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Potential Antimicrobials and Phytochemical analysis of five fruit peels- A Review

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Review Article

ABSTRACT

Numerous nutritive, pharmaceutical and nutraceutical benefits are key attributes of fruits, a prominent product of angiosperms. Main phytochemical constituents of fruits are the secondary metabolites which serve as bioactive compounds for many drugs. Besides its pulp, other parts of fruit like seeds, kernels and more specifically peels have magnificent properties which are wasted annually. For instance, 45.22 million metric tons of mangoes are produced globally every year out of which 11% is wasted as peels, though exact data is not available for all the fruits. The peels contribute to the highest waste production and if not properly processed could be a reason for foul gases which contribute to the greenhouse effects. These peels are sources of important bioactive compounds containing antimicrobial, antioxidant, anti-inflammatory, antitumor and antiviral properties. The important components present in the peels are vitamins, dietary fibers, phenolic compounds, flavonoids and carotenoids. In the current review peels of mango, papaya, citrus, pomegranate and banana are analyzed for their potential bioactive compounds and their associated biological activities. These peels are also sources of vital biochemical compounds which have antimicrobial, antioxidant, anti-inflammatory, antitumor and antiviral properties.

Keywords: Fruit peels, Antimicrobial activity, Phytochemical analysis, Waste

INTRODUCTION

Fruits- the ripened ovaries- have multiple health benefits. The prevalence of cardiovascular infection, malignant growth, Alzheimer disease, diabetes and age-related pragmatic decay (Liu, 2003) has been observed to decline due to use of fruits. Besides, numerous benefits from fruit pulp, the seeds, peels, leaves and other parts also confer health benefits. Peels of different fruits are commonly considered as waste item and are typically discarded (Parashar *et al*., 2014). The peels of most fruits like papaya, banana, citrus, mango and pomegranate are roughly thought as wastes but if processed properly can contribute to the improvement of economy.

Pakistan is one of the biggest producers of citrus and mango (Agriculture Marketing Information Service, 2015) Table 1. As far as banana is concerned Pakistan is the second largest banana producing country annually (Sundaram *et al.,* 2011). Of the whole fruit, the banana peel serves as approximately 35% of the whole weight (Vu *et al.,* 2016). This fruit peel is a potential source of treating various ailments. It also contains numerous important phenolic compounds (Feumba, 2018). As considering mango, it comprises of at least 30-50% of waste. These wastes are contributing to higher cost of waste management (Castro-vargas *et al.*, 2019). So there is need of its proper processing to make it valuable.

Table I: Annual Production of fruits in Pakistan during 2015-2016 (Shafique, 2017).

Sr. No.	Fruits	Produced Annually (Tones)
1	Banana	134634
2	Citrus	2344086
3	Mango	1336473
4	Papaya	6185
5	Pomegranate	40125

The peel of fruit confers about 10-15% of the complete weight of the fruit (Beerh *et al*., 1976) and when discarded as wastes, contributes towards unhealthy and untidy environment. These agro

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wastes often produce a bad odor, soil contamination, can be a harborage for bugs. These bugs can cause various diseases due to contamination (Shalini and Gupta, 2010). Previously, a few endeavors were made to utilize agro wastes particularly for domesticated animals feed and fuel purposes (Anhwange, 2008).

Musa sapientum: It is also known as banana and pertains to the family *Musaceae.* It is endemic to tropical areas of southern Asia and now is developed throughout tropics worldwide. According to 2015-2016 data it is cultivated on 28703 hectares in Pakistan (Anhwange, 2008). There are twenty seven cultivars of banana grown across the world (Vu, Scarlett, & Vuong, 2018).

***Citrus aurantium*:** It is also known as Bitter orange and pertains to the family *Rutaceae.* It is local to tropical Asia however it is found in all tropical and subtropical regions (Suryawanshi, 2011). The highest production of citrus was reported in Pakistan. Among them kinnow holds a lion share in the citrus transport to other countries. An estimated production of citrus has been reported in 2004 which was 1760.3 tons in 176.5 hectares and almost 20-40% of them by weight is discarded as waste. (Mahmood and Sheikh, 2006). Among the 15 major producer of citrus, Pakistan is one of the biggest producer of citrus. Sargodha is the main hub of citrus producer. Among citrus varieties kinnow has a great percentage of about 95%. (Mahmood and Sheikh, 2006). An average yearly production of citrus is 1760.3 thousand tones on an area of 175 thousand hectares (Anon, 2002).

