Nutritional and therapeutic benefits of medicinal plant
*Pithecellobium dulce* (Fabaceae): A review

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ARTICLE INFO
Received on: 07/12/2018
Accepted on: 25/02/2019
Available online: 01/07/2019

Key words: *Pithecellobium dulce*, legume, nutrients, phytochemicals, therapeutic value.

ABSTRACT
"Pithecellobium dulce", an evergreen medium-sized, spiny tree, each part of the plant has vast nutritional values; stuffed with essential vitamins, amino acids, and minerals. The fruits of *P. dulce* were widely used in Ayurvedic medicines and home remedies. The plant has also been a rich source of biologically active compounds such as tannin, olein, and glycosides. Totally 38 active phytocompounds like quercetin, kaempferol, and dulcitol were identified from the various parts of the plant. Notably, this plant has catechol type of tannins in the bark. There are polyphenol classes of phytocompounds which have found to hold potent antivenom activity. Their fruits are a rich source of phenols, flavonoids, and saponins reported for their efficacy to treat diabetes, oxidative stress, and gastrointestinal disorders. The plant leaf and seed have an antibacterial, antifungal, and adulticidal activities. Thus, the present review describes on exploiting the medicinal properties of *P. dulce* and its biomedicinal applications in therapeutic development.

INTRODUCTION
Medicinal plants are the rich source of various natural constituents with extensive pharmacological activities. In recent days, nutraceuticals have gained huge attention as nutritional supplements for their positive physiological effects in the human body (Bagchi and Kumar, 2016). From villages to developed cities, traditional ways of natural medication consecutively becoming popular. Notably, the plant-derived compounds hold huge precious values for healthy living, and the tribal and elders have well known about the plants decades ago (Shyur and Yang, 2008). Lot of bioactive phytochemicals with medicinal properties to cure various health illnesses has been revealed every day by researchers (Satheesh Kumar and Nisha, 2014). These plant-derived bioactive compounds have the enormous potentiality to treat diseases like diabetes, cancer, inflammation, etc. (Saklani and Samuel, 2008). Although, there are numbers of allopathic drugs which have been developed every day since, the permanent recovery from the diseases and the secondary complications aroused during the medication remains a matter of debate (Edzard Ernst, 1998). Sometimes it would cause drastic effects like liver failure, kidney failure, raised blood pressure, and several other complications (Pirkle and Freedman, 2013). We have vast diverse flora with unexplored medicinal values (Hooper and Aedin, 2006). *Pithecellobium dulce* (*P. dulce*) is an important fruit of American origin and it belongs to the family of Fabaceae, a native of tropical America, and is cultivated throughout India and Andaman (Rao et al., 2011). *P. dulce* is one among the category, which is an evergreen medium-sized, spiny tree. It is locally called “Jungal jalebi,” “black bead tree” in English, “Vilayati Babul” in Hindi, and “Kodukkapuli” in Tamil (Orwa et al., 2009). This review discusses the overall bioactive constituents and their pharmaceutical properties of the *P. dulce*.

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Botanical description

Domain: Eukaryota
Kingdom: Plantae
Phylum: Spermatophyta
Subphylum: Angiospermae
Class: Dicotyledonae
Order: Fabales
Family: Fabaceae
Genus: Pithecellobium
Species: Pithecellobium dulce

Plant morphology

The barks of *P. dulce* are gray in color, they become rougher and eventually start peeling when gets matured. The leaves are 2–2.5 × 1–2 cm in size and have kidney-shaped leaflets with a pair of two leaves. Each leaf has a thin spine of 2–15 mm at the leaf base. Hairy corolla shaped flowers of 1 cm diameter are present with small whiteheads in the *P. dulce*. In the flowers, 50 thin stamens are surrounded in the calyx in a united tube. Each pod size is 10–15 × 1.5 cm and spiral and reddish-brown as they ripen (Orwa et al., 2009). The parts of the plant were shown in Figure 1.

Plant distribution

The plant originated from Brazil, Argentina, Bolivia, Colombia, etc., *P. dulce* is one of the species that has become widespread outside from its origin. It is one of 18 species in this genus. It has been distributed naturally in many countries like India, Huawei, tropical Africa, and especially along the coast (Orwa et al., 2009). The species distribution map for *P. dulce* is shown in Figure 2.

