Antioxidant Properties of Orange Peel and Their Implications for Health: A Comprehensive Review

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Abstract

Despite being historically relegated as a by-product, orange peel (OP) has gained prominence as a source of beneficial phytochemicals, such as flavonoids, phenolic acids, carotenoids, and limonoids. These compounds collectively confer potent free radical scavenging capabilities, offering robust protection against oxidative stress-induced cellular damage. For instance, OP has been considered a tale of cultural significance for its outstanding properties. Besides, contains a great variety of antioxidants and nutrients that contribute to its health-promoting benefits. The present study addresses various methodologies employed in the evaluation of antioxidant capability, while also addressing the factors influencing bioavailability and absorption. Additionally, we underscore the diverse health implications associated with the consumption of OP-derived antioxidants, encompassing their potential to mitigate oxidative stress-related disorders. Moreover, this work presents methods for assessing antioxidant capacity in OP. Specifically, this review brings together several essential aspects of OP from health perspective. This mainly includes the consumption of OP, encompassing cardiovascular and dermatological well-being, bolstering the immune system, protecting neurological functions, potentially contributing to the prevention of cancer and maintenance of gastrointestinal health. Finally, this work presents practical dietary suggestions for integrating antioxidants from OP, with due attention to safety considerations. In a nutshell the study highlights the potential incorporation of antioxidants derived from OPs into contemporary healthcare and dietary approaches to promote improved overall health.

Keywords

Orange peel, Antioxidant properties, Health advantages, Bioavailability, Absorption, Bioactive compounds, Mechanism of action

Introduction

In recent decades, there has been a growing interest in natural sources of antioxidants, being a curable source against oxidative stress-related disorders, promote overall well-being, etc. Among all, citrus fruits are considered among the richest source, especially the OP having rich antioxidant content. OP, a by-product of citrus juice, is usually considered a waste material, however, modern research has unveiled its bioactive compounds, emphasizing potential as a valuable component in the realm of functional foods and nutraceuticals. Besides, the antioxidant capacity of OP is primarily attributed to its diverse phytochemical properties, comprising flavonoids, phenolic acids, carotenoids, and limonoids, among others. These bioactive compounds exhibit remarkable properties, including protection against oxidative damage. Moreover, the synergistic interactions between these constituents further enhance the overall antioxidant potential of
OP extracts. This unique combination of phytochemicals positions OP as a promising natural source of antioxidants with health implications [1].

In this comprehensive review, we delve into the chemistry and biological activities of the key antioxidant compounds present in OP. Via current literature, we aim to provide a comprehensive overview of the potential health benefits associated with OP-derived antioxidants. Furthermore, we explore the diverse applications of OP extracts in functional foods, dietary supplements, and pharmaceutical formulations, highlighting their potential to contribute to the prevention of various chronic diseases [2]. As we highlight these benefits, it is essential to understand the significance of the antioxidant properties of OP not only for their potential as a valuable dietary supplement but also for their utilization in waste reduction and eco-friendly practices. Through this review, we shed light on the potential of OP-derived antioxidants from the perspective of enhanced health and well-being.

This work covers a discussion on antioxidants and their effects on our health. Specifically, this work emphasizes antioxidants from OPs and their health benefits, like supporting our heart, skin, immune system, brain, and even preventing cancer and maintaining good digestion. Moreover, this study also suggests ways to include OP antioxidants in our diets while keeping safety in mind.

**Historical perspective**

The significance of OP is about how it has been utilized and seeking its importance in different ways. From years, it is being used as a medicine, and influenced the way we cook in many parts of the world.

Indeed, OP has been used in old-fashioned medicine. People from ancient civilizations like China and India realized that OP, especially the outer part, has a nice smell and can help with health issues. In China, it was used to treat coughs, nausea, and stomach problems, while in India’s traditional medicine, it was valued for relieving stomach troubles. The cooking world also liked using OP. In different parts of the world, especially in the Mediterranean and the Middle East, people often use OP to add a tasty citrus flavor to various dishes. The method of candying OP, a culinary technique that converts the bitter outer layer into a pleasurable sweet treat, has evolved into a revered confectionary custom in Europe, particularly in France and Italy [3].

