POLYPHENOLS - A USEFUL BIOMATERIAL: A REVIEW

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ABSTRACT

Polyphenols are secondary metabolite of the plants and contains more than one phenolic group in their structure. Polyphenols compounds are important for plants as they impart color, flavors and tastes to many plants. Polyphenols include several thousand compounds, among them the flavonoids, flavones, catechins, flavanones, anthrocyanidines and isoflavonoids are important. Polyphenols are antioxidant molecules and neutralize harmful free radicals and prevent oxidative stress, which damage cells and DNA. Polyphenols are important antioxidants molecules which are used in preventing the diseases like cancer, cardiovascular, neuro diseases, inflammation, high blood pressure, cholesterol increase. Researchers have shown that polyphenols can be extracted from citrus fruits peels by using different solvents and different extraction conditions. Antioxidant property is proportional to the Polyphenols concentration present in the sample. It has been reported by research paternity that the polyphenols thus extracted can be used to treat the degenerative diseases. As per the market estimation, the global polyphenols market reach to a total consumption of 21,032.7 tons by the end of 2018. Polyphenol industry faces key challenges like sourcing and supply chain quality. These challenges are multiplying due to increased pressure on land for agriculture and development, the investment in sustainable supply chain and research is focused on finding out the exact class of plant for production. Market study very clearly indicates the importance of research on extracting polyphenols in an economically feasible way and if it could be from the natural resources the advantage will be doubled and a ecofriendly way will make the extraction from the fruits waste best way forward for polyphenols.

Key Words: Polyphenols, Antioxidant, Flavonoids, Extraction, Citrus fruits

INTRODUCTION

Natural antioxidants are preferred over synthetic antioxidants because of presumed safety, potential nutritional benefits and therapeutic effects\(^1\)\(^2\). Among all the natural antioxidants, polyphenols gain significance owing to their high redox potential which allows them to act as reducing agents, hydrogen donors and singlet oxygen quenchers\(^3\). Moreover, polyphenols are abundantly present in our diet\(^4\). The benefits of dietary polyphenols have been studied extensively over the last decade. Polyphenols have been established to play a significant role in preventing diseases like cardiovascular diseases, cancer and other diseases\(^5\). Fruits, vegetables, leguminous plants and some cereals are rich sources of polyphenols. Polyphenols are often present in higher concentration in the outer non edible part of the fruits like peel compared to inner edible part\(^6\)\(^8\). The common fruit like orange peels contains high concentration of polyphenols which makes orange as high antioxidant source\(^9\)\(^10\). Worldwide researches have worked on citrus fruits peels or rinds as the source for polyphenols. As per Agarwal et al., 50% aqueous solvent extracts from citrus fruit have shown that the concentration of the total polyphenol concentration is proportional to their antioxidant property. It is also shown that peels of citrus fruits is a cheapest source of flavonoids\(^11\). Lembe et al., mentions that rinds of citrus fruit can be a source for an effective bioactive compound which can be used for health promoting food product values and phenolic compounds can be extracted rapidly and efficiently from citrus rind tissue\(^12\). Gerhard states that citrus peels and seeds

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contain significant amounts of polyphenol substances and it is worth considering them as dietary supplement\textsuperscript{13}. Maria et al also confirmed that citrus peels exhibit quite high antioxidant activity, which together with polyphenols contained makes them a valuable source for natural antioxidants and the citrus flavonoids in the cosmetic and food industries.\textsuperscript{14} Jayaprakasha et al., reported antioxidant activity of fruits and vegetables significantly increases with the presence of high concentration of total polyphenol content\textsuperscript{15}. The properties of polyphenols give a new dimension for the development of antioxidant from natural resources like fruits. Researchers have also shown that polyphenols can be extracted from citrus fruits peels by using different solvents and different extraction conditions. Antioxidant property is proportional to the Polyphenols concentration present in the sample and antioxidant property helps in preventing the cardiovascular and many other diseases.

