus peel, are well-known for their health benefits. They regulate ion absorption and transportation within the body, impacting various biological pathways [7]. Hesperidin, a derivative of flavonoids in citrus fruits, acts as an antioxidant, metal chelator, and blood pressure regulator. It also exhibits anti-inflammatory properties and may help with conditions like hay fever and menopausal symptoms [12]. Naringin, another flavonoid found in citrus peel, offers antioxidant properties, regulates protein secretion, and improves liver functioning. It has shown promise in various studies, including its potential to control cholesterol levels and liver [13]. Kaempferol, present in citrus fruits, plays a role in regulating apoptosis and signaling pathways, potentially affecting cancer cells [5]. Limonin is a multifunctional bioactive compound in citrus peel, known for its anti-obesity and anticancer properties. It has been studied for its potential role in maintaining weight and combating [6]. These bioactive compounds found in citrus peels offer a wide range of health benefits, including antioxidant and anti-inflammatory effects, regulation of blood pressure and glucose levels, and potential anticancer properties. Incorporating citrus peel into one's diet or considering supplements may provide a natural and holistic approach to improving overall health and well-being.

**Table 1:** Bioactive compounds present in Kinnow peel

| Bioactive compounds | Reference |
|---|---|
| Gallic acid | [4] |
| Chlorogenic acid | [9] |
| Ferulic acid | [10] |
| p-Coumaric acid | [22] |
| Caffeic acid | [11] |
| Catechin | [7] |
| Hesperidin | [12] |
| Naringin | [13] |
| Kaempferol | [5] |
| Limonin | [6] |

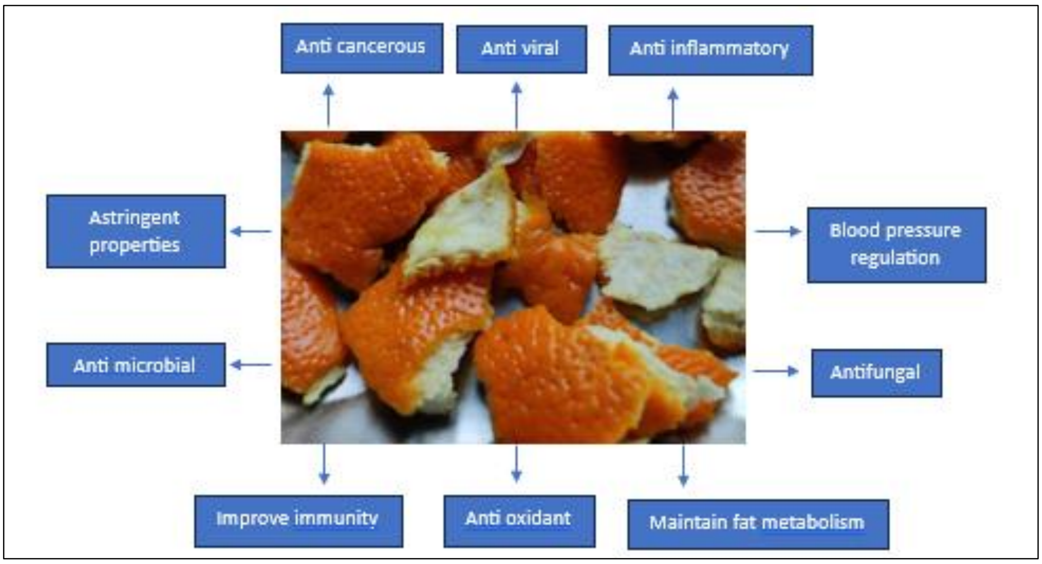


**Fig 1:** Health benefits of Kinnow peel.

### *In vivo* and *In vitro* studies with kinnow

The paper explores a novel strategy to combat Huanglongbing (HLB) in 'Kinnow' mandarin plants by using plant-derived silver nanoparticles (AgNPs). HLB is a severe citrus disease that disrupts the plants' antioxidant defense system, making them vulnerable to oxidative stress. The study's primary goal is to enhance the antioxidant defense system in HLB-affected 'Kinnow' mandarin plants by synthesizing AgNPs from plant extracts.

