International Journal of Pharmacognosy and Pharmaceutical Sciences

**ISSN Print:** 2706-7009
**ISSN Online:** 2706-7017
IJPPS 2024; 6(1): 22-27
www.pharmacognosyjournal.net
Received: 15-11-2023
Accepted: 22-12-2023

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# Orange peel: A comprehensive review on residue properties

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**DOI:** https://dx.doi.org/10.33545/27067009.2024.v6.i1a.134

**Abstract**
Growing consumer awareness has made it more economical and environmentally friendly to use renewable resources. Orange fruits, also known as citrus fruits, are rich in various vitamins, minerals, folic acid, and antioxidants such carotenoids, flavonoids, anthocyanin's, and phenolic acids. They also contain linalool, which is present in large amounts (35%), such as fiber to support healthy immunity, which includes the stomach and digestive system; it is also beneficial for expectant mothers as it enhances digestion and promotes waste removal. All these have laxative and low-cholesterol properties as well as anti-infection, anti-cancer, diabetic, and anti-bacterial effects. Orange peel is thought to be quite useful for a number of medical conditions when consumed regularly. Orange peels can be used in an interesting process called anaerobic digestion, which produces biogas from food waste since it has a high energy content. This work has addressed the analysis of *in-vitro* and *in-vivo* tests for various purposes. Peels are an excellent natural source of health-promoting phytochemicals and can be used in the food sector as natural, preferred antioxidants and antimicrobials, anti-fungal, and used s for production of biofuels. More beneficial than Orange fruit is Orange peel. It is applied topically and taken orally, important information that can be helpful in selecting the best extraction technique for bioactive chemicals from vegetable sources. The review presents a comprehensive description on the Orange peel as various biological properties and other activities.

**Keywords:** Orange peel, antimicrobial, antioxidant, phenolic contents, orange peel extract, orange peel contains

## Introduction
Citrus production reached 122.09 million tons worldwide in 2008. Approximately 60% of the citrus produced worldwide is Orange. Egypt produced 3.23 million tons of citrus fruit in 2008, of which 2.14 million tons were Oranges [1]. The Rutaceous, or Rue family, includes the genus Citrus, which has 1,300 species and roughly 140 genera. Among the significant fruits of the Citrus genus are *Citrus Sinensis* (Orange), Citrus parades (grapefruit), Citrus Limon (lemon), Citrus reticulate (tangerine), Citrus grandis (shaddock), Citrus aurantium (sour Orange), Citrus medical (citrus), and Citrus aurantifolia (lime) [2]. The citrus industry is currently quite interested in studies that examine the presence of polyethoxylated flavones in byproducts produced from processing citrus fruit, as these advantageous actions point to new value-added uses for these compounds as nutraceuticals and specialty ingredients. The concentrations of the primary flavone glycosides in Orange peel molasses were previously published [3]. The presence of several bioactive components in citrus, including phenolic compounds, limuloids, flavonoids, and poly-saccharides, which scavenge single oxygen, hydroxyl radicals, and lipid per-oxyl radicals, is what gives the peel its antioxidant action. Additionally, it was shown that citrus peels have strong antibacterial action against a number of food-borne diseases [4]. Peel waste is an issue for the processing businesses and environmental monitoring agencies because it is particularly perishable and seasonal. The need of turning garbage into valuable products is constantly being highlighted. Materials and leftover Oranges are not an exception. The overall economics of processing facilities can be enhanced by recovering products from fruit trash. In addition, environmental contamination is a problem that can be significantly lessened. Citrus peels are nutrient-dense and packed with phytochemicals, making them useful as dietary supplements or medications.

