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Review Article

ANTIBACTERIAL AND ANTIOXIDANT ACTIVITY OF KIWI FRUIT

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Abstract: *The kiwi fruit has been drawing attention and a great deal of interest because of its health benefits. It is consumed in its natural form, while it is being presented in processed form by the food industry such as sweets, ice creams, frozen juice or pulp, and many other byproducts. The peel of kiwi fruit which is a byproduct of fruit is still under exploration, but it has raised much interest in this by-product because this has many bioactive molecule contents in it such as phenolic compounds. Kiwi fruit has shown antimicrobial activity apart from the antioxidant activity against many pathogenic bacteria i.e. Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus, and Listeria monocytogenes as well as fungi like Penicillium funiculosum, Aspergillus niger, Aspergillus versicolor and Aspergillus ochraceus. With the presence of antibacterial, antifungal, and antioxidant activities in kiwi fruit, it may be used as a potential medicinal fruit.*

Keywords: kiwi fruit, antibacterial, antifungal, antioxidant, polyphenols

Introduction

The kiwi fruit (*Actinidia deliciosa* L.) was originated from river Yangtze in the valley of Northern China and in the province of Zhejiang on eastern China's shore (Garcia *et al*. 2011). China is the major producer in the world due to its highest production of kiwi fruit which estimates around about 1.06 million tons annually (Huang *et al*., 2003). In the whole world, around about 70 species of kiwi fruit are found but only *A. deliciosa* (green kiwifruit) and *Actinidia chinensis* (golden kiwifruit) are commercially processed (Huang *et al*., 2001). In an industrial production a large amount of seeds and peels is discarded away because they only use pulps and juices of fruits. There is little exploration regarding usage of these byproducts, however, in some studies it is described that these byproducts are good source of many other bioactive compounds such as carotenoids, terpenoids and polyphenols(Santana-Méridas *et al*., 2012). Seeds and peels have many biological activities like antioxidant activities (Talukder *et al*., 2016), antimicrobial (Soquetta *et al*., 2016), anti-inflammatory (LLi *et al*., 2014) and anti-diabetic activity (Asghar, 2013) and many other activities that are extensively associated with these biological and chemical compounds, especially these are associated with polyphenols (Latocha *et al*., 2010). So, these factors give us a lead to consider that these residues which are obtained from industrial units and agriculture systems, which have an added value and have rich contents like bioactive molecules which were little explored in past (Folletta *et al*., 2019).

There are 60 species of plant genus *Actinidia*, and according to literature, this Kiwi fruit is native to north-central china. In the beginning of 20th century the commercialization of kiwi fruit was started and the cultivation of Hayward was the most recognized one and commercialized one (Asghar, 2013; Folletta *et al*., 2019). There is a high conservation capacity in Kiwi fruit, as at the temperature of 0 ^{o}C it can be stored for many months without decline in quality of fruit (Krupa *et al*., 2011). According to nutritional point of view kiwi fruit is enriched with dietary fiber, vitamins such as (A, C and E), minerals as well as phenolic compounds (Latocha *et al*., 2010; Zhu *et al*., 2013). The peel of kiwi fruit which is a byproduct of fruit is still under exploration, but it has raised much interest in this by product because this has much bioactive molecule contents in it such as phenolic compounds i.e. 1273 mg/100g when compared with other fruits' peel for example apple peel (329 mg/100g) and orange peel (473mg/100g) (Asghar, 2013; Wojdyło *et al*., 2017). It has been found that the residues of kiwi fruits can be considered as these are rich source for added value compounds that are of great for several industrial sectors. There are many studies in literature which explains the kiwi fruit; hence it is considered that there is still much need of

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research to ensure the complete utilization of kiwi fruits' bioactivity (Wang *et al*., (2018).