In addition to its utilitarian applications, OP acquired symbolic importance within numerous cultural contexts. It began to symbolize auspiciousness and affluence. The peel was frequently used in numerous rites and celebrations because of its vivid orange color and invigorating aroma. Within certain cultural customs, the practice of presenting OP as a symbolic gesture of benevolence and well wishes, notably in the context of celebratory events and the Lunar New Year, has been observed. The increase in popularity of OP during the European Renaissance can be attributed mostly to its exotic attraction. The introduction of oranges to Europe by explorers and traders resulted in a rapid and profound appeal among the upper echelons of society, including monarchy and the elite. The utilization of orange zest, notably that derived from bitter oranges, was employed to impart flavor to wines, liqueurs, and gastronomic treats [4].

The history of OP provides a glimpse into its nutritional impact on humans. In fact, people have been utilizing OP for a longer period in their day-to-day life, especially in ancient times, because of its healing properties. Moreover, it has been considered important in cooking and various cultures, showing how it has had a lasting impact on our history [5].

**Chemical composition of OP antioxidants**

Recent studies revealed that OP consists of various essential properties shown in Table 1 and Table 2, though people often consider OP as waste. Key ingredients in OP work together to make the peel strong and help it fight against damage from oxidative stress [5].

Ascorbic acid, more often referred to as vitamin C, is a key component of the antioxidant properties found in OP. The chemical composition of this compound is denoted as C_{6}H_{8}O_{6}, and it has a six-carbon ring structure with hydroxyl groups, which imparts significant solubility in water. Vitamin C is an efficacious antioxidant that is soluble in water and functions by donating electrons to counteract the harmful effects of free radicals, thereby mitigating cellular harm resulting from oxidative stress. It is crucial for preserving collagen formation, immunological function, and skin health. The nutritious value of OP is enhanced by its presence. OP contains many flavonoids, a broad class of polyphenolic substances. Although their chemical composition varies, they typically have a 15-carbon skeleton with many hydroxyl groups. Flavonoids, such as hesperidin and quercetin, demonstrate significant antioxidant properties shown in Table 1 and Table 2, though people often consider OP as waste. Key ingredients in OP work together to make the peel strong and help it fight against damage from oxidative stress [5].

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## Table 1: Bioactive compounds present in OP.

<table>
<thead>
<tr>
<th>Components</th>
<th>Ranges</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total phenol (g/100 g)</td>
<td>1.13 - 8.0</td>
<td>[6]</td>
</tr>
<tr>
<td>Hesperidin (mg/g)</td>
<td>0.066 - 66.095</td>
<td>[6, 7]</td>
</tr>
<tr>
<td>Naringin (mg/g)</td>
<td>0.02 - 5.10</td>
<td>[6, 7]</td>
</tr>
<tr>
<td>Neohesperidin (mg/g)</td>
<td>0.66 - 7.9</td>
<td>[6, 7]</td>
</tr>
<tr>
<td>Eriocitrin (μg/g)</td>
<td>7.73 - 150.9</td>
<td>[6, 7]</td>
</tr>
<tr>
<td>Hesperetin (μg/g)</td>
<td>5.79 - 24.49</td>
<td>[6, 7]</td>
</tr>
<tr>
<td>Rutin (μg/g)</td>
<td>4.92 - 7.21</td>
<td>[6, 7]</td>
</tr>
<tr>
<td>Nobiletin (μg/g)</td>
<td>7.45 - 72.44</td>
<td>[6]</td>
</tr>
<tr>
<td>Flavonoids (mg/100 g)</td>
<td>2.685 - 52.06</td>
<td>[7]</td>
</tr>
<tr>
<td>Antioxidants (μg/g) (DPPH)</td>
<td>1.388 - 67.90</td>
<td>[6]</td>
</tr>
</tbody>
</table>