An alternate medication is always being sought after due to the rise of bacteria that are resistant to antibiotics. The creation of novel medications to address the issue of antimicrobial resistance is one potential remedy. If citrus peels are shown to have antibacterial properties, they can also be utilized as food preservatives in the food industry, which produces a lot of peel waste [5]. Appropriate techniques must be used to turn Orange pulp and peel into goods with additional value. Reducing environmental contamination is another possibility. Citrus peels are high in minerals and phytochemicals, and they can be effectively employed as dietary supplements or medications. Pathogens that are resistant to antibiotics are becoming more common, and researchers are always looking for safe substitute medications [6]. Citrus peel extract (CPE) polymethoxyflavones (PMFs) have anti-inflammatory properties that are seen in both gene expression and enzyme function. In our laboratory, we have identified and characterized the main constituents of Orange peel extracts (OPE), which include sinensetin, negolitin, tangeretin, tetra, hexa, and hepta-MFs. These six PMFs were supplemented with their 5-demethylated counterparts, which were added as HPLC standards. Using our cell-based biological screening technique, we discovered that OPE caused the down regulation of inflammatory genes like COX-2, TNF-a, ICAM-1, NFkB, IL-1b, IL-6, and IL-8 [7]. Numerous antioxidants, including those that exhibit metal chelation and free radical scavenging properties, are found in Orange peel. Studying the phytochemicals found in C. sinensis is encouraging because reactive oxygen species (ROS) are important in a number of diseases, such as cancer, ageing, cardiovascular dysfunction, and neurodegenerative diseases. C. sinensis contains a high concentration of GOFA, which has been shown to have neuro protective and chemo preventive effects on colon cancer in rats when fed as diet, as demonstrated by recent studies using citrus peel extract to identify 4-gernyloxyferulic acid). Citrus peels have received a lot of interest since they have a wide range of qualities in their poly methyl flavones (PMFs) and alkaloids. [8]. Anaerobic digestion (AD) is one of the intriguing technologies that uses Orange peels since food waste has a high energy content, is abundantly available, and is a promising substrate for the production of biogas [9]. Orange peel is widely used in the soft drink industry and is typically disposed of as waste. Because of its several functional groups, including hydroxyl and carboxyl, it has the potential to be an adsorbent material for the removal of metals. Numerous research regarding the use of modified Orange trash in conjunction with water-based heavy metal adsorption have been proposed in the literature. A number of research demonstrate the manufacture of a modified Orange peel adsorbent and examine its ability to remove five different heavy metal ions (Cu2+, Cd2+, Pb2+, Zn2+, and Ni2+). [10]. A special type of flavonoids known as polymethoxyflavones (PMFs) have at least two methylhydroxy groups on the flavone backbone. Citrus seeds, leaves, stems, juice, and peels are all shown to contain PMFs in significant amounts. Numerous bioactivities, such as neuro protection, anti-inflammatory, anti-cancer, anti-obesity, and anti-atherosclerosis properties, have been demonstrated by PMFs. For many years, PMFs have been researched for their potential to protect against Mets because of their strong anti-inflammatory properties. PMFs have superior bio-efficiency against obesity and dyslipidemia both *in vitro* and *in vivo* when compared to citrus flavones (such as hesperidin and naringenin). Emerging research conducted in the last five years has shown that PMFs regulate *in vivo* lipid and glucose metabolism in addition to the circadian clock and gut micro biome. [11]. Citrus fruits contain citric acid, which aids in the conversion of oxalates into citrates, which are comparatively more soluble in water and may be excreted through the urine, lowering the possibility of internal stone formation. [12]. Fruit peels have the ability to adsorb heavy metals because of the abundance of polysaccharides in their cell walls, which are mostly made of cellulose and pectin molecules. When exposed to an alkaline environment, these compounds ionize and produce negative charges that bind metal cations. Orange peels with cellulose bases and both acidic and alkali treatments have been shown to be adsorbent materials for the adsorption of Cu+2, Zn+2, Co+2, Ni+2, and Pb +.[13].

**What is powdered Orange Peel?**

Natural herbal Orange peel powder can be used to treat a variety of illnesses and achieve attractive skin. It has much more vitamins, minerals, and other nutrients than the Orange itself. [14].

