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# Antimicrobial and Antioxidant activities of fruits and vegetable peels: A review

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**ABSTRACT**
Peels of various fruits and vegetables are generally considered as waste product and are normally thrown away by us. But different studies conducted on peels revealed the presence of important constituents, which can be used for pharmacological or pharmaceutical purpose. Number of components having activities like antioxidant, antimicrobial, antiinflammatory, antiproliferative etc. have been isolated from different peels. The present paper reviews the role of fruits and vegetable peels as therapeutic agents.

**Keywords:** Fruits peels, vegetable peels, antioxidants, antimicrobial agents, bioactive compounds.

## 1. Introduction
Fruits and vegetables are considered as an important part of a good diet. Besides their delicious taste and flavor, they are known to reduce risk of several chronic diseases. Fruits and vegetables contain significant amounts of phytoconstituents which are negatively associated with the morbidity and mortality from cerebrovascular, cardiovascular and certain types of cancers [1, 2, 3]. Foods are generally consumed for their nutritive value and bioactive compounds [4]. Fruits and vegetables wastes and their by-products are formed in great amounts during industrial processing and hence represent a serious problem, as they exert harmful impact on environment. So they need to be managed or they can be utilized [5]. Vegetables are cooked in Indian kitchens as curries and are eaten along with bread or chapatis and fruits are eaten as such. Different components having activities like antimicrobial, antioxidant, antiproliferative, antiinflammatory, etc. have been isolated from different peels. Growing knowledge about antioxidants, that their presence in everyday foods promote health, combined with the assumption that a number of common synthetic preservatives may have hazardous effects [6], has led to multiple investigations in the field of natural antioxidants. Present review is written with a view to present the antioxidant and antimicrobial status of the fruits and vegetables commonly consumed in northern India.

## 2. Antioxidant and antimicrobial activity of some fruits and vegetable peels.
### 2.1 Pomegranate (*Punica granatum*)
The pomegranate tree is native to Asia and Middle East countries. The western scientists showed least interest to this tree, but recently pomegranate fruit has drawn attention of many investigators because of its antioxidant compounds such as tannins and flavonoids. These phenolic compounds are responsible for its exceptional healing qualities [7].
The antimicrobial activity of various extracts prepared from pomegranate fruit peels were evaluated using both *in-vitro* agar diffusion and *in-situ* methods against some food-borne pathogens. It was found that 80% methanolic extract of peels was a potent inhibitor for *Yersinia enterocolitica*, *Listeria monocytogenes*, *Staphyllococcus aureus* and *Escherichia coli*. And the presence of active inhibitors in peels including phenolics and flavonoids were revealed by phytochemical analysis as potent constituents [8].

### 2.2 Mango (*Mangifera indica*)
Mango is native to tropical regions of world and India ranks first in its production. Mango, being a seasonal fruit, is processed for various products such as puree, leather, nectar, pickles, canned slices and pickles which have worldwide popularity [9]. Antioxidant activity of peels of ripe and raw mango in acetone extract was determined using different antioxidant models such as reducing power activity, DPPH free radical scavenging activity, soybean lipoxygenase

inhibition, iron induced lipid peroxidation of liver microsomes. Results showed that the $IC_{50}$ values were in the range of 1.39-5.24 lg of gallic acid equivalents. On phytochemical analysis acetone extract of mango peel was found to contain polyphenols, anthocyanins and carotenoids [9]. In another study, the free radical scavenging activities of mango flesh and peel extracts were evaluated by electron spin resonance and it was found that mango peel extract exhibited stronger free radical scavenging ability on 1, 1-diphenyl-2-picrylhydrazyl and alkyl radicals than mango flesh extract without any relation to its ripeness [10].

**2.3 Apple (*Malus domestica*)**

Apple is the fourth most important fruit crop worldwide, after citrus, *Vitis* and banana. It is the most ubiquitous and well-adapted of the temperate fruit crop species that is grown in areas ranging from high latitude regions of the world where temperature may reach –40 $^0$C, to high elevations in the tropics where two crops may be grown in a single year [11].

The most common varieties of apples grown in New York City are Rome Beauty, Idared, Cortland, and Golden Delicious that are commonly used in apple sauce production. The phytochemical content and antioxidant activity of the peels of Rome Beauty, Idared, Cortland, and Golden Delicious were compared to those of the flesh and flesh-peel combination components and peels of the apples. The result showed total phenolic and flavonoid contents were quantitatively more in the peels, followed by the flesh-peel combination and then flesh. The high content of phenolic compounds and antioxidant activity of apple peels indicates that they are valuable source of antioxidants and can impart health benefits when consumed [12].

