Waste materials such as peels and seeds obtained from post-harvest management are rich source of biologically active phytocomponents possessing various physiological functions. Usually these plant based products are often discarded as waste or utilized as feed or fertilizer. Nowadays the recent area of research interest includes exploiting the use of peels for the production of effectual, safe, inexpensive and novel nutraceuticals as they contain high amount of natural compounds with medicinal properties. The present study was carried out to determine the antioxidant and antimicrobial potential of lemon peel as it is a rich source of molasses, pectin, limonene and other secondary metabolites. The antioxidant activity of lemon peel was determined using DPPH assay, FRAP and phosphomolybdenum assay while the antibacterial activity was tested against four bacterial strains. The result indicated that acetone extract of lemon peel exhibited greater potential to scavenge free radicals and reducing power that increased with increase in concentration. Methanol extract of lemon peel showed greater antimicrobial activity thereby indicating the effectiveness of lemon peel as a potent antimicrobial agent. Hence, lemon peel functions as a potent antioxidant and antimicrobial agent and that in future its use as an ingredient in value added food supplements is promising.

**Keywords:** lemon peel, phenolic compounds, nutraceutical property, antioxidant, antimicrobial.

**INTRODUCTION**

Vegetables and fruits yield about 25% to 30% of non-edible products such as peels and seeds. In most cases these waste by-products contain high contents of antioxidant and antimicrobial compounds that can be successfully utilized as a source of phytochemicals and antioxidant agents.

Lemon is an important medicinal plant that belongs to Rutaceae family. Citrus fruits such as orange, lemon, and lime, have been widely cultured and processed into juice. During the manufacture of citrus juice, very large amounts of byproduct wastes, such as peels are formed every year. Lemon peels exhibit a broad spectrum of biological activity including antibacterial, antifungal, antidiabetic, anticancer and antiviral activities.

There are several *Citrus* (C.) species such as *C. limonum* (lemon), *C. aurantium* (bitter orange), *C. limetta* (sweet lemon), *C. jambhiri* (rough lemon) and *C. paradise* (grape fruit). Lemon peel consists of two layers the outermost layer called zest, contains essential oils (6%) that are composed mostly of limonene (90%) and citral (5%) and a small amount of cintronelene, alphaterpinol, linanyl and gernanyl acetate along with B complex vitamins. It is being used for dissolving gall stones and has anticancer properties too.

Utilization of peel in several possible ways helps reducing solid-waste handling along with adding value to these peel waste. Currently zest, a food ingredient obtained by scraping or cutting the outer skin of citrus fruits such as lemon and orange is commonly used as a flavoring agent in biscuits, puddings, candy, chocolates, pies, cakes and in sour condiments.

Due to rapid increase of antibiotic resistance in our country and use of synthetic anti-oxidant agents an attempt was made in the present investigation to determine the anti-oxidant and anti-microbial activity of lemon peel and to document the use of lemon peel as a natural food ingredient in value added food supplements.

**MATERIALS AND METHODS**

**Collection of plant material**

Fresh lemons were purchased from a local market in Chennai and washed thoroughly under tap water. The peels were removed using a sterile knife and shade dried for 4-5 days at room temperature. The dried peels were pulverized using an electric blender and stored in airtight containers for further use.

**Preparation of peel extracts**

Two different solvents namely methanol and acetone were used for extraction. 5grams of lemon peel powder was soaked in 100 mL of the respective solvents for 72 hours by maceration technique. The supernatant was preserved at 5°C until further use.
Antioxidant activity

The antioxidant activity was evaluated by reduction assay method by the formation of green phosphomolybdenum complex.\(^{14}\) 1 mL of various concentrations of peel extract was combined with 1 mL of reagent solution (0.6 M sulphuric acid, 28 mM sodium phosphate and 4 mM ammonium molybdate). The tubes were capped and incubated in a water bath at 95°C for 90 min. The samples were cooled to room temperature and the absorbance of the mixture was measured at 695 nm against blank.