Dias *et al*., (2020) found that by valorization the application, exploration of food byproducts can be done, hence, Food waste can be reduced, and in this regard more studies are needed. So keeping in view his point, present study aimed at exploring bioactive compounds' properties in 2 different kiwi fruit varieties i.e. *Actinidia spp* (red kiwi pulp) and *Actinidia deliciosa* cv. "Hayward" (green kiwi pulp). Keeping in view boosting the application of kiwi fruit in food industries, chemical properties of pulp and peel were assessed, and being evaluated regarding anti-microbial, anti-inflammatory, antioxidant cytotoxic activities etc. To find the antibacterial activity, kiwi peel along with its pulp were dissolved within water which has concentration of 10mg/ml. And this antibacterial activity of kiwi pulp and peel was assessed through previously used methods (Soković *et al*., 2010) using *Escherichia coli* as well as *Enterobacter cloacae* (human isolate) which are actually gram negative bacteria, on the other hand *Listeria monocytogenes* and *Bacillus cereus* (food isolate), have also been used which are gram positive bacteria. Minimum inhibitory concentration and minimum bactericidal concentrations were determined and ampicillin & streptomycin were used as a positive control. By following the protocols described by Soković and van Griensven (2006) antifungal activity was observed, by using four different species of fungi: *Penicillium funiculosum*, *Aspergillus niger*, *Aspergillus versicolor* and *Aspergillus ochraceus*. Ketoconazole was used as positive control and minimum inhibitory conc. And minimum fungicidal concentrations were determined.

Amina *et al*., (2019) discovered that polyphenols and flavonoids were abundant in pericarp of kiwi fruit as compare to the flesh of the fruit, as these contents were 12.8 mg/g for polyphenols and 2.7mg/g for flavonoids. According to LC/MS analysis, it was found that epigallocatechin, quercitin and catachin contents that were main polyphenols in kiwi fruit were higher in peel of fruit than the flesh of kiwi fruit ($P < 0.05$). As compare to the flesh, the antioxidant activity and anti-bacterial activity of peel was significantly higher. On the other hand, during proliferation of the HepG2 cells, that were time and dose dependant, were inhibited by polyphenols in kiwi fruit. After 72 hours, the IC_{50} for peel and flesh polyphenols of kiwi fruit was 170 µg/mL and 291 µg/mL respectively. Hence it was proved that the peel of kiwi fruit has high polyphenols and flavonoids and it exerts more antibacterial, antioxidant, and anticancer activity than the flesh of the fruit. So, this study strengthens the scientific evidence for kiwifruit development that has excellent bioactivity in its peel.

It has been discovered that the post-harvest commodities have high amount of active elements, which has many physiological and biological benefits for human beings, especially fruits and vegetables. Due to remarkably significant vitamin C contents, balanced nutritional composition i.e. minerals, dietary fibers, and any other health beneficial metabolites, kiwifruit is an economic crop (Liu, J. *et al*., 2018). *Actinidia chinensis* specie is now being cultivated in many countries like including the China and this has attracted many researchers in past decade (Montefiori, M., *et al*., 2005). Studies till date regarding *A. chinensis* are mainly focused on the bioactivity, genome of kiwi fruit, bioactive constituents and factors which are affecting the quality of fruit and other factors in fruit flesh (Huang *et al*, 2013; Kwanhong *et al*., 2017; Zhang *et al*., 2014). In many studies, thin-layer chromatography, ultra-high performance liquid chromatography, and high performance liquid chromatography are being used for characterization and isolation of phenolic compounds in the flesh of kiwi fruit (Sun-Waterhouse *et al*., 2009; Pinelli *et al*., 2013).

Kiwi fruit has shown antimicrobial activity apart from antioxidant activity against many pathogenic bacteria i.e. *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Listeria monocytogenes* (Kichaoi *et al*., 2015). For exploring the health benefits of kiwi fruit flesh on human health, it has been remained in research for many decades. Specially, the kiwifruit peel is used in the citric acid and alcohol production with the process of solid state fermentation due to its commercial potential. Indeed many other fruits' peel is abundant in phenolic and other bioactive compounds than this corresponding fruit's flesh (Fattouch *et al*, 2008). However, there are only 2 papers which are reporting on the polyphenol profile of kiwi fruit' peel (Dawes *et al*., 2008). Till now, study has described the differences between the polyphenol compounds and the bioactivity of flesh and peel of kiwi fruit. According to the results, scientists found that this kiwi fruit is an excellent anti-microbial agent against many microbes like *Streptococcus pyogenes* with a M.I.C (minimum growth inhibitory concentrations) 0.731 mg/ml and *Staphylococcus aureus* with a M.I.C of 3.125 mg/ml. It has been found by researchers there is no specific or significant difference between vancomycine and kiwi fruit extracts in term of their anti-microbial activity against *Staphylococcus aureus* it means both of these

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have comparable antioxidant antibacterial activity. On the other hand, scientists also found that though kiwi fruit is an effective anti-agent against microbes specially *S. pyogenes* and *S. aureus*, but it is inferior to vancomycine which is an active antibiotic against above said microbes. So, kiwi fruit extracts can be understood the potential alternative to this antibiotic vancomycine in treating Staphylococcus aureus or S. pyogenes. However, lower activity is shown by kiwifruit extracts in treating S. pyogenes as compared to the vancomycine (Barario *et al*., 2019).