***Punica granatum L.*:** It is also known as pomegranate and pertains to the family *Punicaceae*. Pomegranates are a supplement source and wealthy in phytochemical compounds (Elfalleh, 2012). The significant source of dietary phytochemicals is peels, seeds and squeeze. Pomegranate tree was created and naturalized throughout the Mediterranean region (Elfalleh, 2012). Its cultivation was started in Iran and later on it spreads to other nearby countries becoming a popular fruit with traditional medicinal properties. In Pakistan it is grown over 9007 hectares *(*Chandra *et al.,* 2010). There are >60 cultivars of pomegranate grown across the world (Ajmia *et al.*, 2017).

***Carica papaya*:** It is also known as papaya and pertains to the family *Caricaceae.* This plant is located in tropical America and was acquainted with India in sixteen century. Papaya is commonly recognized worldwide for its nutritional and healthy advantages and is used as a home remedy for stom ach illnesses. In Pakistan it is grown over 1370 hectares (Yogiraj *et al.,* 2014).

Mangifera indica L.: It is also known as mango and pertains to the family *Anacardiaceae. M. indica* is cultivated worldwide and is an excellent source of regular bioactive substances which can be promising immune boosters and can prevent the onset of sicknesses (Ashoush and Gadallah, 2011). About 1336473 tons of mangoes are produced by Pakistan and is positioned fifth worldwide. The global annual production of mango is about 25 million tones. In Pakistan mango is cultivated on an area of about 167.5 thousand hectares with annual production of around 1,732 thousand tones (Nazish *et al.,* 2017).

General uses of fruit peels

It has been mentioned earlier that fruit peels can be used to create a range of useful products efficiently.

Banana constitute up to 30% of peel accounting for the total weight (Sundaram *et al*., 2011). The peels of banana are even helpful in making banana charcoal and this banana charcoal is often a replacement of domestic fuel. The fruit peels of banana in conjunction with different substances makes a liniment for lessening the intensity of joint inflammation pain and torment. Banana peel has been used in many areas of the globe in traditional medicine for wound healing, diarrhea, cough, ulcers, burns and anemia (Anhwange, 2008). More over banana peel have also role in snake bites and excess menstruation (Pereira and Maraschin, 2015). Other uses of banana peel include its use as fertilizers and as bio-substrates for biofuel production. Use of banana peel as livestock feed has also been reported due to its richness in antioxidant and nutritional contents. Banana peel is a good absorbent of heavy metals which directs its potential uses in bio-remediation for water purification (Pereira and Maraschin, 2015).

Citrus has numerous health benefits because of its wholesome and therapeutic qualities. Yet, utilization of orange organic products creates orange peels waste that could achieve ecological contamination if not legitimately took care of. The peels of *C. aurantium* is frequently utilized in preservatives and dried peels are utilized in various supplements and beverages. (Webb, 2008).

Peels of Papaya like its pulp possesses multiple implications. The papaya peel is utilized in many home remedies. Papaya peels are used as sunscreens and to rejuvenate the damaged skin also, Battle dandruff (Yogiraj *et al*., 2014). Papaya and its various parts like leaves and peels have medicinal properties and is mostly employed for the therapy of various disorders like: warts, blood

pressure, constipation and stimulate reproductive organs (Journal & Sciences, 2015).

Mango and its peels have immense qualities. Gelatin is a major byproduct of mango peels. Mango peels contain around 10 - 15 % gelatin and is basically used by the nourishment processors particularly for the change of second rate sustenance to delicacies like jellies and jams. It is additionally utilized for generations in different pharmaceutical items. Variety of pectin concentrations can be obtained at varying temperatures from mango peels (Nahar *et al*., 2017).

Pomegranate peels may also serve as potential antimicrobial compounds. It may be proposed as a suitable option in contrast to synthetic antimicrobial agents. The antimicrobial properties are due to high tannin content particularly punicalagin (Rosas-Burgos *et al*., 2017).