## Table 2: Nutritional composition of OP.

<table>
<thead>
<tr>
<th>Components</th>
<th>Value</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein (%)</td>
<td>10.34 - 19.15</td>
<td>[8, 9]</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>1.50 - 5.42</td>
<td>[9, 10]</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>5.05 - 7.59</td>
<td>[9]</td>
</tr>
<tr>
<td>Fiber (%)</td>
<td>2.68 - 6.01</td>
<td>[9]</td>
</tr>
<tr>
<td>Total dietary fiber (%)</td>
<td>3.29 - 10.13</td>
<td>[9, 10]</td>
</tr>
<tr>
<td>Carbohydrate (%)</td>
<td>66.59 - 41.49</td>
<td>[9, 11]</td>
</tr>
<tr>
<td>Vitamin C (g/100 g)</td>
<td>0.105 - 0.108</td>
<td>[12]</td>
</tr>
<tr>
<td>Calcium (%)</td>
<td>14.71 - 26.13</td>
<td>[9]</td>
</tr>
<tr>
<td>Iron (%)</td>
<td>5.59 - 69.06</td>
<td>[9]</td>
</tr>
<tr>
<td>Magnesium (%)</td>
<td>29.95 - 62.51</td>
<td>[9]</td>
</tr>
</tbody>
</table>
properties. Recently OP found useful towards getting rid of harmful free radicals, which helps keep the peel healthy and colourful. Besides, scientists are studying flavonoids in the peel since they might help with reducing inflammation, fighting viruses, and even preventing cancer [8].

Carotenoids are the primary compounds accountable for the manifestation of the orange hue in the peel. The compound \(\beta\)-carotene, which is well recognized as a carotenoid, possesses a linear and symmetrical molecular structure consisting of 40 carbon atoms and several double bonds. Carotenoids function as antioxidants that are soluble in lipids, effectively neutralizing free radicals present inside cellular membranes. \(\beta\)-carotene is recognized as a precursor to vitamin A, hence enhancing its antioxidant function. In addition to its role as an antioxidant, \(\beta\)-carotene has been found to contribute to the maintenance of eye health and visual acuity, as demonstrated Johra et al. [13].

The triterpenoid molecules known as limonoids have a complicated structure and are highly oxygenated. Frequently, a fused four-ring system is observed in these instances. The antioxidant activity of limonoids found in OP has been the subject of research, with investigations exploring their possible applications in cancer prevention and as agents for reducing inflammation. The presence of phenolic substances, namely caffeic acid and \(p\)-coumaric acid, within OP is characterized by the presence of a phenol ring structure accompanied by hydroxyl groups. The presence of phenolic compounds in OP plays a significant role in enhancing the antioxidant capacity. This is achieved through the process of scavenging free radicals and regulating pathways associated with oxidative stress. Moreover, there is evidence linking them to prospective advantages in terms of cardiovascular well-being and the mitigation of long-term ailments [14].

Terpenes, such as d-limonene, are hydrocarbon molecules characterized by a basic structure composed of several isoprene units. The compound known as D-limonene has been the subject of scientific investigation due to its capacity to function as an antioxidant and its potential to safeguard against oxidative harm. Additionally, it demonstrates anti-inflammatory and anticancer characteristics. As per the recent study, OP is made up of different antioxidants, and each one has a special job in keeping our cells healthy by preventing damage from oxidative stress. The various compounds in OP, with their different shapes and properties, work together to make it a powerful antioxidant [15]. They not only increase the fruit’s nutritional worth but also highlight its potential as an important dietary component with significant benefits for human health and wellbeing.

**Mechanisms of antioxidant action**

OP contains antioxidants that serve as cellular protectors against oxidative stress, a detrimental process that can cause significant damage to cellular constituents, as depicted in figure 1.