The methodology involves synthesizing AgNPs through a phytomediated process, employing plant extracts as reducing agents. HLB-infected 'Kinnow' mandarin plants are treated with these AgNPs. The study assesses the impact on the antioxidant defense system, measuring antioxidant levels (e.g., ascorbic acid, glutathione), enzymatic activities (e.g., superoxide dismutase, catalase), and oxidative damage (e.g., lipid peroxidation). Results indicate that plant-derived AgNPs significantly improve the antioxidant defense system in HLB-affected 'Kinnow' mandarin plants, increasing antioxidant levels, enhancing enzymatic activities, and reducing oxidative damage. This enhancement boosts plant resilience against HLB. The study suggests that phytomediated AgNPs hold promise for mitigating HLB's adverse effects on 'Kinnow' mandarin plants by bolstering their antioxidant defense system. This eco-friendly approach may revolutionize HLB management, reducing reliance on chemical treatments and promoting sustainable citrus production.

In a study harnessed the unique phytochemical composition of Kinnow mandarins to create K-AuNPs. The process likely involves utilizing extracts from Kinnow mandarin peels and other parts rich in bioactive compounds to reduce gold ions into nanoparticles. The antimicrobial properties of K-AuNPs are of particular interest. These nanoparticles demonstrate the ability to inhibit the growth of various pathogenic microorganisms, potentially offering a natural and effective approach to combat infections. The study likely presents data showing the inhibitory effects of K-AuNPs against bacteria, fungi, or other harmful microbes. Furthermore, the research explores the antidiabetic potential of K-AuNPs. These nanoparticles play a role in regulating blood glucose levels, making them a valuable candidate for managing diabetes. The study probably discusses experiments demonstrating the impact of K-AuNPs on insulin sensitivity, glucose metabolism, or other relevant factors the study highlights how Kinnow mandarins can serve as a source of natural gold nanoparticles with notable antimicrobial and antidiabetic properties. The potential applications of K-AuNPs in healthcare and medicine are significant, offering promising avenues for further research and development in the fields of infection control and diabetes management [14].

A study focuses on inducing *in vitro* flowering in embryogenic cultures of Kinnow mandarin (*Citrus nobilis* Lour × *C. deliciosa Tenora*) through a variety of techniques. The researchers sought to develop a reliable and efficient method for flowering in citrus cultures, which is crucial for breeding programs and year-round fruit production. In their investigation, they explored several factors influencing the flowering process, including the growth medium, hormonal treatments, and environmental conditions. The researchers meticulously optimized these parameters to induce flowering in the embryogenic cultures successfully. The findings of the study reveal that by carefully manipulating the growth conditions and employing specific hormonal treatments, they were able to stimulate *in vitro* flowering in the Kinnow mandarin cultures. This achievement is significant as it offers a potential means to accelerate breeding programs and improve fruit production in citrus crops. The development of this *in vitro* flowering technique could have broader implications for citrus agriculture, ultimately contributing to enhanced citrus cultivation and sustainability [15].

A study focuses on enhancing somatic embryogenesis in Kinnow mandarin through modified in ovulo nucellus culture, while also ensuring true-to-the-type plantlet regeneration via molecular and histological validation. The researchers aimed to improve the efficiency of somatic embryogenesis, a crucial technique for citrus propagation, by refining the in ovulo nucellus culture method. The modifications made in the culture conditions and the use of specific growth regulators were designed to boost the competency of somatic embryogenesis. Through this modified approach, the researchers were able to induce the development of somatic embryos more effectively. To ensure the fidelity of the regenerated plantlets, molecular and histological techniques were employed. These methods helped verify that the newly generated plantlets were indeed true-to-the-type, preserving the desirable genetic characteristics of Kinnow mandarin, this study presents an improved method for somatic embryogenesis in Kinnow mandarin, validated through molecular and histological means to ensure the retention of desired traits in regenerated plantlets. This advancement holds promise for efficient citrus propagation and the maintenance of genetic purity in citrus crops [16].

A paper investigates the effectiveness of essential oils both *in vitro* and *in vivo* against significant postharvest pathogens that affect Kinnow mandarin. Postharvest diseases often lead to substantial citrus fruit losses, and finding eco-friendly and efficient methods to control these pathogens is crucial. In the study, they evaluated various essential oils for their antifungal properties against key postharvest pathogens of Kinnow mandarin. The results demonstrated that essential oils derived from certain plant sources exhibited notable antifungal activity *in vitro*, suggesting their potential as natural alternatives to synthetic fungicides. Furthermore, the study extended its findings to *in vivo* experiments, where the selected essential oils were applied to Kinnow mandarin fruits. The results indicated that these essential oils effectively reduced disease development and extended the shelf life of the fruit. In summary, this research highlights the promising potential of essential oils as natural and eco-friendly alternatives to combat postharvest pathogens in Kinnow mandarin, offering a sustainable approach to preserving fruit quality and reducing postharvest losses [17].