Cosmetics and medicine

Fruit peels have tremendous implications in making cosmetics and medicines. Agro wastes are generally considered huge reservoir of bioactive compounds (Ashoush and Gadallah, 2011). Phytochemicals are the bioactive non-nutritive compounds obtained from vegetables, grains, and other herbaceous plants and are considered as valuable bioactive compounds against several illnesses (Liu, 2003). Various important phytochemicals present in the peels will be described later in this review.

Among all the magnificent characteristics, fruit peels are a major source of antimicrobial compounds (Parashar *et al*., 2014). Phytochemical (alkaloids, tannins, terpenoids etc.) obtained from citrus fruit peels have anti-parasitic and antimicrobial compounds (Mathur *et al*., 2011).

Substances that anticipate or ease back oxidative harm to human bodies hence protecting the body from major oxidative damages are termed as antioxidants (Mathur *et al*., 2011).

Phytochemical constituents of fruit peels are considered anti-cancerous with least side effects and their synergistic behaviors have been observed in case administered along with the chemotherapeutic agents. Due to multidrug resistance in cancers a need for novel anticancerous drugs is always there. Plants can be prospective candidates for such research as a significant source of naturally generated bioactive compounds (polyphenols, carotenoids, vitamins, dietary fibers, oils and enzymes) (Chen *et al.,* 1997). Various fruit peels that have powerful anticancerous activity may be helpful in this regard (Montanari and Widmer, 1997).

In current study the possible utilization of fruit peels usually discarded as waste and are endemic to Pakistan are discussed with respect to their families, important phytochemicals and bioactivities.

Peels as a source of biofuel

In current era modern advances have made everything more efficient. Ethanol, which is now used as fuel alternative, is now obtained from fruit peels. The peel of agro wastes are now utilized to make useful products that are environmental friendly like biofuel. Fruit byproducts in the form of peels is producing several tones of wastes so smart processing make it beneficial. One such reported example includes the production of ethanol used as biofuel from banana peel (Mishra, 2016). The banana peels are pretreated by the use of microwaves. The microwave process is continued for a duration of about 5 min at 160 W.

Mango peels are also utilized in biofuel production. As peels contain up to 40% of reducing sugar the direct fermentation of these peels give about 5.13% of ethanol (Reddy *et al.,* 2011). The production rate of ethanol may be further improved to 7.14% (w/v) by the use of nutrient supplements like yeast extract, peptone and wheat bran.

Similarly, the peels of orange fruit are recycled in such a way that the found application as an excellent biodiesel. The oil obtained from peels is utilized to make biodiesel. This is done by the process of trans-esterification. The temperature may range from 80-83°C. The oil from orange peels were extracted by the use of n-hexane. It also involves the use of catalyst sodium hydroxide (Cc, 2014). There are various strategies through which we get benefit from the peels of fruit. One of the strategy through which we can utilize the peels of fruit is biofuel production. Fruit peels are a good substitute of ethanol in current era. They are cost effective and environment friendly (Reddy *et al.,* 2011). Beside their use as biodiesel they are also becoming important in the production of bio fertilizer (Rakholiya *et al.,* 2014).

The discarded part of fruit mainly the peel in case of mango, pomegranate and many others is a waste material. From these waste material useful substances can be separated for the benefit of mankind. The peels of certain fruits have proven antimicrobial activities against pathogenic microbes and can be utilized as bio fertilizers. Furthermore, they also have anti cancerous effects. (Rakholiya *et al.,* 2014).

Phytochemical profiling of fruit peels

Phytochemicals are sure non-nutritional substances obtained from plants, which have some disease preventive properties (Mathew *et al.,* 2012). These phytochemicals cannot be utilized for primary nutrition but can be used against pathogens and several diseases (Kokate *et al* 2006).

Musa sapientum

Keeping the pre-treatment methods and extraction conditions significant influencing the quality of phytochemicals from peel, it also depends upon the variety, cultivation conditions and maturity of fruit (Vu *et al.,* 2018).