He *et al*. (2019) found that extracts from all parts of kiwi fruit including pulp, skin, stems and seed have antibacterial activity against many bacteria like *Streptococcus pyogenes, Staphylococcus aureus, Klebsiella pneumonia, Escherichia coli, Pseudomonas aeruginosa*, *S. faecalis, Proteus mirabilis*, and *Salmonella typhi*. With the MIC valueof 8 & 4 µg/ ml, the pulp and skin of kiwi fruit showed maximum inhibition activity against *S. pyogenes* and *S. aureus*, but minimum inhibition activity was shown against *S. faecalis, K. pneumonia, S. typhi, P. mirabilis, E. coli* and *P. aeruginosa* with MIC value that ranged from 16-128 µg/ml. on the other hand, with the MIC value of 64 and 32 µg/ml, the extracts from stem ad leaves inhibited *S. pyogenes* and *P. aeruginosa.* With the MIC valueof1 and 8µg/ml, the extracts from seed showed maximum bacteriostatic activity against selected bacterial strains (Basile *et al*., 1997; Deng *et al*. 2013).

A significant bactericidal effect was shown against *Bacillus cereus, Shigella flexneri, B. subtilis, Salmonella typhi* and bacteriostatic against *B. thurigiensis*, by polyphenols extracted from seeds of *A. cinensis*. Deng *et al.* (2013) found that the activity of extracts from kiwi fruit that contains polyphenols exerts more antibacterial. He *et al*. (2019) found that due to health benefits, economic and nutritional values, Chinese kiwi fruit and its related products are gaining popularity throughout the whole world. Kiwi fruit is the good source of carbohydrates, sugars, vitamin C, minerals and phenolic compounds. Especially, kiwi fruit possess vitamin C and minerals K in it. Flavonoids and organic acids are the phenolic compounds that are present in kiwi fruit, a variety of phenolic compounds are present in flesh, leaves, peel and roots of kiwi fruit. Tri-terpenoids which are characterized through 12-en-28-oic acids of ursane and oleanane types, are the major compounds found in roots of kiwi fruit. In roots and flowers of *A. chinensis*, the major and dominant volatile compounds were alcohols, esters, straight chain alkenes and terpenes.

As proved from many in vivo ad in vitro studies, these biochemical compounds reside in kiwi fruit with many sensory qualities like pharmacological properties and nutritional properties. From these crude extracts or fractions or isolated compounds, the claimed bioactivities were immunoregulatory, hypolipemic, antibacterial, anti-inflammatory, and antioxidant, antitumor, ant diabetic and protective effects from cardiovascular diseases. Especially, the claimed biochemical activities like immunoregulatory, antioxidant and anti-tumor were due to the polyphenols, polysaccharides, flavonoids, triterpenoids, vitamin C and unsaturated fatty acids. So these findings show that this miraculous fruit may prove as an excellent agent for treatment for oxidative stress, aging and pathologies related to cancer. There are also many opportunities for utilization, better protection and better development for human consumption and usage of kiwifruit. For safe human consumption, studies should be conducted on toxicity analysis, quantitative and qualitative metabolite research, inhibitory activities by cytochrome P450, clinical studies and standardized and effective quality standard building. On the other hand, attenuation and synergism effects, molecular mechanism and in vivo mechanism that are responsible for different biological and metabolic behavior of many ingredients, studies should be conducted on them.

It was discovered that a little studies supported *A. chinensis* cultivars, hence, more confirmative studies should be conducted for the verification of their health benefits. For the effective utilization of kiwi fruit, the parts of kiwi plant other that fruit like roots, leaves, stem and twigs should be explored. Similarly, more studies are needed on harvest and post-harvest for avoiding the damage caused by mildew, soft rot, chilling damage and decrease in chemical profile of kiwi fruit and for improving the chemical properties during storage of kiwi fruit. Antioxidant activities of the bioactive compounds of *A. chinensis* have been studied many times in in vivo and in vitro assay. The in vitro assay consisted of biological assay and chemical assay like ABTS, FRAP, ORAC HO, DPPH, lipid oxidation and oxidative stress caused by H_2O_2 (Chai *et al*., 2014; Deng *et al*., 2018; Hwang *et al*., 2017; Lee *et al*., 2015). While the in vivo assay was consisting on ALT, AST, SOD, GSH, lipid oxidation and oxidative damage to DNA (Hwang *et al*., 2017; Iwasawa *et al*., 2011; Sun *et al*., 2017; Wang *et al*., 2018). The results indicated that to various extents kiwi fruit is a good source of antioxidants, antibiotics and many bioactive compounds. Antioxidant properties are much