NUTRITIONAL VALUES

The fruits and seeds of *P. dulce* contain vital vitamins like ascorbic acid, thiamine, riboflavin, and some essential amino acids like lysine, phenylalanine, tryptophan, and valine, as shown in Figure 3 and few essential minerals such as Na, K, P, Fe, and Ca, as shown in Figure 4 and secondary metabolite classes like tannins, 25.36% fixed oil, and 18.2% olein are found in the *P. dulce* (CSIR, 1988). Catechol, a notable type of tannin compound which is present in the bark (37%). Quercetin, afezilin, kaempferol, and dulcitol were identified from the leaf extract of *P. dulce*. Its fruit contains phenols, flavonoids, and saponins. The phenolic and flavonoids have a hydroxyl functional group that possesses radical scavenging ability to prevent oxidative damage (Katekhaye and Kale, 2012). Proteins and peptides with the potential to combat...
protein malnutrition are richly present in *P. dulce* seeds. The steroid, saponin, lipids, phospholipids, glycosides, glycolipids, and polysaccharides are present in *P. dulce* seeds. The lists of phytochemical constitutions and their structures were shown in Table 1 and Figure 5. Recently, the alkylated resins were identified from the seed oil. The water-soluble polysaccharides were isolated from the seeds and are used as humanoid ailments; it also has an anti-oxidant activity that prevents the oxidative stress (Bagchi and Kumar, 2016). Three different hetero-polysaccharides are isolated from *P. dulce* fruits; those were used as pharmaceutical adjuvants (Preethi and Mary Saral, 2016). The protein and fiber contents of *P. dulce* are shown in graph Figure 5. The entire plant of *P. dulce* has medicinal values and its leaves are also used as a feed for goat (Kahindi et al., 2007) because of its good nutritional content (Olivares et al., 2013).
THERAPEUTIC AND BIOLOGICAL VALUES OF P. DULCE

Each part of the plant P. dulce contains notable medicinal values, like the estrogenic activity was proposed in the root extracts (Saxena et al., 1998), the anti-inflammatory activity of the saponin fraction of P. dulce fruits (Bhargavakrishna et al., 1970; Sahu and Mahato, 1994), and their various parts have been reported to be as a remedy for earache, leprosy, peptic ulcer, toothache, venereal disease, and it also acts as emollient, abortifacient, anodyne, and larvicides (Govindarajan et al., 2012). The bark of P. dulce also acts as an astringent for dysentery, febrifuge. In addition, this plant also has a useful remedy for dermatitis eye inflammation. The polyphenols content of the bark extract has reported for their anti-venomous activity by Pithayanukul et al. (2005). In seeds, active classes of phytoconstituents like steroids, saponins, lipids, phospholipids, glycosides, glycolipids, and polysaccharides were identified (Nigam and Mitra, 1968; 1970). This plant is a potential source of antioxidant and effective medicine for adulticide problem (Rajeswary and Govindarajan, 2014). The lists of biological therapeutic values were shown in Table 2. Beside of all the above properties, it is a nutritional feed for goats and other livestock (Olivares et al., 2013).

Adulticidal activity

The Phytochemicals of P. dulce are also used as an insecticide as they have an adulticidal activity against mosquitoes like Aedes aegypti (A. aegypti), Culex quinquefasciatus (C. quinquefasciatus), etc. Dengue, filariasis, malaria, and viral encephalitis are major Mosquito-borne diseases in developing countries. Aedes aegypti mosquitoes are responsible for dengue fever. Chemical based mosquito repellent spray is usually toxic to other beneficiary life forms, may cause severe breathing problems in human too. To avoid such circumstances, naturally derived repellents can be used (Govindarajan and Rajeswary, 2015). The leaves and seed extracts of P. dulce have the tendency to control mosquitoes and are very safe. The larvicidal and ovicidal effects are moderate in the leaf and seeds of this plant. The comparison studies were undertaken and is reported that the leaf extract using methanol has the highest larval mortality and the seed extract using hexane have lower potency towards mosquitoes.