This paper investigates the impact of Kinnow juice consumption on the pharmacokinetics of sustained-release theophylline in healthy male volunteers. Theophylline is a widely used bronchodilator for treating respiratory conditions like asthma and chronic obstructive pulmonary disease (COPD). Understanding how dietary factors can affect its pharmacokinetics is essential for optimizing treatment outcomes. The study involved administering sustained-release theophylline to volunteers both with and without the consumption of Kinnow juice. The results indicated that Kinnow juice consumption led to a significant alteration in the pharmacokinetic parameters of theophylline. This alteration could potentially affect the drug's therapeutic efficacy and safety profile. These findings emphasize the importance of considering dietary factors when prescribing theophylline to patients. Healthcare providers may need to adjust dosages or advise patients on dietary restrictions to ensure optimal drug efficacy and minimize the risk of adverse effects. This research underscores the need for healthcare professionals to be aware of potential interactions between medications like theophylline and dietary components like Kinnow juice, as these interactions can have clinical implications for patient management and treatment effectiveness [18].

Kinnow peel, the often-discarded outer layer of the Kinnow fruit, holds immense potential across various industries. It can be transformed into edible candy, offering a unique and sustainable confectionery option while reducing food waste. Moreover, its use as a source of biofuel and carbon nanofibers underscores its role in renewable energy and advanced materials production. Kinnow peel's versatility extends to the culinary world, where it enriches bread with enhanced attributes, emphasizing its value as a functional food ingredient. Beyond bread, Kinnow peel represents a broader trend in utilizing fruit and vegetable waste in innovative food formulations, reducing waste and enhancing nutrition. Additionally, Kinnow peel's supercritical extracts prove suitable for food-grade plastics production, presenting an eco-friendly solution to packaging with food-preserving properties. In essence, Kinnow peel's applications and utilizations span candy production, biofuels, functional foods, waste reduction, and sustainable packaging, highlighting its significance in addressing environmental concerns and promoting resource efficiency across multiple sectors.

Noteable application and utilization of Kinnow peel

| Application | Result | Reference |
|---|---|---|
| Candy | Kinnow peel can be repurposed into edible candy by drying it, shaping it, and cooking it with varying levels of sugar syrup at different temperatures and durations. | [19] |
| Biofuel | As a biofuel and a source of carbon nanofibers, kinnow peel has the potential to be utilised as a source of energy. | [19] |
| Fuctional ingredient in bread | Kinnow peel, a significant by-product (30%–34%) of Kinnow processing, is a valuable source of phytochemicals. This study examined the impact of kinnow peel powder (KPP) at various concentrations on bread's functional, baking, texture, antioxidant, and sensory attributes. | [23] |
| Peel enriched functional food | Utilization of fruit and vegetable residues in various food compositions. | [20] |
| Food grade plastics | Supercritical extracts and fractions obtained from peel sources have demonstrated their suitability for the production of food-grade plastics that possess food-preserving characteristics. | [21] |

## Conclusion

In conclusion, this review paper has shed light on the multifaceted potential of Kinnow peel, a by-product often overlooked and discarded in the fruit processing industry. Our exploration of various applications and utilizations has unveiled a spectrum of opportunities that can contribute to sustainability, waste reduction, and innovation across several industries. From its transformation into edible candy to its role as a source of biofuel and carbon nanofibers, Kinnow peel has demonstrated its versatility and value in addressing pressing challenges such as food waste and renewable energy. The incorporation of Kinnow peel powder into bread not only enhances the bread's functional attributes but also underscores its significance as a functional food ingredient, contributing to improved nutrition. Furthermore, the broader concept of utilizing fruit and vegetable waste in diverse food formulations showcases the potential for Kinnow peel to inspire similar waste-reduction initiatives, fostering a more sustainable food industry. Additionally, the production of food-grade plastics from Kinnow peel extracts offers an eco-friendly alternative for packaging solutions, aligning with the growing demand for environmentally responsible materials. In essence, this review paper highlights the importance of recognizing and harnessing the untapped potential of agricultural by-products like Kinnow peel. These applications and utilizations not only mitigate waste but also pave the way for a greener, more resource-efficient future, where sustainability and innovation go hand in hand to address the complex challenges facing our world.

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