Traditional Chinese medicine galla Chinesis were the transformed abnormal growth tissues of the plants infected by insects. During the process of galla formation, the oxidative damage of plant cells was caused and secondary metabolites were produced in plant tissues. The contents of antioxidant and the abilities of antioxidative function were determined in 8 insect galls and 6 host plants leaves. The antioxidative capacity of galls and leaves was evaluated by grey decision making based on antioxidative functions. The preference order for antioxidative capacity indicated that galls have higher antioxidative capacity than their host leaves to scavenge free radicals effectively for balancing the increases of free radicals in their bodies. The contribution degree of antioxidative variables to four antioxidative functions was compared using grey relational analysis. The determination antioxidative functions were the most relevant to the antioxidant ability, and that of chlorophyll is the less.

Determinant of antioxidative functions

The antioxidative functions were determined, including DPPH scavenging activity. Fe3+ ion scavenging activity, superoxide anion scavenging activity and reducing power. All methanol extract of galls and their host plants exhibited a relatively higher scavenging effect of scavenging DPPH radicals than the leaves of the F. erecta (6.22%). The highest and lowest scavenging activity of ferrous ions were found in the extract of the S. chinensis nuthgalls (82.98%) and the C. nokoiai cat’s claw-shaped galls (5.32%), respectively. The highest and lowest scavenging activity of the extracts towards superoxide anion showed in the C. nokoiai galls (99.65%) and the leaves of the F. erecta (0.39%), respectively. The leaves of the F. erecta contained a significant lower level of reduction power (0.65) compared to other extracts of the galls and host plants leaves. (Table 3)

Table 2. The contents of polyphenols, flavonoids, anthocyanins, chlorophylls and carotenoids were measured. Polyphenol contents from the galls were significantly higher than their host plants, except for the Unknown 2 galls on the S. sinensis. The highest and lowest polyphenol contents were found in the S. chinensis galls and the leaves of the F. erecta, respectively. The highest and lowest levels of flavonoids were observed in the leaves of the F. erecta and S. chinensis galls, respectively. The D. tainwanesans galls on the M. thunbergii contained significantly high antioxidancy contents than others. Compared with the host galls and leaves, chlorophylls in the insect-induced galls drastically decreased by approximately 18% while carotenoids declined by about 1.6–4 fold, except for the leaves of S. suberifolia with 91 µg carotenoids content. (Table 2)

Table 3. The ability of various antioxidative functions from galls and their host plants leaves.

DPPH scavenging activity (%) | Fe3+ ion scavenging activity (%) | Superoxide anion scavenging activity (%) | Reducing power
---|---|---|---
Daphnephila sueyenae (gall) | 95.91 | 40.02 | 74.03 | 1.19
Daphnephila sueyenae (leaf) | 85.46 | 40.68 | 77.06 | 1.28
Machilus thunbergii (gall) | 83.50 | 39.59 | 75.07 | 1.28
Machilus thunbergii (leaf) | 89.91 | 20.69 | 67.72 | 2.20
Litsea acuminata (leaf) | 79.75 | 27.64 | 64.40 | 2.18
Unidentified sp. 1 | 87.50 | 20.22 | 67.72 | 2.19
Unidentified sp. 2 | 86.22 | 27.02 | 63.70 | 2.17
Styrax formosana (leaf) | 98.20 | 41.13 | 66.05 | 2.22
Daphnephila sueyenae (gall) | 93.00 | 30.38 | 68.23 | 2.22
Daphnephila sueyenae (leaf) | 83.00 | 10.59 | 51.24 | 2.22
Ceratovacuna nekoashi (gall) | 90.37 | 27.08 | 35.37 | 2.18
Ceratovacuna nekoashi (leaf) | 85.00 | 5.20 | 47.05 | 2.33
Styrax formosana (leaf) | 83.50 | 24.61 | 20.76 | 2.30
Schlechtendalia chinensis (gall) | 53.68 | 20.92 | 73.17 | 2.32

Table 4. The rank of antioxidative capacity in insect galls and host plants leaves based on grey decision making.

<table>
<thead>
<tr>
<th>Host plants</th>
<th>Polyphenols (µg/g)</th>
<th>Flavonoids (µg/g)</th>
<th>Anthocyanins (µg/g)</th>
<th>Chlorophyll (µg/g)</th>
<th>Carotenoids (µg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schlechtendalia chinensis (gall)</td>
<td>79.00</td>
<td>1.00</td>
<td>9.00</td>
<td>2.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Daphnephila sueyenae (gall)</td>
<td>88.00</td>
<td>8.00</td>
<td>8.00</td>
<td>8.00</td>
<td>8.00</td>
</tr>
<tr>
<td>Machilus thunbergii (leaf)</td>
<td>68.00</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
</tr>
<tr>
<td>Schlechtendalia chinensis (gall)</td>
<td>58.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
</tr>
</tbody>
</table>

The number in parenthesis was grey order.

Grey relational analysis

When the antioxidative contents were listed in descending order of the contribution they make to the DPPH scavenging activity, the order was polyphenols > carotenoids > anthocyanins > flavonoids > chlorophyll. The grey relational value were anthocyanins > polyphenols > flavonoids > carotenoids > chlorophyll to the Fe2+ ion scavenging activity, polyphenols > flavonoids > anthocyanins > carotenoids > chlorophyll to the superoxide anion scavenging activity, and carotenoids > polyphenols > anthocyanins > flavonoids > chlorophyll to the reducing power, respectively. (Table 5)

Table 5. The grey relational value and order of antioxidants contents and antioxidative functions in the galls and host plants leaves.

<table>
<thead>
<tr>
<th>Antioxidant function</th>
<th>Polyphenols (µg/g)</th>
<th>Flavonoids (µg/g)</th>
<th>Anthocyanins (µg/g)</th>
<th>Chlorophyll (µg/g)</th>
<th>Carotenoids (µg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPPH scavenging activity (µmol/g)</td>
<td>0.875</td>
<td>0.784</td>
<td>0.673</td>
<td>0.742</td>
<td>0.682</td>
</tr>
<tr>
<td>Fe2+ ion scavenging activity (µmol/g)</td>
<td>0.749</td>
<td>0.739</td>
<td>0.754</td>
<td>0.656</td>
<td>0.786</td>
</tr>
<tr>
<td>Superoxide anion scavenging activity (µmol/g)</td>
<td>0.886</td>
<td>0.748</td>
<td>0.742</td>
<td>0.716</td>
<td>0.739</td>
</tr>
<tr>
<td>Reducing power (µmol/g)</td>
<td>0.782</td>
<td>0.781</td>
<td>0.789</td>
<td>0.740</td>
<td>0.584</td>
</tr>
</tbody>
</table>

The preference order for antioxidative capacity was Schlechtendalia chinensis (gall) > Daphnephila sueyenae (gall) > unidentified sp. 2 (gall) > Daphnephila tawnwanesans (gall) > Brugmannia sp. (gall) > Ceratovacuna nekoashi (gall) > Styra formosana (leaf) > Syzygium sinensis (leaf) > Styra formosana (leaf) > U. acuminata (leaf) > Machilus thunbergii (leaf) > Psidium baccatum (gall) (leaf) = Ficus erecta var. beechnya (leaf). (Table 4)

Conclusion

In conclusion, the contents of polyphenols from galls and their host plants leaves were the most relevant to the antioxidative ability, whereas the content of chlorophyll is the less. Different samples expressed various antioxidant abilities and functions, and the galls generally had better abilities and functions than their host plants leaves. The galls had enhanced level of antioxidative capacity to balance the increases in free radicals in their bodies, and may be valuable for the use of crude drugs in the future.