**2.4 Banana (*Musa paradisiaca*)**

Banana is a tropical plant and one of the most popular fruits of world [13]. Banana peel is rich in dietary fiber, proteins, essential amino acids, polyunsaturated fatty acids and potassium [14].

The antioxidant activities of the extracts obtained from fresh green and yellow banana peel fruits were evaluated by using the thiocyanate method, ß-carotene bleaching method and 1,1-diphenyl-2-picrylhydrazyl free radical elimination method. The fresh green and yellow banana peel fruits were treated with 70% acetone, which was then partitioned with chloroform and ethyl acetate. The antimicrobial activities of the extracts and isolated components were evaluated using paper disc methods for minimum inhibition concentration. The water soluble and ethylacetate fractions of green peel displayed high antimicrobial and antioxidant activity. Antioxidant activity of water extracts was more pronounced and comparable to those of synthetic antioxidants such as butylated hydroxyanisole and butylated hydroxytoluene. Among all isolated components succinic acid, ß-sitosterol, palmitic acid, malic acid, 12-hydroxystrearic acid, glycoside, d-malic and 12-hydroxystrearic acid were the most active against all the gram-negative and positive bacterial species tested [13].

**2.5 Lemon (*Citrus lemon*)**

Lemon is an important medicinal plant of family Rutaceae. It is cultivated mainly for its alkaloids, which are having anticancer activities [15].

The citrus peel oils show strong antimicrobial activity. The antimicrobial activity has been checked in terms of minimum inhibitory concentration by using different solvents against microorganisms like *Pseudomonas aeruginosa* NCIM 2036 for which minimum inhibitory concentration was 1:20 in presence of methanol, for *Salmonella typhimurium* NCIM 5021 the observed minimum inhibitory concentration was 1:20 in presence of acetone and for *Micrococcus aureus* NCIM 5021 the observed minimum inhibitory concentration was 1:20 when ethanol was used as solvent. The compounds like tetrazene and coumarin were identified by GC/MS of *lemon* peel extract [15]. It is also found to have antioxidant activity [16].

**2.6 Orange (*Citrus sinensis*)**

Citrus is genus of flowering plants in the family Rutaceae, native to tropical and subtropical areas in Southeast Asia. Citrus fruits have peculiar fragrance partly due to flavonoids and limonoids present in the peel and these fruits are good sources of vitamin C and flavonoids [17]. The antioxidant/radical scavenging capacity and reducing power ability of different extracts of orange peel were investigated and results showed that ethanolic extract showed the highest values for yield i.e. total phenolic content, total flavonoid content, chelating and antioxidant activities (% DPPH scavenging activity). It was also observed that solvent played a vital role in the extraction of the plant constituents, specifically, methanol and ethanol were highly polar among the solvents used [18]. It is also found to have antifungal activity [19].

**2.7 Wax gourd (*Benincasa hispida*)**

Wax gourd (*Benincasa hispida*) besides being native to Malaysia, is also found in hills (4000 ft) of some tropical countries like India, Burma and Ceylon. It is one of the well-known vegetable in Thailand, India, Philippines, China, and Vietnam in Asia [20]. The antioxidant activity of various parts of wax gourd were evaluated using ferric reducing antioxidant potential, 2,2-diphenyl-1-picryl hydrazyl, β-carotene bleaching assays .In addition, Folin-Ciocalteu reagent assay was used to determine their total phenolic content. The antioxidant activity of peel extract was 21.73 mM Trolox equivalent /g extract weight, respectively as determined by FRAP assay. $EC_{50}$ values of DPPH assay was 392.21mcg/ml and on β-carotene bleaching assay was 34.39%. The antimicrobial activity of the extracts was tested against six Gram positive and seven Gram-negative bacteria, one yeast, two mold using the disc diffusion method. The antimicrobial activity of the extracts showed an inhibition towards Gram-negative bacteria (*Salmonella typhimurium, Pseudomonas aeruginosa, Proteus vulgaris, Serratia liquefaciens, Cronobacter muytjens, Shigella boydii* and *Serratia marcescens*) compared to Gram-positive bacteria, however, there were no inhibition towards yeast and mold for all extracts [21].