Free radicals are molecular species characterized by the presence of unpaired electrons, rendering them highly reactive. In their pursuit of stability, they engage in the acquisition of electrons from molecules present within cells, resulting in cellular harm and triggering a chain reaction of oxidative stress. The antioxidants included in OP, specifically vitamin C and flavonoids, function as electron donors. These entities willingly donate their own electrons to counterbalance the presence of unpaired electrons, averting the detrimental sequence of oxidative injury. Moreover, it is revealed that when antioxidants stop the bad cycle, they become stable and non-reactive. In OP, these antioxidants are important because they help protect the important parts of our cells, like DNA and proteins, from the damage that free radicals can cause. This protection is like a shield for the tissues and organs in our body, keeping them safe and working well [16].

Transition metal ions, represented by iron (Fe) and copper (Cu), have the capacity to act as catalysts in reactions that yield deleterious free radicals, as observed in the Fenton reaction. According to Jomova et al. [17], the presence of these metal ions has the potential to enhance oxidative stress. Several antioxidants found in OPs, particularly phenolic compounds, exhibit metal-chelating abilities. These metal ions exhibit a notable propensity for forming strong associations, so effectively sequestering them and impeding their involvement in processes that give rise to the generation of free radicals. The chelation of metal ions serves as an effective defense mechanism, effectively reducing oxidative stress at its origin. The antioxidants play a role in cellular and tissue protection by restricting the accessibility of metal ions involved in detrimental reactions.

The generation of antioxidant enzymes and other oxidative stress defense systems is controlled by a sophisticated gene regulatory network inside of cells. Flavonoids and limonoids are two antioxidants found in OP that have shown promise in modulating oxidative stress-related gene expression. The stimulation of antioxidant enzyme synthesis can enhance the cell’s ability to counteract free radicals and restore oxidative damage. Through the coordination of the synthesis of crucial antioxidant enzymes, these antioxidants augment the cellular capacity to withstand the detrimental effects of oxidative stress. The regulatory function of this mechanism guarantees
that the cell is adequately prepared to confront oxidative problems directly, hence reducing the likelihood of potential harm. A complex balance of different antioxidants functioning together is necessary for the body's antioxidant defense network to function. Vitamin C, which is abundantly present in OP, assumes a distinctive function within this network. One notable characteristic of this substance is its capacity to facilitate the regeneration of several antioxidants, including vitamin E. Following the process of neutralizing free radicals, vitamin E has the potential to be depleted. The presence of vitamin C serves to reinstate the antioxidant capacity, hence preserving the functionality of the comprehensive antioxidant defense system. The presence of vitamin C and other antioxidants in OP helps to prolong cellular vitality and protect against oxidative damage, even in difficult circumstances [18].

Lipid peroxidation, a damaging chain reaction that affects cell membranes and vital lipids, can be carried on by oxidative stress. The presence of antioxidants in OP, particularly carotenoids such as β-carotene, is significant in the prevention of lipid peroxidation. The scavenging of free radicals plays a crucial role in preventing the initiation of chain reactions, hence safeguarding the integrity of cell membranes and lipid-based structures. The antioxidants included in OP play a crucial role in protecting lipid-rich structures from peroxidation. This protective mechanism helps maintain the integrity and functionality of cells, hence promoting cellular health. The relationship between oxidative stress and inflammation is highly interconnected. In the organism, excessive oxidative stress might open inflammatory pathways. Several antioxidants found in OPs, such as phenolic compounds, have been shown to possess anti-inflammatory activities. Besides, it is revealed that these antioxidants in OP can help reduce inflammation and the risks it brings to our health by decreasing oxidative stress. Moreover, the fact that they can control inflammation shows how important these antioxidants are for keeping us healthy overall. Thus, protecting against oxidative stress, they also have anti-inflammatory powers [19].

Methods for assessing antioxidant capacity in OP

To identify its potential health advantages and to contrast various types or processing techniques, it is crucial to evaluate the antioxidant capacity of OP. Various techniques are frequently utilized to assess the antioxidant potential of extracts derived from OPs. Here are some of the most widely used methods.