**FRAP Assay**

Different concentrations of the peel extract was mixed with 1 mL of phosphate buffer (0.2 M, pH 6.6) and 1 mL of potassium ferricyanide (1%). The mixture was incubated at 50°C for 20 min. 1 mL of 10% trichloroacetic acid was added to the mixture. Then 1 mL of 0.1% of freshly prepared ferric chloride was added and the absorbance of the resultant solution was measured at 700 nm.\(^{15}\)

**RESULTS AND DISCUSSION**

<table>
<thead>
<tr>
<th>Phytochemicals</th>
<th>Methanol extract</th>
<th>Acetone extract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenol content</td>
<td>26.58µg/mg GAE</td>
<td>119.6µg/mg GAE</td>
</tr>
<tr>
<td>Flavonoid content</td>
<td>4.5µg/mg QE</td>
<td>56.28 µg/mg QE</td>
</tr>
</tbody>
</table>

From the above table it is clear that flavonoids and phenolic compounds are present in lemon peel. Studies have reported that higher amount of phenolic compounds and ascorbic acids are found in the peel than in pulp.\(^{18}\) Phenolic compounds possess different antioxidant properties such as oxygen scavengers, peroxide decomposers, and metal chelating agents and free radical inhibitors. Wang et al.\(^{18}\) reported that lemon peel contains polymethoxylated flavones that are responsible for anti-cancer, anti-viral, anti-inflammatory activities, and reduced capillary fragility.
FRAP assay or Ferric Reducing Ability of Plasma is based on the reduction ferric tripyridyltriazine (Fe(III)-TPTZ) complex to the ferrous tripyridyltriazine (Fe(II)-TPTZ) by the sample with subsequent formation of a bluish green colored phosphate/Mo (V) complex. Greater absorbance indicates higher reducing potency. From the results obtained it is evident that both methanol and acetone extract exhibited good reducing power capacity which increased with increase with concentration. Majority of fruit peels exhibits 2 to 27 fold higher antioxidant activity than the fruit pulp. Antioxidants donate electrons to free radicals thereby neutralizing the action of free radicals and making them more stable and unreactive.

As the prevalence of antibiotic resistance still continues it is therefore essential to develop plant based products with antibacterial activity. Abdullah reported that lemon juice showed inhibition against S. aureus and K. pneumoniae with inhibition zones 17.4 and 13.3 mm respectively. The result of the present study indicated that lemon peel too showed antibacterial activity against all the tested bacterial strains due to the presence of components such as ascorbic acid, flavonoids, polyphenols and phenolic compounds. Methanolic extract of lemon peel exhibited highest activity against S. flexneri followed by S. aureus and E. coli. Acetone extract also inhibited the growth of S. aureus and E. coli which is on par with methanolic extract. Limonoids present in citrus fruit peels contribute to antibacterial and antifungal activity. Alcoholic extract of lemon peel also exhibited antimicrobial activity against P. aeruginosa and S. Typhimurium.

CONCLUSION

The hazardous effects of synthetic antioxidants along with the emergence of antibiotic resistant strains has revived the search for novel antioxidant and antimicrobial agents from natural sources. The present study paves a way to researchers and scientists to utilize the potential of lemon peel in various domains such as food and nutraceutical industries as a natural, novel and economic source as lemon peel exhibited potent antioxidant activity.
antioxidant and antimicrobial activity. Utilization of fruit and vegetable peels in several ways not only improves the nutritional status of well-being but at the same time provides opportunity for income generation.

Table 5: Antimicrobial efficacy of lemon peel

<table>
<thead>
<tr>
<th>S. No</th>
<th>Extracts</th>
<th>Pathogens</th>
<th>Standard Tetracycline 50µL</th>
<th>Zone of inhibition (mm) 75µL</th>
<th>Zone of inhibition (mm) 100µL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Methanol</td>
<td><em>E. coli</em></td>
<td>24</td>
<td>-</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Staphylococcus aureus</em></td>
<td>26</td>
<td>12</td>
<td>13</td>
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<tr>
<td></td>
<td></td>
<td><em>Shigella flexneri</em></td>
<td>22</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Klebsiella pneumoniae</em></td>
<td>29</td>
<td>-</td>
<td>11</td>
</tr>
<tr>
<td>2.</td>
<td>Acetone</td>
<td><em>E. coli</em></td>
<td>20</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Staphylococcus aureus</em></td>
<td>25</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Shigella flexneri</em></td>
<td>24</td>
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</tr>
<tr>
<td></td>
<td></td>
<td><em>Klebsiella pneumoniae</em></td>
<td>23</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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Source of Support: Nil, Conflict of Interest: None.