The larvicidal and ovicidal activities were proved in A. aegypti (Rajeswary and Govindarajan, 2014) and C. quinquefasciatus (Govindarajan et al., 2012) mosquitoes. Pithecellobium dulce derived bioactive compounds are also used as a natural synthetic insecticide. The silver nanoparticles synthesized from an aqueous extract of P. dulce’s leaf exhibited larvicidal activity against C. quinquefasciatus. Further, the FT-IR report identifies the saponin; a class of phytocompounds in the plant is responsible for the synthesis of the silver nanoparticle (Raman et al., 2012).

Anti-diabetic activity

Diabetes mellitus is a very complex and uncontrollable metabolic disorder. There are numbers of the chemical agents that control the insulin and glucose level in the blood. It happens either due to improper secretion or action of insulin in the body during diabetes mellitus (Chaudhury et al., 2017). The synthetic pharmaceutical drugs prescribed for these conditions are having more harmful side effects like causing secondary organ damage (kidney failure, liver failure, etc.) on the human body. The plant bioactive chemicals are alternate medicines for diabetes allopathic medication. The methanolic crude extract of P. dulce seed was tested in Streptozotocin (STZ)-induced diabetic rat (albino Wistar male model) and the extract has the ability to protect the functional β-cells that produce and maintain the insulin level in the blood (Fu et al., 2013). This insulin treatment improves the glycogen content. In the methanolic extract treated STZ induced rats, the liver glycogen level was higher compared with the control group of Wistar rat and the functional glucose metabolism could be due to better insulin secretion from β-cells and the glucose was utilized in the oral glucose tolerance test. Thus, it could be a potential therapeutic for diabetic patients (Nagmoti et al., 2015). The P. dulce fruit containing a cyclic polyol pinitol and it has reported for having anti-diabetic activity (Gao et al., 2015; Kim et al., 2007).

Anti-hyperlipidemic

The excess glucose is usually preserved as glycogen and then fat in our body tissues as storage fuel for future. But the continuous accumulation for a longer period may lead to hyperlipidemia. It is one of the major risk factors involved in the development of Type II diabetes, heart disease, etc.
(Nelson, 2013; Zhou et al., 2015). High-density lipoprotein cholesterol (HDL-C) is mainly involved in protecting us from heart diseases, especially atherosclerosis (Vergeer et al., 2010) and it transports excess cholesterol out of the body. Nagmoti et al. (2015) checked the methanolic crude extract of P. dulce seed on STZ-induced diabetic rat model. The histopathological analysis showed the increased levels of HDLC and the very low-density lipoproteins cholesterol (VLDLC), low-density lipoproteins cholesterol (LDLC), serum cholesterol, and triglycerides level were significantly decreased in the P. dulce treated rats. From the results, the bioactive compounds of P. dulce seeds have active potentiality against the hyperlipidemic condition. Hence, P. dulce could also holding hyperlipidemic activity against STZ induced animal model has been proved (Nagmoti et al., 2015).

### Anti-oxidant activity

Imbalance of electron on any atom or oxidative stress is one of the key important factors which triggers majority of diseases like cancer, arthritis, diabetes, renal damage, etc. (Ung et al., 2017). The unstable radicals cause severe damage to the inner organs, tissues, and cause various health problems. Nitric oxide, hydroxyl, and superoxide radicals are few common free radicals responsible for some autoimmune diseases like rheumatoid arthritis.