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attributed to flavonoids, polyphenols, the unsaturated fatty acids and vitamin C. In addition; different antioxidants properties were shown by different parts of kiwi fruit plant, extraction method of these bioactive compounds and genetic makeup and diversity of plant. Followed by the pulp and core of kiwifruit, the peel of the fruit shown maximum antioxidant activity. Due to the presence of vitamin C in pulp, antioxidant activity was shown and this antioxidant activity in peel was mainly dependent on the presence of polyphenols (Zhang *et al*., 2016). Deng *et al*. (2018) found that the kiwi fruit cultivars like Hongyang and Hort 16A were rich in attractive materials such as unsaturated fatty acids and this showed scavenging capacity for FRAP, DPPH, HO and ORAC with IC50 of 3.3 mg Trolox /kg (32.4 mg/ml, 1.04 mg/ml), 1.69 mg Trolox/kg, and 107.3 mg Trolox/kg (31.4 mg/ml, 1.09 mg/ml), 1.99 mg Trolox/kg, respectively.

Fresh and freeze-dried kiwifruit variety (Hort 16A) was having radical scavenging capacities and these were rich in flavonoids and polyphenols for ORAC, DPPH, ABTS were 98.3, 8.8, 8.8 and 40.3, 5.0, 6.0 mg VCE/g accordingly (Hwang *et al*., 2017). On the other hand the scavenging capacity for Cuiyu and Red sun which were rich in polyphenols and flavonoids for FRAP, ORAC, DPPH, ABTS were 1.50, 10.78, 1.01, 1.35 and 1.28, 8.87, 0.9, 1.32 mg VCE/g accordingly (Wang *et al*., 2018; Hwang *et al*., 2017). On oral administration of kiwi fruit, t protected lymphocytes from oxidative damage and it also inhibited the lipid oxidation in mice, on the other hand it decreased AST and ALT levels and increased the GSH and SOD levels in patients. Hence, it is confirmed that kiwi fruit is is residing antioxidant activity, therefor, appropriate extraction method, proper screening of plant parts and genotypes of the plant is required to maximize and enhance antioxidant activities of *A. chinensis* (Hwang *et al*., 2017; Sun *et al*., 2017).

It was discovered by Zhang *et al*., (2018) for checking the antiviral activity of kiwi fruit (*A. chinensis*) some bioactive compounds were isolated from roots of the plant and the findings of the research showed that spathodic acid-28-O-β-D-glucopyranoside and 5-methoxy-coumarin-7-β-D-glycosidase was having high anti-phytoviral activity along with inactivation effect which ranged from 42.56% to 56.76% which was higher than other compounds like ningnanmycin which was used as control. The extract from roots of *A. chinensis* removed the DPPH, wich is a superoxide anion and it also inhibited the HO (hydroxyl radicle) production (Yang and He, 2012). Olatunde *et al*. (2019) found that some pure compounds and extractions from *A. chinensis*' roots showed biochemical properties such as antiviral, antioxidant, detoxifying agent, homeostatic agent, and antidiuretic, antitumor, anti-hepatitis which were in agreement to the folkloric stories for usage of *A. chinensis* as a medicinal plant. Studies and researches showed that triterpenoids are fixed and bound in the roots of kiwi fruit which are mainly responsible for the anticancer property of kiwifruit. To verify this hypothesis, more researches and analysis should be carried out. For example more biological analysis of *A. chinensis* and isolation of biochemical compounds from roots should be carried out. In vivo and in vitro analysis of antitumor efficacy should be judged for providing the mechanism and evidences to drug candidates and for the development of new drug discovery.