**Fig 1:** Orange Peel. [15].

**Phenolic content**

Phytochemicals, particularly the phenolic found in fruits and vegetables, are important bioactive substances with proven health advantages. Studies have shown that plant phenolic are found in both edible and non-edible portions of the plant, and that these components of the plant can benefit from the compounds' numerous biological benefits. The processes underlying phytophenolics' role in disease prevention and health promotion include, but are not limited to, changes in estrogens metabolism, cell differentiation, DNA repair maintenance, pro-carcinogens deactivation, and suppression of N-nitrosamine production. Free radical scavenging and metal chelation activities are two important processes for the antioxidant impact of phenolic in functional meals. Reactive oxygen species (ROS) have been discovered to be supportive in the pathogenesis of humans. Examples of ROS include the superoxide radical O}-2 \, hydrogen peroxide ($H_2O_2$), hypochlorous acid (HOCl), and the hydroxyl radical (HO). By scavenging free radicals and quenching ROS, Phyto phenols offer efficient ways to prevent and treat diseases mediated by free radicals, including cancer, diabetes, neurodegenerative diseases, the aging process, and cardiovascular dysfunction. Furthermore, a large number of antioxidants present in plants have a variety of biological effects, such as antiviral, antibacterial, anti-inflammatory, antiallergic, antithrombotic, and vasodilators properties. Numerous potent phytochemicals that can safeguard health can be found in citrus, one of the

most widely grown fruits in the world (*Citrus* L., Rosacea). Additionally, it offers a good amount of potassium, folic acid, pectin, and vitamin C. The phytochemical makeup of citrus species has been assessed for its potential to promote health from a variety of backgrounds. Primary bioactive substances with well-established health advantages are phytochemicals, particularly the phenolic found in fruits and vegetables. Research findings indicate that phenolic found in plants are not limited to Several biological impacts of their existence have been documented in non-edible plant parts in addition to their presence in edible plant parts. Among other things, cell differentiation, pro-carcinogens deactivation, DNA repair maintenance, inhibition of N-nitrosamine production, and altered estrogen metabolism are the mechanisms underlying Phyto phenolics' role in promoting health and preventing disease. The primary processes via which phenolic in functional foods have an antioxidant impact are their ability to scavenge free radicals and to chelate metals. Reactive oxygen species (ROS) have been discovered to be supportive in the pathogenesis of humans. Examples of ROS include the superoxide radical ̧O}-2 \, hydrogen peroxide ($H_2O_2$), hypochlorous acid (HOCl), and the hydroxyl radical (HO). By scavenging free radicals and quenching ROS, Phyto phenols offer efficient ways to prevent and treat diseases mediated by free radicals, including cancer, diabetes, neurodegenerative diseases, the aging process, and cardiovascular dysfunction. Furthermore, a large number of antioxidants present in plants have a variety of biological effects, such as antiviral, antibacterial, anti-inflammatory, antiallergic, antithrombotic, and vasodilators properties. Citrus (*Citrus* L., Rosaceae), one of the most widely grown fruits in the world, has a variety of potent phytochemicals that have potential health benefits. It also offers a good amount of potassium, folic acid, vitamin C, and pectin. Citrus species from different regions have been assessed for their phytochemical makeup and role in promoting health. [16].

**Flavonoid content**

Polyphenol substances known as flavonoids have a phenyl benzopyrone structure, which is made up of two benzene rings (C6) connected by a linear three-carbon chain (C3) and a carbonyl group at position C. Despite the fact that flavonoids are typically thought of as non-nutritive substances, many researchers are interested in learning more about their possible function in the prevention of serious chronic diseases. Citrus flavonoids consist of two classes of flavones: O-methylated flavones (like nobiletin and tan-gratin), which are relatively frequent polyethoxylated flavones (PMFs), and a class of glycosides like hesperidin and naringin. Citrus fruits' peels are said to have the largest concentrations of PMFs when compared to the fruit's other edible sections. Citrus flavonoids have been discovered to possess health-related properties, such as reducing cervical fragility, inhibiting human platelet aggregation, and having anti-inflammatory, antiviral, and anti-cancer properties. It is simple to transform some glycosylated flavones into their equivalent dihydroxy chalcones, which are strong naturally occurring sweeteners. The flavonoids in Orange peel have a wide range of biochemical roles, which have been thoroughly investigated recently. They decreased the oxidative stress experienced by the elderly and raised serum antioxidant capacity against lipid peroxidation. These substances have anti-inflammatory, anti-tumor, and anti-atherosclerotic properties [16].