### Table 1. List of bioactive compounds reported in *Pithecellobium dulce*.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Phytochemical name</th>
<th>Molecular formula</th>
<th>Molecular weight (g/mol)</th>
<th>Part of the plant</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Catechol</td>
<td>C₆H₆O₃</td>
<td>110.10</td>
<td>Bark</td>
<td>CSIR, 1980</td>
</tr>
<tr>
<td>2</td>
<td>Campesterol</td>
<td>C₁₄H₂₀O₂</td>
<td>242.34</td>
<td>Wood</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Leucofisetinidin</td>
<td>C₁₅H₁₃O₈</td>
<td>290.27</td>
<td>Wood</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Melacardin</td>
<td>C₁₅H₁₃O₈</td>
<td>290.27</td>
<td>Wood</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Hederagenin</td>
<td>C₁₅H₁₃O₈</td>
<td>472.70</td>
<td>Seeds</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Pitheduloside A</td>
<td>C₁₆H₁₆O₁₀</td>
<td>766.96</td>
<td>Seeds</td>
<td>Nigam et al., 1996</td>
</tr>
<tr>
<td>7</td>
<td>Pitheduloside B</td>
<td>C₁₆H₁₆O₁₀</td>
<td>883.08</td>
<td>Seeds</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Pitheduloside C</td>
<td>C₁₆H₁₆O₁₀</td>
<td>883.08</td>
<td>Seeds</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Pitheduloside D</td>
<td>C₁₆H₁₆O₁₀</td>
<td>899.08</td>
<td>Seeds</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Pitheduloside E</td>
<td>C₁₆H₁₆O₁₀</td>
<td>899.08</td>
<td>Seeds</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Pitheduloside F</td>
<td>C₁₆H₁₆O₁₀</td>
<td>1045.22</td>
<td>Seeds</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Pitheduloside G</td>
<td>C₁₆H₁₆O₁₀</td>
<td>1045.22</td>
<td>Seeds</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Pitheduloside H</td>
<td>C₁₆H₁₆O₁₀</td>
<td>2144.31</td>
<td>Seeds</td>
<td>Yoshikawa et al., 1997</td>
</tr>
<tr>
<td>14</td>
<td>Pitheduloside I</td>
<td>C₁₆H₁₆O₁₀</td>
<td>488.69</td>
<td>Seeds</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Pitheduloside J</td>
<td>C₁₆H₁₆O₁₀</td>
<td>488.69</td>
<td>Seeds</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Pitheduloside K</td>
<td>C₁₆H₁₆O₁₀</td>
<td>1061.21</td>
<td>Seeds</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Octacosanol</td>
<td>C₂₄H₄₀O₆</td>
<td>414.76</td>
<td>Leaves</td>
<td>Nigam et al., 1970</td>
</tr>
<tr>
<td>18</td>
<td>α-spinasterol</td>
<td>C₁₆H₁₆O₁₀</td>
<td>414.76</td>
<td>Leaves</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Kaempferol</td>
<td>C₁₆H₁₆O₁₀</td>
<td>286.83</td>
<td>Leaves</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>kaempferol-3-rhamnoside</td>
<td>C₁₆H₁₆O₁₀</td>
<td>431.73</td>
<td>Leaves</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>β Glucoside–α spinasterol</td>
<td>C₁₆H₁₆O₁₀</td>
<td>574.85</td>
<td>Leaves</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Pithogenin</td>
<td>C₁₆H₁₆O₁₀</td>
<td>444.62</td>
<td>Seeds</td>
<td>Nigam et al., 1962</td>
</tr>
<tr>
<td>23</td>
<td>Ellagic acid</td>
<td>C₁₆H₁₆O₁₀</td>
<td>302.19</td>
<td>Fruits</td>
<td>Megala and Geetha, 2009</td>
</tr>
<tr>
<td>24</td>
<td>Gallic acid</td>
<td>C₁₆H₁₆O₁₀</td>
<td>170.12</td>
<td>Fruits</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Mandelic acid</td>
<td>C₁₆H₁₆O₁₀</td>
<td>152.14</td>
<td>Fruits</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Ferulic acid</td>
<td>C₁₆H₁₆O₁₀</td>
<td>194.18</td>
<td>Fruits</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Vanillic acid</td>
<td>C₁₆H₁₆O₁₀</td>
<td>168.14</td>
<td>Fruits</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Coumarinic acid</td>
<td>C₁₆H₁₆O₁₀</td>
<td>164.16</td>
<td>Fruits</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Rutin</td>
<td>C₁₆H₁₆O₁₀</td>
<td>610.52</td>
<td>Fruits</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Naringin</td>
<td>C₁₆H₁₆O₁₀</td>
<td>580.54</td>
<td>Fruits</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Daidzein</td>
<td>C₁₆H₁₆O₁₀</td>
<td>254.23</td>
<td>Fruits</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Dulcitol</td>
<td>C₁₆H₁₆O₁₀</td>
<td>182.17</td>
<td>Leaves</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Quercetin</td>
<td>C₁₆H₁₆O₁₀</td>
<td>302.23</td>
<td>Leaves, fruits, fruit peel</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Stigmasterol</td>
<td>C₁₆H₁₆O₁₀</td>
<td>412.69</td>
<td>Seeds, fruit peel</td>
<td>Sukkanta and Subashini, 2015</td>
</tr>
<tr>
<td>35</td>
<td>Pinitol</td>
<td>C₁₆H₁₆O₁₁</td>
<td>290.26</td>
<td>Fruit peel</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Prenylapigenine</td>
<td>C₁₆H₁₆O₁₁</td>
<td>646.63</td>
<td>Stem</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Oleanolic acid</td>
<td>C₁₆H₁₆O₁₁</td>
<td>456.70</td>
<td>Seeds</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Echinocystic acid</td>
<td>C₁₆H₁₆O₁₁</td>
<td>472.70</td>
<td>Seeds</td>
<td></td>
</tr>
</tbody>
</table>
Figure 5. Important chemical structure reported in *Pithecellobium dulce*. 
and diabetes mellitus (Asmat et al., 2016; Mateen et al., 2016; Saegusa et al., 2006). In our human body, various mechanisms like enzymatic and non-enzymatic antioxidants protect the inner cellular molecules and tissues against reactive oxygen species (ROS) induced damage (Aruoma, 1998).