**Sources**
Polyphenols are present in the variety of plants like food grains such as sorghum, barley, dry beans, peas, pigeon peas, winged beans and other legumes, fruits such as apples, black cranberries, grapes, peaches, pears, plums raspberries and strawberries and vegetables such as broccoli, cabbage, celery, onion, potato and parsley are rich in polyphenol antioxidants.

**Classification and nomenclature**
Polyphenols are generally divided into hydrolyzable tannins, phenyl propanoids and condensed or non hydrolyzable tannins\textsuperscript{16-18}.

**DISCUSSION**

**Hydrolyzable tannins**
Tannins are distributed in species throughout the plant kingdom. They are mainly physically located in the vacuoles or surface wax of plants. These storage sites keep tannins active against plant predators, but also keep some tannins from affecting plant metabolism while the plant tissue is alive, it is only after cell breakdown and death that the tannins are active in metabolic effects. Hydrolyzable tannins are derivative of gallic acid. Gallic acid is esterified. To a core polyol and galloyl groups are further esterified or oxidatively cross linked to yield more complex hydrolyzable tannins\textsuperscript{19}. (Fig. 1)

**Phenylpropanoids**
The phenylpropanoids are a diverse family of organic compounds they are synthesized by plants using amino acid phenylalanine, their name is derived from the six-carbon, aromatic phenyl group and the three-carbon propene tail of cinnamic acid, which is synthesized from phenylalanine in the first step of phenylpropanoid biosynthesis. (Fig. 2) Phenylpropanoids are found throughout the plant kingdom, where they serve as essential components of a number of structural polymers.

![Fig. 1: Hydrolyzable tannins](image-url)
provide protection from ultraviolet light, defend against herbivores and pathogens and mediate plant-pollinator interactions as floral pigments and scent compounds. Flavonoids are phenylpropanoids and are the most common group of polyphenolic compounds in the human diet and are found ubiquitously in plants. There are different subgroups of flavonols as indicated in the picture below.

Condensed tannins or non-hydrolyzable tannins

Proanthocyanidins, also known as OPCs (oligomeric proanthocyanidins) or condensed tannins, are a subgroup of the flavonoid class of polyphenols. The most widely studied condensed tannins are based on flavone 3-ols, like epicatechin and catechin (Fig. 3).

Absorption and bio-availability in the humans

Certain classes of polyphenols, such as flavonols, isoflavones, flavones and anthocyanins are usually glycosylated. The linked sugar is often glucose or rhamnose, but can also be galactose, arabinose, xylose, glucuronic acid or other sugars. The number of sugars is most commonly one but can be two or three and there are several possible positions of substitution on the polyphenol. The sugars can be further substituted, for example, with a malonic acid group. The glycosylation influences chemical, physical and biological properties of the polyphenol.

The chemical structure of polyphenols determines their rate and extent of intestinal absorption and the nature of the metabolites circulating in the plasma. The few bioavailability studies in humans show that the quantities of polyphenols found intact in urine vary from one
phenolic compound to another. (Fig. 4) A major part of the polyphenols ingested (75–99%) is not found in urine. This implies they have either not been absorbed through the gut barrier, absorbed and excreted in the bile or metabolized by the colonic microflora or our own tissues. Only very rare measurements of the intestinal absorption of polyphenols in humans are available.  

**Fig. 4**: A hypothesis for prediction of the absorption of polyphenols in humans based on evidence from *in vivo* and *in vitro* studies

**Extraction of polyphenols**

Polyphenols are usually produced from seeds and skins of grapes and tea leaves. First the seed and skins are dried and powdered. Extraction process used in generally are using solvent fruits like grapes and tea leaves by chemical treatments in dilute aqueous solutions of alcohols and higher temperatures. The extracts were then screened for total polyphenol contents, antioxidant and antibacterial activities.