## Materials and Methods

**Collection and preparation of extract**

I bought Oranges at the Shah Faisal colony local market in Karachi. After washing and drying in natural sunshine at 37±2 °C for six days, the Orange peel was kept in a hot air oven for fifteen minutes at 20 °C to eliminate any residual moisture. Six grams of dry peel were macerated in 50 milliliters of ethanol for two days at room temperature (25±2 °C) after six days. What man filter paper was used to filter the solvent-extracted material, and the extract was stored in the refrigerator until needed [17].

**Extract preparation**

**Extraction of soxhlet**

Using a Soxhlet extractor, the Orange peel powder was extracted using a variety of solvents, including hexane, methanol, and acetone. 100g of powdered Orange peel was extracted using the Soxhlet extraction method for five hours at 50 °C using 750 ml of solvent (hexane, methanol, or acetone). Following extraction, the extract was filtered using what man Use filter paper No. 2 to get rid of any peel particles that might be in the extract. A rotary evaporator was used to evaporate the filtered extract until it was completely dry under vacuum at 60 °C. Until they were used again, the extracts were kept in a refrigerator at 4 °C. [18].

**Aqueous extraction**

With few adjustments, the extraction process was used. In short, 200 ml of distilled water was used to soak 15g of the powdered plant separately for 24 hours at room temperature while shaking. Subsequently, the extract was filtered using what man filter paper No. 1 and dried by utilizing a water bath heated to 70 ºC. The extract's yield is measured using a weighing balance. Before being used, each extract was put into a glass vial and stored at 4 ºC. [19].

The best way to utilize the phenolic content of citrus peel should be through a multi-factor extraction process optimization that considers both extraction efficiency and the preservation activities of phenolic compounds.

**ASE:** Accelerated solvent extraction.
**CE:** Conventional extraction.
**DIC:** Instant controlled pressure drop.
**DIC-UAE:** Instant controlled pressure drop and ultrasound assisted extraction.
**DW:** Dry weight.
**EAE:** Enzyme assisted extraction.
**FW:** Fresh weight.
**HHP:** High hydrostatic pressure.
**MAE:** Microwave assisted extraction.
**PEF-pressing extraction:** Pulsed electric field-pressing extraction.
**PFE:** Pressurized fluid extraction.
**RT:** Room temperature.
**SC-$CO_2$:** supercritical $CO_2$ extraction.
**SWE:** subcritical water extraction.
**UAE:** ultrasound assisted extraction.
**UAEE:** ultrasound assisted enzymatic extraction.
**US:** ultrasonic.
**USFE:** ultrasound assisted supercritical fluid extraction. [20].