The phytochemicals are widely known to be the precious sources for antioxidant activity. It stabilizes the radicals generated through various factor and help in promoting the antioxidant enzymes in our body. The leaves, seeds, fruits, and wood barks extract of P. dulce have potential activity against free radicals has proved. The whole plant has active free radical scavenging potential against synthetic radicals of DPPH, NO, superoxide, and hydroxyl ions (Katekhaye and Kale, 2012; Nagmoti et al., 2012; Sukantha et al., 2011). Further, the HPLC profiling confirms the

Table 2. Pharmaceutical and biological effects of Pithecellobium dulce.

<table>
<thead>
<tr>
<th>S. no</th>
<th>Biological activity</th>
<th>Part of the plant</th>
<th>Extraction</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Adultical</td>
<td>Leaf and seed</td>
<td>Hexane, Benzene, Chloroform, Ethyl acetate, Methanol</td>
<td>Govindarajan et al., 2012; Rajeswary and Govindarajan, 2014; Raman et al., 2012</td>
</tr>
<tr>
<td>2.</td>
<td>Antidiabetic</td>
<td>Seed</td>
<td>Methanol</td>
<td>Nagmoti et al., 2015</td>
</tr>
<tr>
<td>3.</td>
<td>Hypolipidemic</td>
<td>Seed and seed</td>
<td>Methanol</td>
<td>Nagmoti et al., 2015</td>
</tr>
<tr>
<td>4.</td>
<td>Anti-oxidant</td>
<td>Wood bark, leaf</td>
<td>Methanol, acetone</td>
<td>Katekhaye and Kale, 2012; Nagmoti et al., 2012; Sukantha et al., 2011</td>
</tr>
<tr>
<td>5.</td>
<td>H&lt;sup&gt;+&lt;/sup&gt;, K&lt;sup&gt;+&lt;/sup&gt;-ATPase inhibition</td>
<td>Fruits</td>
<td>Aqueous, hydro alcoholic</td>
<td>Megala and Geetha, 2009</td>
</tr>
<tr>
<td>6.</td>
<td>Anti-ulcer</td>
<td>Fruits</td>
<td>Hydro alcoholic</td>
<td>Megala and Geetha, 2009</td>
</tr>
<tr>
<td>7.</td>
<td>Nephroprotective</td>
<td>Fruit</td>
<td>Aqueous</td>
<td>Pal et al., 2012</td>
</tr>
<tr>
<td>8.</td>
<td>Anti-diarrheal</td>
<td>Leaves</td>
<td>Ethanol</td>
<td>Rashid et al., 2015</td>
</tr>
<tr>
<td>9.</td>
<td>Anti-bacterial</td>
<td>Pod pulp, Fruit Peel</td>
<td>Ethanol</td>
<td>Pradeepa et al., 2014</td>
</tr>
<tr>
<td>10.</td>
<td>Anti-fungal</td>
<td>Leaves and seed</td>
<td>Aqueous, Ethanol</td>
<td>Bautista et al., 2003; Shanmugakumar et al., 2006</td>
</tr>
</tbody>
</table>
abundant active phenolic and flavonoid contents in the fruits (Megala and Geetha, 2009).