**Biological effects and uses of polyphenols**

Polyphenols exhibit a wide range of biological effects as a consequence of their antioxidant properties. They inhibit LDL oxidation *in vitro*. Polyphenols show reduced susceptibility to oxidation. Thus, polyphenols probably protect LDL oxidation *in vivo* with significant consequences in atherosclerosis and also protect DNA from oxidative damage with important consequences in the age-related development of some cancers. In addition, flavonoids have antithrombotic and anti-inflammatory effects. The antimicrobial property of polyphenolic compounds has been well documented. Several types of polyphenols (phenolic acids, hydrolyzable tannins and flavonoids) might interfere in several of the steps that lead to the development of malignant tumors, inactivating carcinogens, inhibiting the expression of mutant genes and the activity of enzymes involved in the activation of procarcinogens and activating enzymatic systems involved in the detoxification of xenobiotics. (Table 1)

**Table 1: Benefits and functions of polyphenols**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Benefits and functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Most flavonoids are powerful antioxidants that help neutralize harmful free radicals and prevent oxidative stress which damage cells and DNA and which can lead to aging and degenerative diseases like cancer ad Alzheimer’s or Parkinson’s disease</td>
</tr>
<tr>
<td>2</td>
<td>Enhances the effects of the other antioxidant vitamins and increases levels of glutathione, an important and powerful antioxidant</td>
</tr>
<tr>
<td>3</td>
<td>Enhances the use of Vitamin C by improving its absorption, prolonging its effectiveness and protecting it from oxidation</td>
</tr>
<tr>
<td>4</td>
<td>Clinically proven in treatment of hemorrhoids and varicose veins</td>
</tr>
<tr>
<td>5</td>
<td>Works with Vitamin C to alleviate oral herpes</td>
</tr>
<tr>
<td>6</td>
<td>Flavonoids with Vitamin C may help prevent cold sores, to treat cold sores. Try taking 1000</td>
</tr>
</tbody>
</table>
mg of vitamin C with 1000 mg of bioflavonoid, then reduce to 500mg each 3 times a day

7. May help prevent and treat cataracts

8. Stimulated bile production

9. Used in treating sports injuries as it relieves pain, bumps, bruises

10. Helpful for relieving leg and back pains

11. Has antibiotic like effect due to anti-viral and anti-bacterial activity and also anti-allergic and anti-inflammatory properties

12. Protects against cancer by inhibiting tumor growth

13. Reduces risk of cardiovascular disease and heart attack by lowering LDL cholesterol level and stopping blood platelets from clumping, which minimizes blood clotting and prevents buildup of atherosclerotic plaque on artery walls as effectively as aspirin, but without its side effects

14. Known to lower hypertension (high blood pressure) and so lessen risk of stroke and heart disease

15. Quercetin has natural anti histamine and anti-inflammatory properties and taken with bromelin may be useful in preventing and treating asthma and other allergies

However, some polyphenols have been reported to be mutagenic in microbial assays and co-carcinogens or promoters in inducing skin carcinogenesis in the presence of other carcinogens. Several studies have shown that in addition to their antioxidant protective effect on DNA and gene expression, Polyphenols, particularly flavonoids, inhibit the initiation, promotion and progression of tumors, possibly by a different mechanism.

**Uses of polyphenols**

Polyphenols can be used for treating skin diseases. Use of cacao polyphenols for treating a prostate hyperplasia, a specific cacao extract and applications. Emerging clinical studies suggest that the polyphenols in tea, especially green tea, may play an important role in the prevention of cancer. Results from several animal and human studies suggest that one of the polyphenols present in green tea, known as catechin, may help treat viral hepatitis (inflammation of the liver from a virus). The polyphenol EGCg has received significant attention for its effects on inhibition of HIV infection and multi resistant *Staphylococcus aureus* infection. The given table summarizes the uses of polyphenols.

**CONCLUSION**

Present literature research complements the prediction that polyphenols can be beneficial antioxidant that can be used for preventing degenerative diseases like cardiovascular disease, cancer, Parkinson diseases and other.

The properties of polyphenols give a new dimension for the development of antioxidant from natural resources like fruits. More researches on procuring the polyphenols from the fruit waste should be encouraged as polyphenol concentrations are higher in the seeds and skin of the fruits. Various studies reveal the requirement, urgency and importance of extracting polyphenols in an economically feasible way. If it could be from the natural resources the advantage will be doubled and an ecofriendly way will make the extraction from the fruits waste best way forward for polyphenols.

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