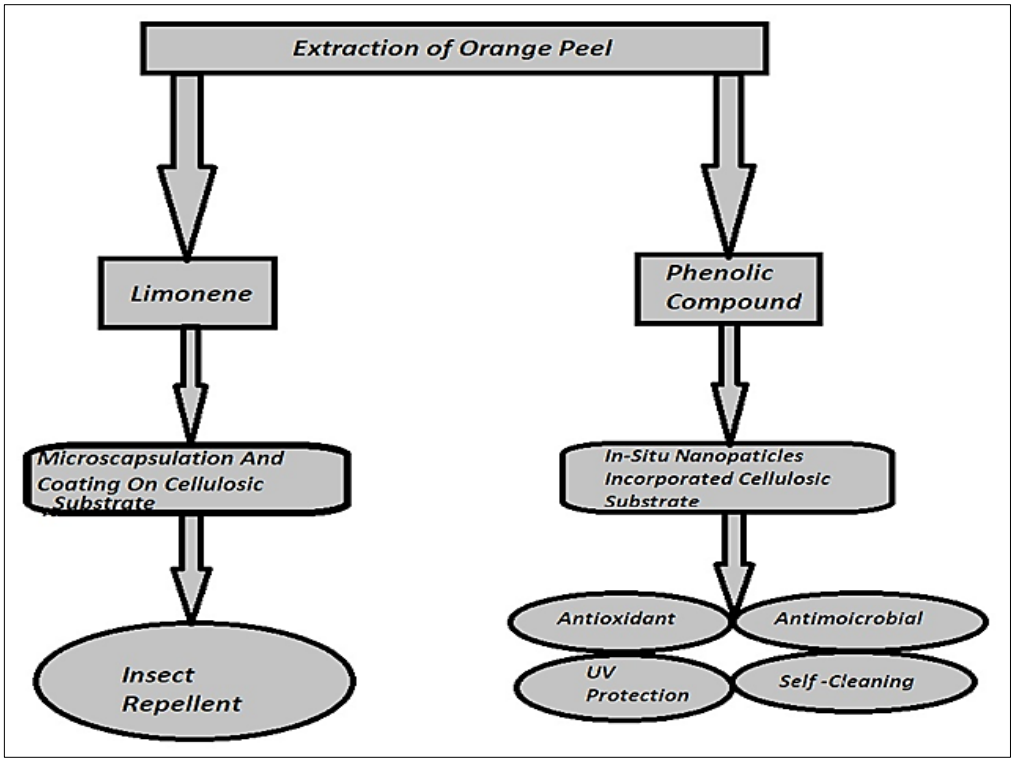


**Fig 2:** Flowchart

**Composition of Orange peel**

The composition of the volatile oils is significantly different in flowers, leaves and peel.

- Linalyl acetate (50%)
- Linalool (35%)
- Limonene
- Folic acid**.**
- D-limonene
- Hesperidin
- Naringin
- Auraptene. [21]

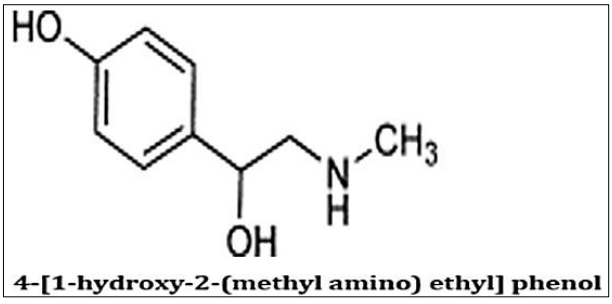


**Fig 3:** Chemical Structure of Synephrine

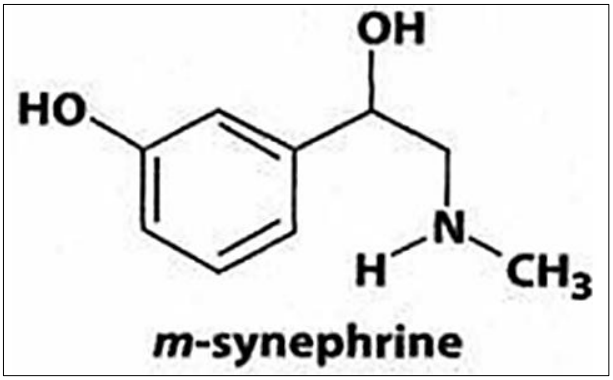


**Fig 4:** Chemical Structure of Synephrine. [21]

**Test of chemical Extracts for *In Vitro* & *In Vivo***

**Evaluation of citrus peel and pulp antimicrobial activity (*In vitro*)**

The bacterial culture was grown on nutrient agar medium (NAM)/broth. The well diffusion method 5 was used to gauge the extracts' antibacterial activity. Separate test tubes were filled with nutrient broth, each sterilized, and injected with a different bacteria. The test tubes were then incubated for 48 hours at 37 degrees Celsius. Positive controls for bacterial cultures were ampicillin (1 mg/ml). The molten media was added to separate sterilized plates along with 1 ml of an inoculum of several bacterial cultures. After being stored for a while to harden, the plates were pierced using a sterile borer or needle. Different peel and pulp solvent extracts were added to the wells one at a time [19].

***In Vivo* in mice**

The test samples were dissolved in 2% tween 80 and injected intravenously (IV) into tail veins while the patient was under a light ether anesthesia: (i) Blood was collected from 4 groups of mice that received Orange peel extract solution at doses of 0 (saline), 1.1, 3.3, and 10 mg/kg; (ii) 3 groups of mice that received Orange peel extract solution or heparin at a dose of 10 mg/kg or saline; blood was then collected at 0.5, 1, 2, and 3 hours after the test or vehicle agents were administered [21].

**Other properties shown by Orange peel laxative**

In China, a combination of rheum species, Magnolia officials, and Citrus aurantium was distilled and tested for laxative properties. It is active, and a multi-component prescription explains its effects [21].