**Anti-ulcer activity**

Peptic ulcer is one of the major and common global health issues. Because many of the anti-inflammatory drugs [called non-steroidal anti-inflammatory drugs (NSAIDS)], dietary factors, stress, or painkiller drugs were found to be affect the stomach and causes an ulcer (Lanas and Chan, 2017). Continuous alcoholic adductors are also affected by peptic ulcer. The development of ulcer is correlated with oxidative stress by hypersecretion of HCL and reactive oxygen species (ROS) generation (Osefo et al., 2009; Suzuki et al., 2012). The hypersecretion of HCL is caused by H⁺, K⁺-ATPase action. Omeprazole, Lansoprazole, Ranitidine, and Famotidine are the major H⁺ and K⁺-ATPase inhibitors used to treat the ulcer and to control the acid secretion. But these anti-secretary drugs produce adverse side effects on the human body.

The aqueous crude extract of *P. dulce* was orally treated in acetylsalicylic acid (ASA)-induced rat model (Male albino Wistar rats). The phytocomponents reacted and inhibited the gastric mucosal H⁺, K⁺-ATPase (Megala and Geetha, 2009). The H⁺, K⁺-ATPase level was analyzed and compared with the standard drug of Omeprazole. Gastric mucin is an important factor in protecting the gastric mucosa. Gastric mucin, myeloperoxidase activity, and prostaglandin E2 (PGE2) level were analyzed and reported in Megala and Geetha (2012). The important role of PGE2 is to maintain the gastric mucosa by increasing the gastric mucus secretion and decreasing the gastric acid secretion. In the *P. dulce* treated rats, the PGE2 level was found to be increased and that indicates the stimulation of cytoprotective factors that contribute to accelerate the ulcer healing effect. From the results, *P. dulce* have an ability to cure the gastrointestinal disorders (Peptic ulcer). So, the *P. dulce* extract can be used as an antiulcer agent and it also act as an anti-acid secreting agent and cytoprotective factor (Megala and Geetha, 2012).

**Nephroprotective**

Carbon tetrachloride (CCl₄) is an environmental toxin and is also used as medicine for hookworm disease and it affects and damages the kidney and liver (Rahmat et al., 2014). It causes fibrosis, cirrhosis, and hepatic carcinoma. Cytochrome P450 isozymes produce trichloromethyl free radical (TCCM free radicals) with higher toxicity of CCl₄. TCCM Free radicals react with oxygen to form the reactive trichloromethyl peroxy radical (high level toxic), a reactive oxygen species (ROS). Free radical also induces the lipid peroxidation and it is a major factor for cell membrane damage in many pathological situations. CCl₄ generates free radicals and cause renal disorders by generating free radicals in hepatic disorder (Al-Yahya et al., 2013). *Pithecellobium dulce* crude extract was orally administered in the CCl₄ induced rats (orally before CCl₄ induced rat) and crude extract was also administered to the rat before inducing CCl₄ toxin (orally after CCl₄ induced rat). The crude extract of *P. dulce* decreased the lipid peroxidation and protein carboxylation after inducing CCl₄ in rats, as the *P. dulce* compounds have antioxidant activity. In the CCl₄ administrated rats, the ROS level was found increased, while *P. dulce* fruit extract treated rats have decreased ROS level when compared with CCl₄ administrated untreated rats. Anti-oxidants enzymes are mainly involved in cellular defense and to prevent and protect from oxidative stress or oxidative damage. Glutathione reductase (GR), Superoxide dismutat (SOD), Glutathione-S-transferase (GST), and catalase (CAT) are major antioxidant enzymes and CAT & SOD are important enzymes to eliminate the ROX. In the *P. dulce* extract pretreated rats, higher amount of anti-oxidant enzyme level was observed as compared with CCl₄ induced rats and the rats treated with *P. dulce* extract. The aqueous extract of *P. dulce* also prevents and protects the renal DNA damage and cell death, by means of stabilizing the oxidative radicals, which disturbs the mitochondrial membrane and causes loss of ATP production that directly leads to cell death. Pal et al. (2012) evaluated and proved the anti-necrotic properties and nephroprotective properties of *P. dulce*.