The prospective uses of banana peels also depend on the chemical structure of peels of differe nt banana cultivars. Along with it the biochemical composition of the peel varies depending upon the extent of ripeness of the fruit. There are forty different compounds identified from the peels of banana till date (González-Montelongo, Gloria Lobo and González, 2010). These 40 compounds can be classified into sub divisions: flavonols, flavan-3-ols, hydroxycinnamic acids and catecholamines. Banana peel is rich in phenolics with the 4.95 to 47mg GAE/g DM which is found greater than in common fruits (Vu *et al.,* 2018). *M. sapientum* peels extracts were analysed for the presence of different compounds or substances like: unstable oils and gums (G., A. O, & J.E, 2014). Other compounds are also reported in banana peel such as glycosides (Odebiyi and Sofowora, 1978), alkaloids (Ogukwe *et al*., 2004), saponins, tannins and steroids (Trease and Evans, 1996) and flavonoids (Odebiyi and Sofowora, 1978). Moreover, Phenolics (54% out of 100 grams of banana peel) anthocyanins (3.3% out of 100 grams of banana peel) and cyanidin 3-glucoside equivalents were found to be present. In addition banana peels were found loaded with high amounts of L-DOPA and catecholamines. Dopamine exhibit antioxidant properties. It has been reported that the amount of dopamine in peel (80–560mg/100g) is much more than in rest of the pulp (2.5–10mg/100g) (Kanazawa and Sakakibara, 2000). The best solvent for extraction was acetone: water with a possibility of alteration in the amounts of phytochemicals obtained using specific physical methods to enhance the yield. The data presented above was found similar in different cultivars of banana (González-Montelongo *et al.,* 2010). The presence of low fat by products are also observed in fruit peels. The content of low fat by products in banana is 0.7% (Espiard, 2002).

Punica granatum L

The phytochemical analysis of pomegranate peels was performed with different solvents (water, ethanol and acetone). Surprisingly high values of phytochemicals (tannins, flavonoids and polyphenols) were observed with alcoholic extracts of acid ecotype. The observed gallic acid content in this ecotype is 304.6 mg gallic acid equivalent/g. The observed values for the rest three ecotypes were: gallic acid equivalent/g 292.23 mg; Quercetin/g 15.46 mg and cy-3-glu/100 g 54.51 mg respectively (Abid *et al.*, 2017).

The different phytochemical isolated from peels are: triterpenoids (Kumar Bhandary, 2012), steroids (Kumari), glycosides (Bhat, 2012), alkaloids, proteins, flavonoids, saponins, free amino acids, tannins, vitamin C and starch (K.P., and Prasad Bekal, 2012). The pomegranate peel is also a great source of dietary fibers mainly the insoluble fibers. These fibers may range from 28.10 to 33.93% dw (in Gabsi and Tounsi ecotypes) (Abid *et al*., 2017). The ecotypes present in Pakistan have a content of about 21% dw (Ullah *et al*., 2012). The presence of low-fat by products were also observed to be present in pomegranate peels. (Espiard, 2002). Pomegranate peels consists mainly of tannins. The observed tannins content in pomegranate peels are 90-95% of the total polyphenols present. While flavonoid contents may vary from 9.98- 15.25, 5- 7.49 and 10.27- 15.46 mg/g respectively for water, ethanol and acetone (Abid *et al.,* 2017). These observations made on phytochemical analysis has showed that the higher content of polyphenols in peels has been linked with their effective role in antidiabetic and antiperoxidative effects (Parmar and Kar, 2008).

Carica papaya

Different phytochemicals were reported from the peel of *C. papaya.* The observed phytochemicals are: tannins (Edeoga *et al*. 2005), saponins (Sofowara, 1993), steroids (Trease and Evans, 1996) and anthraquinones (Harborne, 1973). High phenolic contents are also found in peels of papaya. While the total flavonoid content and radical scavenging activities are best shown when ethanolic extracts (80%) are used. Papaya peels showed excellent antimicrobial and antioxidant activities (Siddique *et al.,* 2018). The highest total phenolic contents are observed while using 90% acetone (v/v). The observed total phenolic contents are 15.18 µg GAE/mL (Ang *et al.,* 2012).