**Antifungal properties**

An agar plate approach was used in Paraguay to evaluate essential oils for antifungal activity (plant pathogens). It is effective against Lenzites trabea, Lentinus Lepidus, and

Polyporus versicolor. When essential oil was tested in Egypt using the agar plate method for antifungal efficacy, it was discovered to be ineffective against *P. Cyclopium* and Trichoderma varied [21].

**Antioxidant activity**

DPPH, ABTS, and ORAC assays are three distinct chemical methods that were used to assess the antioxidant activity of OPE. The ORAC assay measures the chain-breaking antioxidant activity since it is based on the hydrogen atom transfer (HAT) reaction. On the other hand, the electron transfer (ET) reaction is used in the DPPH and ABTS tests to measure the reducing ability of antioxidants. The three chemical techniques have been extensively employed to evaluate the antioxidant capacity of food and biological systems [22].

**Other applications of Orange peel**

To enhance the physical and antioxidant properties of edible carboxymethylcellulose films, both the aqueous extract and the powder of CPP have been added to the biofilms. This has resulted in a formulation that contains a high concentration of phenolic compounds and battalions, as 1.7% of the aqueous extract and 3.3% of peel powder were added. Furthermore, the mucilage of CPP is removed to produce a biopolymer that can be used in biodegradable containers due to its high solubility in water, foam, and emulsion capacity, as well as its thermal stability up to 250 °C. It has been effective to employ raw CPP as a cleaning agent for wastewaters containing heavy metal ions, dyes, pesticides, and high turbidity conditions. With just 0.5 g of CPP applied at a with a particle size of 10 mm, the strong bio absorption capacity of the CPP produces a highly effective decontamination power [23].

**Beneficial uses of Orange peels**

Vitamin C, which is present in Orange peel powder, aids in the formation of collagen and elastin, the building blocks of flawless skin.

**Boost the digestive system**

- Encourage losing weight.
- Assist in the fight against allergies.
- A possible treatment for cancer.
- Encourage skin care.
- Aid in the battle against foul breath.
- Assist in lowering inflammation.
- Strengthen your heart.
- Serve as a cholagogue.
- It stimulates libido.
- Beneficial for nursing mothers and expectant mothers. The management of bronchitis. [14]

**Scope of the study for Orange peel**

The presence of antioxidant bioactive components in citrus fruit peels may be the cause of their antibacterial properties. Therefore, via more research, the precise chemical makeup of the substances causing them to function against the different bacteria may be determined. If this objective is soon accomplished, we will be able to create formulations of specific chemical compounds from these plant components that are very accurate and less expensive, or we will be able to try to create synthetic equivalents of them [5].

**Table 1:** Method of Extraction and uses of various bioactive compounds recovered from Orange peel. [24]

| SL No. | Bioactive compound | Extraction method | Uses |
|---|---|---|---|
| 1. | Hesperidin flavonoid | Subcritical water extraction | Antioxidant and antimicrobial capacity, Low risk of cancer types. |
| 2. | Limonene | Solvent extraction using (CPME) & (2-MeTHF) | Cosmetics, pharmaceutical food industry & antioxidant and fragrance character. |
| 3. | Methane | Fermentation/ anaerobic digestion | Fertilizer as to generate electricity & used as fuels in vehicles. |
| 4. | Narirutin flavonoid | Subcritical water extraction | Antioxidant properties |
| 5. | Pectin | Fermentation/ anaerobic digestion | Used in pharmaceutical & food industry. |
| 6. | polyphenol compounds (natural antioxidants) | Solid-liquid extraction | Production cosmetics & paints also used in food & pharmaceutical industry. |

**Conclusion**

Citrus peel is proven to be an excellent choice in this area due to its high phenolic content and antibacterial, antiviral, and antioxidant properties. In light of this, *C. sinesis*'s health benefits make it a good choice for either developing new products or treating or aiding in the treatment of a condition because it contains bioactive chemicals, or drug candidates, that demonstrate significant activity. This review serves as a great resource for learning about this natural product because Orange industrial waste is used to make biofuels like ethanol and biogas, as well as for other purposes like making citric acid, removing dyes for the textile industry, and extracting flavonoids for use in medicine as anti-inflammatory and analgesic compounds.

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