**Anti-venom effect**

The tannin was extracted from *P. dulce* barks using aqueous extraction. The venom lethality was inhibitied and the necrotizing activity of the venom was minimized by this crude extract. The extract also inhibited 90% of acetylcholine esterase activity as it contains higher tannin concentration or combined hydrolyzable tannin concentration. α-cobra toxin protein was docked with four different tannin compounds using Autodock 3 and tannic acid, Digallic acid has −14.7 kcal/mol, −10.38 kcal/mol binding energies were studied. The plant extract selectively blocks nicotinic acetylcholine receptor and non-selectively precipitate the venom protein (Pithayanukul et al., 2005).

**Anti-diarrheal effect**

The ethanolic extract of *P. dulce* showed an anti-diarrheal effect in the castor oil-induced mice. Loperamide is the standard anti-diarrheal drug used to compare the results. The phytochemicals of *P. dulce* has the ability to increase the latent period, delay, and decrease the frequency of defecation (Rashid et al., 2014).

**Anti-bacterial effect**

The ethanolic extract of *P. dulce* pod pulp has potent to inhibit the Gram-positive bacteria (*Bacillus subtilis*) and Gram-negative bacteria (*Klebsiella pneumonia*). The secondary metabolites (flavonoid, saponin, etc.) are responsible for the inhibition of bacterial growth (Pradeepa et al., 2014). The aqueous, methanolic and ethyl acetate extract of *P. dulce* fruit peel inhibit the eight different microorganisms (*Staphylococcus epidermis, Escherichia coli, Klebsiella pneumonia, Staphylococcus aureus, Enterococcus faecalis, Pseudomonas aeruginosa, Pseudomonas putida, and Proteus vulgaris*) isolated from wound infection. The higher zone inhibition was found in the crude methanolic extract. From the result, *P. dulce* fruit peel metabolites could be used as an antimicrobial agent and wound healing agent was proved. The ethanolic extract of *P. dulce* leaf has also been investigated and their effective anti-bacterial property was reported by Sukantha et al., 2014.

**Anti-fungal effect**

The plant pathogens like fungus cause contamination in strawberry fruits during storage. Many of the preventive agents are used to prevent fungal contamination on fruits but they are usually
holding some toxic effects, *Pithecellobium dulce* is a natural resource that could be used against fungal contamination. The aqueous and hydroalcoholic extracts of *P. dulce* have potentiality against *Rhizopus stolonifer*, *Botrytis cinerea*, and *Penicillium digitatum* contamination. In the aqueous extract, the secondary metabolite of kaempferol and some other mixture of compounds are mainly involved against the fungal contamination. While comparing the aqueous and hydro alcoholic extracts, the aqueous extract has better activity against fungal contamination (Bautista-Banos et al., 2003; Shanmugakumar et al., 2006).

CONCLUSION

The present review concludes that this *P. dulce* has several beneficiary health effects and pharmaceutical activities such as anti-ulcer, anti-fungal, anti-diabetic, and anti-venom activities. From this review, presents a comprehensive view of the plant *P. dulce* physiological, pharmaceutical properties, and traditional applications of *P. dulce*. The origin, distribution, nutritional, metabolites, and pharmaceutical properties information given above will be beneficiary to the society over various health issues. Further, this study encourages consuming traditionally practiced herbs and fruits to face modern life-threatening illness.

CONFLICT OF INTEREST

All authors declare that there is no conflict of interests regarding publication of this paper.

FINANCIAL SUPPORT AND SPONSORSHIP

None.

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