Total antioxidant capacity (TAC) assays

**DPPH (2,2-diphenyl-1-picrylhydrazyl) assay:** This widely used method relies on the principle of electron transfer. The stable free radical DPPH, characterized by its distinct deep violet hue, undergoes a reaction when exposed to extracts derived from OPs. The color transition from violet to yellow occurs because of the electron donation from antioxidants present in the extract to the DPPH radicals. According to spectrophotometric measurements, the OP's antioxidant capacity is inversely correlated with the degree of discoloration [20].

**ABTS (2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)) assay:** ABTS radicals are produced through the reaction between ABTS and peroxidase (H2O2) in the presence of OP extracts. The extract's antioxidant properties result in the reduction of ABTS radicals, leading to a noticeable shift in hue from green blue to colorless. The decline in absorbance serves as an indicator of the antioxidant capacity, which may be measured in relation to a Trolox standard curve [21].

**Ferric reducing antioxidant power (FRAP) assay**

The FRAP assay is utilized to evaluate the antioxidant capacity of OP extracts. The process entails the conversion of a colorless ferric-tripyridyl triazine complex into a blue-colored ferrous form through the action of antioxidants present in the extract. The quantification of antioxidant capacity in OP is determined by measuring the variation in absorbance at a designated wavelength, and the results are reported as the amount of Fe²⁺ equivalents per gram of OP [22].

**Trolox equivalent antioxidant capacity (TEAC) assay**

The TEAC assay, like the ABTS assay, assesses the capacity of antioxidants found in OP to effectively neutralize ABTS radicals. The outcomes are quantified in terms of Trolox equivalents, which is a synthetic antioxidant employed as a benchmark standard. As a result, the antioxidant content of various OP samples can be compared [23].

**Oxygen radical absorbance capacity (ORAC) assay**

The antioxidant potential of OP extracts is evaluated using the ORAC assay, which quantifies their effectiveness in safeguarding against peroxyl radicals, highly reactive oxygen species. Fluorescent compounds serve as indicators, with the decline in fluorescence intensity over a period serving as a reflection of the antioxidant capacity. The findings are commonly reported in terms of trolox equivalents per gram of OP [24].

Total phenolic content (TPC) assays

**Folin-ciocalteu assay:** The Folin–Ciocalteu reagent reacts with phenolic chemicals in OP extracts in this colorimetric experiment. The magnitude of the resultant blue hue exhibits a direct correlation with the overall concentration of phenolic compounds. The total phenolic content (TPC) is commonly quantified in terms of milligrams of gallic acid equivalents per gram of OP [25].

**Tannin assay:** In the case of OP samples that possess a high concentration of tannins, specialized assays are employed to measure the tannin content. These procedures often entail precipitating tannins with proteins and measuring the amount of unbound protein afterward to ascertain tannin concentration [26].

**Flavonoid content assays**

Flavonoids, like hesperidin and naringin, play a crucial role as antioxidants within the OP. The quantification of flavonoid content frequently necessitates the utilization of specialist methodologies, such as high-performance liquid chromatography (HPLC). This technique enables the identification and quantification of individual flavonoids that are present within the extract [27].

**Electrochemical methods**

Electrochemical techniques, such as cyclic voltammetry or amperometry, entail the quantification of electric current
produced upon subjecting OP extracts to predetermined redox potentials. These techniques offer insights into the redox properties and antioxidative potential of antioxidants found in OPs [28].

**Cell-based assays**

In vitro cell-based assays involve culturing cells and exposing them to oxidative stressors. The inclusion of OP extracts is implemented in order to evaluate their efficacy in safeguarding cells from oxidative harm. Typical assessments encompass the quantification of intracellular reactive oxygen species (ROS) concentrations and cellular viability [29].

**Animal and human studies**

The addition of OP in regulated diets in animal and human studies allows for the assessment of the impact on oxidative stress indicators in living organisms [30]. This methodology offers valuable perspectives on the effects of antioxidants found in OPs on overall health.

The choice of methodology is contingent upon the objectives of the research, the accessibility of equipment, and the compounds of interest found in OP. The combined use of multiple complimentary methodologies can yield a thorough assessment of the antioxidant capacity exhibited by OP, as well as its possible implications for human health.