**2.8 Potato (*Solanum tuberosum*)**

Potato peels have shown antioxidant properties. In an experiment freeze-dried extract of potato peels were evaluated for their antioxidant potency in various in-vitro systems such as lipid peroxidation in rat liver homogenate, 1, 1-diphenyl-2-picrylhydrazyl / hydroxyl/superoxide radical scavenging, reducing power, and ferric ion chelation. Aqueous extract of freeze dried potato peel powder demonstrated strong inhibitory activity toward lipid peroxidation of rat liver homogenate induced by the $FeCl_2$-$H_2O_2$ system and strong concentration-dependent inhibition of deoxyribose oxidation. Potato peel extract also demonstrated a considerable antioxidant activity in the DPPH radical assay system. It also showed antioxidant activity in multiple systems such as superoxide scavenging ability, reducing power and also ferrous ion chelating potency. These results established the antioxidant potency of freeze-dried extract of potato peel [22].

**2.9 Quince (*Cydonia vulgaris*)**

The quince has been cultivated from prehistoric periods in

countries extending from Iran to India. The ancient Greeks and Romans grew the quince for its attractive pinkish flowers and fragrant fruit. It is cultivated throughout Turkey but especially in western Anatolia [23]. In an experiment, a number of secondary metabolites were isolated from *Cydonia vulgaris* peels. Some of the metabolites such as 3b-oleoyl-24-hydroxy-24-ethylcholesta-5,28(29)-diene, 3b-(18-hydroxylinoleoyl)-28- hydroxyurs-12-ene, 3b-linoleoylurs-12-en-28-oic acid, tiglic acid 1-O-b-D-glucopyranoside, and 6,9-dihydroxymegastigmasta-5, 7-dien-3-one 9-O-b-D-gentiobioside, were isolated and elucidated for the first time. The compounds were tested for their antioxidant and free radical-scavenging activities by measuring their capacity to induce the reduction of Molybdenum(VI) to Molybdenum(V), scavenge the 2,20-diphenyl-1-picrylhydrazyl radical and anion superoxide radical. The strongest antioxidant activity was shown by flavonol, quercetin and its 3-O-rutinoside [24].

**2.10 Thai gac (*Momordica cochinchinensis*)**

*Momordica cochinchinensis* Spreng is grown in many countries in tropical regions. It may be called by different name such as Gac in Viet Nam, Fak kao in Thailand, Bhat kerala in India, Moc Niet Tu in China and Mak kao in Laos. It is belongs to Cucurbitaceae family and has long been used as a food and traditional medicine in East and Southeast Asia [25].

The fractions of peel, pulp and aril of *Momordica cochinchinensis* Spreng) were evaluated for presence of lycopene, beta-carotene, lutein and phenolic compounds and also for their antioxidant activity. The results showed that the aril contained the highest lycopene and beta-carotene and peel contained the highest amount of lutein. The two phenolic compounds known as p-hydroxybenzoic acid and gallic acid were found in all fractions. Myricetin was the only flavonoid found in all fractions whereas apigenin was the most predominant flavonoid in pulp. Highest FRAP value was found in aril extract which also showed highest content of rutin and luteolin. The antioxidant activities were highest in extracts prepared from immature peel and pulp, whereas seed extracts showed increase in antioxidant activity from mature stage to ripe stage. The total phenolic and flavonoid content in peel and pulp decreased during the fruit development stage, thereby lower antioxidant capacity, but similar observation not shown by seeds [25].

**2.11 Jabuticaba peel (*Plinia cauliflora)***

Jabuticaba is native to Brazil and is the richest source of anthocyanins. Fresh Jabuticaba fruit is widely consumed and commonly found in Brazil markets. Its popularity is comparable to grapes found in the United States [26].

The anthocyanin and antioxidant contents of freeze-dried Jabuticaba peel were investigated. Jabuticaba peel showed a strong antioxidant potential: 25,514.24±3037 μM TE g−1, 45.38±0.50 μg mL−1 and 9458±97 μM TEAC g−1, for ORAC, DPPH and ABTS, respectively. The anthocyanins present in Jabuticaba peels were identified and quantified using HPLC-PDA and LC–MS/MS. The results revealed the presence of delphinidin 3-glucoside and cyanidin 3-glucoside [26].

**2.12. Jamun (*Syzygium cumini*)**

Jamun (*Syzygium cumini*) is native to tropical America and Australia, but also has a worldwide distribution in various other tropical and subtropical regions. This plant is available in Indian plains ranging from the Himalayas to southern India [27].