There are fifty four species of Actinidiaceae which are evenly distributed in different province of china (Liang *et al*., 2007; Datson *et al*., 2011). It was found that family of kiwi fruit i.e. Actinidiaceae is rich in biochemical compounds like flavonoids, triterpenoids, alkaloids, anthraquinons, polysaccharides, organic acids and steroids (Fu *et al*., 2010; Lai *et al*., 2007; Zhou *et al*., 2010). A. chinensis' roots which are often recognized as tengligen are being used as folklore medicine for the cure of gastric cancer, liver cancer and esophagus cancer (Song 2001; Jiangsu New Medical college 1977 & 1986; Wang, L., *et al*., 2010; Huo *et al*., 2013; Cheng *et al*., 2015). In addition, kiwi fruit is also being used a hemostatic, anti-hepatitis, anti-diuretic and detoxifying agent, because tengligen which are the roots of A. chinensis is rich in biochemical compounds (Chang *et al*., 2005; Lahlou *et al*., 2001; Lai *et al*., 2007; Yutaka *et al*. 1992) which induces a broad spectrum biochemical activity as discussed earlier.

Like China, Italy and Chile, *Actinnidia chinensis* L., (Syn. *Actinidia deliciosa*) is a commercially grown crop in New Zealand (Ferguson and Huang 2007; Lahlou *et al*., 2001; Nishiyama 2007). In India, due to exotic introduction of kiwi fruit, the area under cultivation of this crop is very low. With the help of development support and extensive research on kiwifruit, the cultivation of above said crop has been extended in hills of Arunachal Pradesh, Jammu Kashmir and Himachal Pradesh. Due to availability of many biochemical compounds in peel which leads to distinct flavor of the fruit, Kiwi fruit is often consumed as fresh fruit (Atkinson and Macrae, 2007). The vitamins and minerals present in fruit often affect the appearance and nutritional values of the kiwi fruit, whereas, the taste of the fruit is

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generally influenced by the sweetness, volatile compounds and acidity of the fruit. For quantifying the acid contents of fruit, generally two methods are used i.e. titratable acidity (TAD) and initial pH. Actual and Immediate acidity (actual hydrogen ion concentration in solution) is being provided by the magnitude of pH. Total or potential acidity which includes the total number of acid molecules is being indicated by the titratable acidity. The molecules which are totally soluble in aqueous sample are called as soluble solid contents (SSC). And this SSC value is used for indicating the sweetness of kiwi fruit in commercial standards (Crisosto and Crisosto, 2001). Soluble solid contents (SSC) are being measured as unit of Brix and it is defined as percent sugar by weight. SSC value indicates the eating quality of the ripened kiwi fruit. The flavor quality is related to the ratio of sugar and organic acids present in kiwi fruit and also it indicates the optimum time for harvesting kiwi fruit (Burdon *et al*. 2004).

Health related attributes of kiwi fruit is the presence of Ascorbic acid in it (Ferguson and Huang, 2007), presence of flavonoids (Atkinson and Macrae 2007) and polyphenols (Sheng *et al*., 2005). In traditional medicine, kiwi fruit is being used for the cure of many diseases like stomach, liver and lungs cancer (Yang, 1981). Some studies shown that cancer cell growth is inhibited by the extracts obtained from the kiwi fruit (Song, 1984) and in in-vitro assay cells are being protected from oxidative DNA damage (Beever, *et al*., 1990; Collins *et al*., 2001; Lahlou *et al*., 2001). Antioxidants have become an important topic in modern researches they are not naturally produced on human body hence they should be consumed from some artificial sources or diet like kiwi fruit. Hence antioxidants are the substances which at low concentrations prevent or delay the oxidation of the substrate which is happening in chain reaction (Beever, *et al*., 1990; Halliwell and Whiteman 2004). The quality of the kiwi fruit is determined by its low Kcal contents in fruit (Tavarini *et al*., 2008), and high amount of phytochemicals and antioxidants (Tomas *et al*., 1997), such as polyphenol compounds (Park, *et al*., 2009), and ascorbic acid (Lahlou *et al*., 2001; Nishiyama, *et al*., 2004). The concentration of ascorbic acid has been found significantly influenced on harvest time (Park, *et al*., 2009). In kiwi fruit, the concentration of ascorbic acid varies from 37-200 mg 100g-1fw (Lintas *et al*., 1991; Selman, 1983), and this ascorbic acid concentration is higher than lemon (Cioroi, 2007), peach fruit and apple (Beever, *et al*., 1990); however this concentration is also effected from storage conditions (Esti, *et al*., 2002). Total antioxidant capacity and polyphenol contents are affected from harvest time, fruit ripening stage, storage conditions and green pruning (Tavarini *et al*., 2008; Gullo *et al*., 2013).

Conflict of interest

The authors declared absence of conflict of interest.

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