The largest TPC of 15.18 µg GAE / mL was obtained from papaya peel when extracted using 90% acetone (v/v) for 60 min. Measured antioxidant

activities were 37.34% and 28.30% when DPPH and ABTS assays used. On the other hand highest TPC of 6.75 µg GAE/mL was obtained from papaya seed when extracts with deionized water for a duration of about 120 min and the measured antioxidant activities were 57.30% and 11.19% when DPPH and ABTS assays used. It has been stated that the byproducts of papaya fruit (peel) are excellent source of bioactive compounds (lycopene, β-carotene, flavonoid and anthocyanins comparative to rest of the fruit) (Suchiritha Devi *et al.,* 2017). It has also been observed that the PPP (papaya peel paste) contain crude fiber: 12.43%, TFC 44.66%, sodium and potassium: 3.61mg/10g and 79.34 mg/100g. The β-carotene present in papaya peel paste is 15.46 µg/100g (Suchiritha Devi *et al.,* 2017).

The amount of fat present in the papaya peel was observed to be: 2.27% (papaya peel powder) and 0.01% (papaya peel paste) (Baddi *et al.* 2015). While the amount of observed proteins were: 5.31% (papaya peel powder) and 1.40% (papaya peel paste) (Romelle *et al.* 2016). The observed carbohydrate quantity was reported to be: 64.65 % (papaya peel powder) and 9.82 % (papya peel paste) (Ajila, *et al.,* 2008).

Compared with fruit pulp, the fruit by-products are an excellent source of bioactive compounds such as lycopene, β-carotene, anthocyanins and flavonoids. The papaya peel powder (PPP) had 15.32 and 11.6 dehydration and rehydration ratio. The color of PPP was also changed compared to PSP. The crude fiber content was 12.43 and 0.94% for PPP and PSP. The total content of dietary fibers were 44.66 and 2.0% for PPP and PSP. The content of potassium and sodium was 2.09 and 3.61 for PPP and PSP respectively. While the content of β-carotene was 15.46 and 2.06 µg/100g for PPP and PSP**.**

Mangifera indica L.

Around 250 cultivars of mango are developed in Pakistan (Masood *et al*., 2011). The phytochemical analysis of fruit pulp as well as peel was identified. Mango peel is also known to constitute largely of polyphenols. Polyphenols in mango peel include oligomers (Pierson *et al*., 2014), flavonoids (Berardini *et al.,* 2004), flavonols and xanthones (Schieber *et al.,* 2003).

The peels also constitute of dietary fibers present in peels are 387 mg/g (dry weight). Among these dietary fibers the soluble dietary fibers constitute about 23-42%. The sweet taste of mangoes may refer to the presence of rhamnose (de Lourdes García-Magana *et al.,* 2013). Mangiferin (2-beta-D-glucopyranosyl-1,3,6,7 tetrahydroxyxanthen-9-one) – a flavonoid is also reported in the *M. indica L.* peel along with stem, kernel and bark (Nong *et al.,* 2005). This Mangiferin exhibit great antioxidative properties. Mangiferin has also good impact on iron whelm (excess of iron, leading to accumulation of iron in liver & spleen) (Estuningtyas *et al.,* 2018).

Table II. Illustration of various fruits, types of waste they generate and their obtained phytochemicals (Babbar *et al.,* 2015).

Fruits	Waste categories	Phytochemicals	Concentration of phytochemicals	References
Musa Sapientum	Peels	Anthocyanins, gallocatechin, cyaniding, delphindin, catecholamine	Total phenolic content (TPC) 75.01 to 685.57 mg GAE (gallic acid equivalents)/100 g Total flavonoid content (TFC) 39.01 to 389.33 mg CEQ/100 g.	Kanazawa and Sakakibara, 2000; Someya *et al.,* 2002; Monelongo *et al.,* 2010 Fatemeh *et al.,* 2012
Punica granatum L	Peels	Triterpenoids, steroids, alkaloids, glycosides, flavonoids, saponins, Proteins, Tannins, Vitamin C, Starch and Free Amino Acids**.**	TPC 85.60 ± 4.87 mg GAE/g DW flavonoids 51.52 ± 8.14 mg RE (rutin equivalents)/g DW Anthocyanins 102.2 ± 16.4 mg CGE/g DW Hydrolysable tannins 139.63 ± 4.25 mg TAE (tannic acid equivalent)/g DW	Kumar Bhandary *et al.,* 2012. Elfalleh *et al.,* 2012