**Bioavailability and absorption of OP**

The utilization of antioxidants and other bioactive components in OP by the human body is influenced by crucial parameters such as bioavailability and absorption. Comprehending these processes is crucial in evaluating the prospective health advantages associated with the consumption of antioxidants found in OP.

**Bioavailability**

The concept of bioavailability pertains to the fraction of a food or compound that is assimilated and subsequently accessible for use in the physiological processes of the human body. The bioavailability of OP antioxidants is influenced by multiple factors, it can be influenced by their chemical composition. Certain kinds of antioxidants, such as flavonoids or polyphenols, may have enhanced absorption capabilities. In fact, the way our bodies take in the good stuff from OP, like vitamins and other helpful things, can be affected by what else we eat. For example, the vitamin C in OP might help our bodies absorb other antioxidants better [31].

The enzymatic activity and physiological environment within the gastrointestinal system are essential factors in the process of enzymatic degradation of antioxidants found in OPs, facilitating their conversion into bioavailable forms. The process is influenced by various factors such as pH, enzymes, and bile salts. Upon absorption, the antioxidants found in OP have the potential to undergo metabolic processes in the liver. These metabolic processes can subsequently impact the bioavailability and activity of these antioxidants throughout the body. Certain antioxidants may necessitate the presence of certain transport proteins to facilitate their entry into the bloodstream and subsequent delivery to desired tissues. The impact on bioavailability can be influenced by the availability and functionality of these transporters. The absorption and use of OP antioxidants can be influenced by interactions with other dietary components, medicines, or supplements. According to Molteni et al. [32] these interactions have the potential to either improve or limit bioavailability.

**Absorption**

The term "absorption" pertains to the mechanism via which compounds, such as antioxidants derived from OP, traverse from the gastrointestinal system into the bloodstream, facilitating their dispersion to different tissues and organs. The primary site of absorption for OP antioxidants is the small intestine, where they traverse the intestinal epithelial cells and enter the bloodstream. The degree of absorption may exhibit variability dependent upon the solubility and structure of the molecule [33].

Researchers found that the antioxidants in OP have characteristics that make it easy for them to dissolve and pass through the cell walls in our intestines, which are rich in fat. How well these antioxidants get through the intestines can depend on their size and shape. Smaller molecules that like water might get absorbed more quickly. The absorption of these antioxidants from OP can also be affected by other things we eat, like fiber or minerals, which compete for absorption spots in our intestines. Once absorbed, these antioxidants might go through some changes in the liver before entering our bloodstream. From there, they spread to different parts of our body, protecting us from oxidative stress. It’s important to know that the way our bodies take in and use these antioxidants can be different for each person, depending on things like genes, diet, and overall health. Scientists are still figuring out ways to make sure we get the most out of these antioxidants, like trying different cooking methods or ways of preparing food to make them more effective in promoting good health [32].

**Health implications of OP antioxidants**

OP, which is sometimes disregarded, offers a wealth of antioxidants with important health benefits. Numerous facets of human health can benefit from these antioxidants. This section provides a brief overview of the health implications associated with the consumption of antioxidants found in OPs as illustrated in figure 2.

Oxidative stress is a key mechanism that serves as the basis for the aging process and the development of numerous chronic diseases. The antioxidants found in OPs, specifically flavonoids, polyphenols, and vitamin C, exhibit strong capabilities in neutralizing free radicals. These hazardous chemicals are effectively neutralized, hence minimizing oxidative damage to various biological components such as DNA, lipids, and proteins. OP antioxidants contribute to the preservation of the health and functionality of all cells in the body by lowering oxidative stress. The antioxidants found in OPs have a diverse variety of effects on cardiovascular health. The capacity to induce vasodilation, which refers to the relaxation of blood vessels, contributes to the reduction of blood pressure and enhancement of systemic circulation. Moreover, these antioxidants can mitigate inflammation inside the arterial walls, so inhibiting the development of atherosclerotic plaque, which can lead to...
the constriction and rigidity of blood vessels. They promote improved heart health and lessen the risk of heart disease and stroke by lowering the risk of atherosclerosis [33].