The antioxidant activity of the fruit peel has been analyzed using different assays such as DPPH radical-scavenging assay, superoxide radical-scavenging assay based on photochemical reduction of nitroblue tetrazolium in the presence of a riboflavin-light-NBT system, hydroxyl radical-scavenging assay based on the benzoic acid hydroxylation method and lipid peroxidation assay using egg yolk as the lipid-rich source. Total antioxidant capacity was determined by the assay based on the reduction of Molybdenum (VI)-Molybdenum(V) by the extract and formation of a green phosphate/Molybdenum(V) complex. In all above systems, significant correlation was found between concentration of the extract and percentage inhibition of free radicals as well as percentage inhibition of lipid peroxidation. The antioxidant property of the fruit peel was partially from the antioxidant vitamins, phenolics or tannins and anthocyanins present in the fruit [4].

**2.13. Longan (*Dimocarpus Longan*)**

Longan is a member of the Sapindaceae family, which is a highly attractive subtropical fruit widely distributed in the south of China [28].

The longan peel was extracted with 95% ethanol employing soxhlet extraction method and microwave-assisted extraction and evaluated for their total phenolic content. The total phenolic content of Soxhlet extract and microwave-assisted extract of Longan peel reached 90.35 mg/g and 96.78 mg/g of dry weight expressed as pyrocatechol equivalents, which were quantified using Folin-Ciocalteu reagent. Subsequently, antioxidant properties of two extracts were investigated employing various established *in-vitro* systems which were 2, 20-diphenyl-1-picrylhydrazyl radical scavenging assay, hydroxyl radical scavenging assay using a new resonance scattering method, reducing power and total antioxidant capacity. Microwave-assisted extraction and soxhlet extraction method showed excellent antioxidant activity in all test systems when compared to synthetic antioxidant 2,6-di-ter-butyl-4-methylphenol (BHT) and it was also observed that antioxidant activities of microwave-assisted extraction were all superior to those of soxhlet extraction method [28].

**2.14 Tori (*Luffa Cylindrica*)**

*Luffa cylindrica* is a sub-tropical plant commonly called sponge gourd, loofa, vegetable sponge, bath sponge or dish cloth gourd belonging to family Cucurbitaceae. Commercial production of this plant is done in several countries such as China, Korea, India, Japan and Central America since the warm summer temperatures of tropicals and long frost-free growing season of temperate are suitable for its growth [29]. The antioxidative potential of peel extract of *Luffa cylindrica* was investigated on hydrogen peroxide, ferrous sulphate and carbon tetrachloride induced lipid peroxidation in liver. The antioxidant effect was compared with the butylated hydroxy anisole as standard antioxidant. The results demonstrated a dose dependent inhibition in all the three i.e. $FeSO_4$, $H_2O_2$ and $CCl_4$ induced hepatic lipid peroxidation. It was observed that polyphenols and flavonoids of *Luffa cylindrica* peels could be inhibiting lipid peroxidation [30].

**2.15 Kumquat (*Fortunella margarita*)**

Kumquat, which belongs to genus *Citrus*, is a relative of Citrus and belongs to family Rutaceae. Fresh kumquat fruits can be eaten raw or they can be used in making liquor, marmalade, jam, sauce and pickle. The fruits and leaves of the Fortunella species have been used in folk medicine in China. Recently, attempts have been made to study the pharmacological activities of some bioactive compounds isolated from Kumquat [31].

In an experiment, polyphenolic composition of two *Fortunella margarita* samples from Egypt & Greece were investigated using the techniques of fractionation by solvent partition and liquid chromatography-mass spectrometry. The results of investigation reported the presence of C-glycosylated flavones, C-glycosylated flavones, O-glycosylated flavones, O-glycosylated flavones, flavonols, phenolic acids, chalcones and their derivatives. In addition, the antioxidant activity of fractions of above fruit samples was assessed employing *in-vitro* assays like hydroxyl free radical scavenging and antiradical activity. Results revealed that the ethyl acetate fractions from both specimens had higher polyphenol content and their higher polyphenolic contents were responsible for their better antioxidant characteristics [31].

## 3. Conclusion

The hazardous effects of synthetic antioxidants and the emergence of antibiotic resistant strains have revived the search for antioxidant and antimicrobial agents from natural sources. From different studies conducted on peels, it has been found that peels of fruits and vegetables hold a tremendous potential to serve as a source of newer, effective, safer and better antioxidant and antimicrobial agents.

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