Carica Papaya	Peels	Phenolic compounds, flavonoids	TPC 3.23 ± 0.05 g GAE/100 g CE Contents of ferulic acid (1.33–1.62 g kg^{-1} dry weight), Caffeic acid (0.46–0.68 g kg^{-1} dw) Rutin (0.10–0.16 g kg^{-1} dw)	Siddique *et al.,* 2018 Rivera-Pastrana *et al.,* 2010.
Mangifera indica L.	Peels	ellagic acid, gallic acid, gallotannins, gallates, condensed tannins	TPC 87.38±0.43 mg of GAE/g TFC 15.6±0.23 mg of QE/g)	Arogba, 2000; Puravankara *et al.,* 2000.

DW dry weight.

Antimicrobial properties of fruit peels

Musa sapientum

Whole banana plant, for example stem, peels and leaves have therapeutic applications (Imam and Akter, 2011). Bioactive compound, for example: tannins, alkaloids, phlobatannins, glycosides, terpenoids and flavonoids, are reported in banana peel. These bioactive compounds are responsible for the pharmacological impact, particularly as a cell reinforcement, antidiabetic, mitigating, and anti-microbial agents (Kapadia *et al.,* 2016).

Periodontitis is an ailment with multifactorial etiology prompts loss of tooth supporting structures and tooth loss (Van Winkelhoff *et al*., 2002). Various Gram-negative microorganisms are involved in periodontal illnesses, among the major putative periodontal pathogens that are involved in various stages of periodontitis, *Aggregatibacter actinomycetemcomitans* (*A.actinomycetemcomitan*) and *Porphyromonas gingivalis* (*P. gingivalis*) are mostly reported (Slots J. 2000). Maximum antibacterial activities were also observed when water extracts were used (Siddique *et al.,* 2018). The peels of banana were also known to show antibacterial activity against different bacteria including *A. actinomycetemcomitans* (*A. actinomycetemcomitans)* and *P. gingivalis* (*P. gingivalis*) bacteria that are involved in the pathogenesis of damaging periodontal illness (Van Winkelhoff *et al.,* 2002). For this purpose, the peel was dried, chopped into pieces, dipped into solution of isopropyl alcohol and the activity as checked using well diffusion assays respectively (Kapadia *et al*., 2016).

The ethanolic extracts of banana peels showed a minimum inhibitory concentration in a range of 16mg/mL - 512.5mg/mL. *Salmonella typhi* had a MIC of 16mg/mL while *Staphylococcus aureus* and *Bacillus subtilis* had a maximum MIC of 512.5 mg/mL (G. *et al.,* 2014). Various antimicrobial activities against *Pseudomonas* and *Staphylococcus* were also observed. The IC_{50} values for *P. Staphylococcus* and species were reported to be 183.1 µg/mL and 143.5µg/mL respectively (Imam and Akter, 2011).

Citrus aurantium

The investigations on biologic impacts of *C. aurantium* (orange) showed potential mosquito repellent, larvicidal and insecticidal activities (Cetin *et al.,* 2006)**.**

Human jungle fever also called as malaria, as a mosquito-borne illness, caused by parasitic protozoa.

Plasmodium is considered to be the most v ector-borne disease and females of Anopheles mosquitoes is involved in the transmission of it (Lehane, 1991). Natural antimicrobial activity against malarial vector was also shown by the peel of citrus (Sanei-Dehkordi *et al.,* 2016).

The antimicrobial activity was also reported against *gram* negative bacteria (*Escherichia coli*) and also for gram positive (*Staphylococcus aureus)* (Gulay Kirbaslar *et al.,* 2009)**.** The ethanolic extracts of *Citrus sinensis* peel showed Minimum inhibitory concentration of 12-15 mg/mL against dental caries pathogens (Shetty *et al*., 2016).