Long-lasting swelling in the body, known as chronic inflammation, can lead to many ongoing illnesses and weaken the immune system. The antioxidants in OPs have anti-inflammatory powers that help balance the immune system. They make sure the body can fight off infections and diseases by managing constant inflammation and ensuring the immune responses are just right. The antioxidants in OPs are also thought to help prevent cancer by stopping the start, growth, and spread of cancer cells. Some studies in labs show that certain things in OP can fight against cancer. And these antioxidants protect our DNA from damage caused by things that can lead to cancer, creating a kind of shield that stops cancer from growing [34].

Fluctuations in blood glucose levels can have detrimental health consequences, especially for persons diagnosed with diabetes or those who are predisposed to the condition. The antioxidants found in OP have been shown to enhance insulin sensitivity, thereby contributing to the regulation of blood sugar levels. Due to the efficient utilization of glucose by cells, blood sugar levels are stabilized and the likelihood of complications from diabetes is decreased. The presence of dietary fibers in OP plays a vital role in maintaining optimal gut health. These fibrous materials function as substrates for beneficial gut microbes, facilitating their proliferation and metabolic processes. A healthy balance in the gut microbiota has a crucial role in facilitating efficient digestion, mitigating inflammation within the gastrointestinal tract, and diminishing the susceptibility to gastrointestinal illnesses, such as irritable bowel syndrome (IBS). The antioxidants found in OP are known to enhance the appearance of the skin, promoting a youthful and beautiful complexion. These substances provide a safeguard against the harmful effects of UV radiation and environmental contaminants, hence mitigating the occurrence of premature aging manifestations such as wrinkles and fine lines. Additionally, these antioxidants increase the formation of collagen, which improves skin suppleness and encourages a more youthful appearance. The investigation into the potential neuroprotective effects of antioxidants found in OPs has garnered considerable attention in recent times. Antioxidants can help keep brain cells safe from damage and inflammation, which are linked to diseases like Alzheimer’s and Parkinson’s. We need more research to be sure about how well the antioxidants in OP protect the brain. But early signs show that these antioxidants might be good for brain health [35].

The presence of dietary fiber in OP is known to contribute to feelings of fullness and satisfaction. When incorporated into meals, they aid in the regulation of hunger and the reduction of total caloric consumption, hence offering potential advantages for the management of body weight and the achievement of weight loss objectives. Using low-calorie OP in a recipe can make food healthier without adding many calories. OP has things like flavonoids and polyphenols that might be good for your bones. These compounds seem to help your body absorb calcium and prevent damage to your bones. When you eat them with a diet that has lots of calcium, they can keep your bones strong and lower the chances of getting osteoporosis [36].

The inclusion of OP in one’s dietary regimen can provide a pleasurable and beneficial gastronomic experience. Individuals have the opportunity to obtain various health benefits from OP antioxidants, whether it be by methods such as zesting, infusions, or the utilization of innovative recipes. Nevertheless, it is recommended to seek advice from healthcare professionals or nutritionists to obtain tailored dietary recommendations and to ensure that the consumption of OP is consistent with individual health objectives and dietary preferences.

Safety considerations

When incorporating OP antioxidants into one’s diet, it is crucial to consider safety considerations. Certain individuals may exhibit allergies or sensitivities towards citrus fruits, such as oranges and their peels. Allergic reactions encompass a spectrum of manifestations, ranging from mild symptoms such as pruritus and urticaria to the more severe and potentially life-threatening condition known as anaphylaxis. Individuals with a documented citrus allergy must exercise caution and refrain from consuming OP and any related products that may contain it. Like many other types of fruits, oranges are subject to the application of pesticides throughout their production to safeguard them against potential harm caused by pests and illnesses. To mitigate the potential risks associated with pesticide exposure, it is advisable to either procure organic oranges or employ a thorough washing and peeling regimen for conventionally farmed oranges [37].