***Punica granatum L*.**

Insecticidal, antiviral and antibacterial activities of pomegranate peel against pathogens of plants and humans have also been observed (Rosas-Burgos *et al*., 2017). *P. granatum* also have positive effect towards killing oral pathogenic bacteria (Rosas-Burgos *et al*., 2017). The high tannin content, especially punicalagin, fou nd in pomegranate peel, was responsible for antimi crobial action (Rosas-Burgos *et al*., 2017).

Pomegranate peels have shown powerful activity against various foodborne illness (Al-Zoreky, 2009).

Candida species, which are predominant and critical pathogens distinguished in hospitalized patients with nosocomial diseases (Pfaller *et al*., 2014) are also treated using biochemical leads from pomegranate peel.

A few investigations have also mentioned noteworthy inhibitory activities against *Candida albicans* using pomegranate (Pai *et al*., 2011). The pomegranate peel extracts show minimum inhibitory concentration of 25 μg/μL against *Streptococcus* mutans ATCC 25175 strain whereas the MIC value for *Rothia dentocariosa* is 20 μg/μL (Ferrazzano *et al*., 2017).

Carica papaya

The antimicrobial activities of papaya peel was identified against various gram positive bacteria, gram negative bacteria, and against different fungi as well (Rakholiya *et al*., 2014). It has been reported that C. papaya peels shows antimicrobial activity against *Escherichia coli, Staphylococcus aureus* and *Pseudomonas aeruginosa* (Aravind *et al.,* 2013). The peels of papaya may serve as natural antimicrobial agent to help fight with diseases that are caused by pathogens. Papaya peel showed minimum inhibitory concentration of 25.31µg/mL against *Salmonella typhimurium* (Saeed *et al.,* 2017).

Isolation of compounds from fruit peels

Musa sapientum

Flavonoids are one of the important phenolic compounds present in banana peel. The ethanol extract from banana peel exhibit antimicrobial activities against different microorganisms. Various phenolic compounds present in the peels are: gallocatechin and anthocyanins like peonidin and malvidine (Yusoff, 2008). Some carbohydrates, glycosides, anthocyanins, tannins, flavonoid are also present in peels (Alisi *et al* 2008).

Citrus aurantium

The methanolic extracts of citrus peel powder has anticancer activities (Yang *et al*., 2011). These methanolic extracts have wield robust antioxidant activity on hydroxyl and alkyl radicals and 2,2- diphenyl-1-picrylhydrazyl (DPPH) (Senevirathne *et al*., 2009).

Bioactive compounds are found in the peels and inward white mesh of the peels. Among citrus peel flavonoids are the major components. Other significant constituents in peels are polymethoxylated flavonoids (PMF's), terpenoids, such as linalool and limonene; and other volatile oils. These polymethoxylated flavonoids (PMF's) have numerous properties like: anticarcinogenic and antiatherogenic properties (O, 2006). These PMF's have inhibitory action for soybean 15-lipoxygenase. One of their component 3,5,6,7,3′,4′-hexamethoxyflavone show maximum inhibition (Malterud and Rydland, 2000). The structures of these isolated compounds are identified by MS/UV. The volatile fraction of citrus peel constitute of aldehydes, ketones and esters. Two of them are: n-hexanal, carvone (Haven, 1969) and perillyl acetate (Guenther and Grimm, 1938).

Mangifera indica L.

Mango peels have high content of phenolic compounds and carotenoids. Studies on mango peels have shown that the phenolic contents have wield robust bioactive properties. The bioactive compounds have anti-inflammatory and antioxidant properties (Castro-vargas *et al*., 2019). One of the common phenolic compound present in the peel is Mangiferin. Mangiferin has great antiviral properties and antioxidant properties (Gold-Smith, 2016) extracts have been checked to get insight about bioactive properties. The IC_{50} of *M. indica L.* 1.39-5.24 lg of gallic acid equivalents (Parashar *et al*., 2014). This is done by calculating their radical scavenging activity.

Vitamin C is the major constituent of mango peel. Carotenoids and some dietary fibers are also reported (Jahurul *et al*., 2015). The presence of these compounds was linked with a decrease in the incidence of various diseases such as: Alzheimer's disease, cataracts and Parkinson disease respectively (Ayala-Zavala *et al.*, 2011).