According to Gao et al. [38], peeling oranges can remove a lot of pesticide residues. If you’re worried about pesticides or have sensitivities, it’s better to use OP from places that are certified pesticide-free. You can find such oranges at health food stores or from trusted farmers who grow organic oranges. When you peel oranges, especially if you separate the peel...
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from the fruit, it can go bad if you don’t store it correctly. To prevent mold and spoilage, wash and dry the OP thoroughly, then store it in a sealed container in a cool, dry place. OP contains dietary fibers that are considered beneficial in several ways for individuals. But, eating too much might cause stomach discomfort, like bloating or gas. Start with a little bit and gradually eat more to see how your body reacts. If you’re taking medications like blood thinners or drugs for diabetes, it’s essential to talk to a healthcare professional before eating a lot of OP. These medications and OP can interact and cause problems.

Oranges, inclusive of their peels, provide a significant source of oxalates. The ingestion of high quantities of oxalates in individuals predisposed to kidney stones may elevate the likelihood of stone development. Individuals with a documented medical history of nephrolithiasis are advised to exercise caution in their consumption of OPs, while concurrently augmenting their fluid intake, to mitigate the concentration of oxalates in their urine. Like other dietary components, individual reactions to OP can exhibit variability. Certain individuals may encounter stomach pain, heartburn, or other digestive complications upon swallowing substantial amounts of OP. It is recommended to closely observe and evaluate the physiological reactions of one’s body and make appropriate adjustments to dietary consumption [39].

While OP antioxidants are good for your health, it’s crucial to have a balanced diet that includes different fruits and vegetables. Depending only on OP for antioxidants is not a great idea. To get the most nutrition and a variety of helpful plant chemicals, it’s better to eat a mix of colorful fruits and veggies. If you’re thinking of making big changes to your diet or taking OP extracts as a supplement, especially if you have health issues, it’s a good idea to talk to a healthcare professional or a dietician for guidance [40].

OP can be a delightful and healthy addition to your diet, but it’s important to do so while being mindful of any potential allergies, sensitivities, and interactions. Important guidelines for successfully utilizing the antioxidant properties of OP include moderation, variation, and interaction with healthcare professionals.

Conclusion and Future Perspectives

The presence of antioxidants in OP offers a potentially advantageous pathway for improving human well-being. The presence of a substantial quantity of flavonoids and vitamin C in these compounds leads to their efficient mitigation of oxidative stress and inflammation, hence enhancing cardiovascular well-being and potentially reducing the likelihood of developing heart disease. Moreover, the inclusion of dietary fiber in one’s diet promotes gastrointestinal well-being and fosters a harmonious gut microbiota. There is emerging evidence indicating possible anti-cancer capabilities and immune-enhancing effects in promising research trials.

Additionally, the utilization of extracts and essential oils derived from OP has been found to yield significant advantages for the maintenance of skin health. These substances exhibit anti-inflammatory effects, thereby aiding in the reduction of inflammation, and contribute to the attainment of a more youthful and vibrant complexion. The incorporation of OP into contemporary healthcare and nutritional practices, via its integration into regular culinary applications and the availability of supplements, presents significant prospects for enhancing general wellness.

Looking forward, there exist numerous promising possibilities for future research. Investigation into the precise mechanisms that underlie the antioxidant properties of chemicals found in OP has the potential to facilitate the development of focused therapies for illnesses associated with oxidative stress. The analysis of appropriate techniques for extraction and preservation is of utmost importance in order to maximize the bioavailability and efficacy of substances. Additionally, conducting clinical trials will be important in validating the observed health advantages and providing evidence-based recommendations. In a nutshell, the study into the antioxidant capacity of OP holds significant promise as a subject of scholarly inquiry, carrying extensive implications for the well-being of individuals. By means of persistent investigation and rigorous scientific analysis, it is possible to effectively utilize the advantageous properties of antioxidants found in OPs to enhance overall health and mitigate the occurrence of chronic ailments.

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Conflict of Interest

None.

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