Carica papaya

Papaya peel as well as other parts contain a great reservoir for oligosaccharides. The structural information of these oligosaccharides were determined by HPLC. Different oligosaccharides in the peels are: raffinose, maltotriose, maltotetriose, maltopentaose and maltohexaose (Khalili *et al.,* 2014). These oligosaccharides are used as prebiotics that are substrates to only various beneficial bacteria in our body like *lactobacilli* and *bifidobacteria* (Manning and Gibson, 2004).

Chemical nature and Mode of action of phenolic compounds

Phenolic compounds comprises of group of plant metabolites which
are found in a variety dietary commodities such as vegetables, chocolates, beverages and fruits. Phenolics are categorized into few groups: Flavonoids, phenolic acids and tannins. Carboxylic acid is the functional group in almost every phenolic acid and they are the hydroxylated derivative of cinnamic acid and benzoic acid. Among benzoic acid, gallic acid (GA) and p-hydroxybenzoic acids are included. While cinnamic acid includes: caffeic acid and ferulic acid (FA). The difference in properties of phenolic products is attributed mainly due to the position and numbers of hydroxyl groups on the aromatic ring as well as the type of substitutes. Relative toxicity to microorganism is also associated with position and numbers of hydroxyl groups attached. The more hydroxyl groups attached (more hydroxylation) is related to the more toxicity in microorganisms (Borges *et al.,* 2013). Moreover phenolic products are also known to exhibit various biological effects such as antimicrobial effects which are discussed in this review.

The Mode of action of various classes has also been reported (Cowan *et al.,* 1999)
Phenolics have various subgroups.

Simple phenols (catechols and epicatechin) they act by depriving of substrate and by disruption of membrane (Peres *et al.,* 1997, Toda *et al.,* 1992). Quinones (Hypericin) they inactivate enzymes by binding to adhesins form complex with cell wall (King *et al.,* 1994, Duke *et al.,* 2002). Flavonoids (Chrysin) similar to quinones (Perrett *et al.,* 1995). Flavones (Abyssinone) they inactivates enzymes as well as also causes inactivation of HIV reverse transcriptase (Rojas *et al.,* 1992, Ono *et al.,* 1989, Taniguchi *et al* 1993). Tannins (Ellagitannin) they causes membrane disruption and formation of metal ion complex by binding with proteins and adhesins, Furthermore the also causes enzymes inhibition (Schultz, J. C. (1988), Stern *et al.,* 1996, Scalbert, A. (1991), Brownlee *et al.,* 1990, Butler, L. G. (1989)).

Terpenoids and essential oils do not have further subgroupings.

Their example include capsaicin. Their mechanism of action is similar to various phenols. They mostly cause membrane disruption (Cichewicz and Thorpe (1996)).
Alkaloids also do not have further subgroupings.

Their examples include berberine and piperine. They act by intercalating into cell wall or DNA (Burdick, E. M. (1971), Freiburghaus *et al.*, 1996).

Lectins and polypeptides also do not have further subgroupings.

Their examples include mannose-specific agglutinin. They form disulphide bridges and block viral fusion or adsorption (Meyer *et al.,* 1997, Zhang and Lewis (1997)).

CONCLUSIONS

The horticultural agro wastes have been found to contain various important constituents, helpful for our body. So, irrespective of making them as waste and discarding them, these peels if utilized effectively can be beneficial. These peels also contain nutritional constituents like lipids, carbohydrates, proteins, vitamins and minerals. Along with these several important phytochemicals having magnificent biological activities are also being reported from fruit peels. Different studies on fruits peels have shown antimicrobial, antioxidant, antiviral and anticancer properties. The antimicrobial activity of various fruits has been checked for different strains of bacteria and is found very promising. *M. sapientum* peels shows antibacterial activity against *A. actinomycetemcomitans and P. gingivalis*. *P. granatum* show antimicrobial properties against *C. albicans while C. papaya* show antimicrobial activity against *S. typhimurium.* Phytochemical profiles of peels have also made them important for the therapy of different diseases. The pulp along with peel are also good source of antioxidants. Their careful utilization also makes the environment clean and pose numerous health benefits.
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