Macadamia (Macadamia spp.) is an evergreen tree indigenous to eastern Australia and grown commercially in the subtropical regions worldwide. The kernel is the main nutritious product of macadamia consumed by humans. In China, macadamia is cultivated in about 200,000 ha, accounting for more than 70% of the world’s planting area.1 Two taxa of macadamia, Macadamia integrifolia and Macadamia tetraphylla, and their hybrids are cultivated widely to produce edible nuts. Macadamia trees usually generate numerous flowers, and a mature tree in a flowering season can produce more than 2500 racemes, each comprising 100 to 300 flowers.2 However, only less than 2% of flowers can successfully set mature fruits.3 To gain a higher nut yield, many flowers are removed to reduce the nutrient consumption and promote young fruit development in a few macadamia orchards of China. However, these detached flowers are underused and often treated as waste products.

Numerous studies have demonstrated the presence in flowers of nutrients and phytochemicals such as carbohydrates, proteins, lipids, minerals, vitamins, and phenolic compounds.4,5 Edible flowers possess potent healthcare benefits due to high natural antioxidants such as phenolic acids and flavonoids.6 Notably, the antioxidant activities of phenolic compounds are much higher than those of the nutrients.8 Consequently, edible flowers have received more appreciation and are considered important sources of antioxidant substances in the human diet.4,6,7 Phenolic acids and flavonoids are the main polyphenols in flowers,9–11 existing predominantly in bound forms, such as glycosides, amides, or esters, and rarely in the free form.10 The extraction of these phenolic compounds largely depends on their chemical characteristics, polarities, and concentrations.12 Generally, solvents such as water and a mixture of organic solvents/water (mixture of water and ethanol or methanol and acetone) are used to extract phenolic compounds from flowers.7,10,13,14 However, the polarity differences among the solvents may lead to differences in the final yield, composition, and bioactivity of the phenolic extract.15 In addition, the phenolic profiles of flowers are related to petal color, taxon, and genotype.7,11,13

Keywords
Macadamia flower, flavonoids, phenolics, antioxidant activity, solvents

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Typically, the flowers of M. integrifolia are creamy white, and those of M. tetraphylla and their hybrids are pink. Liu et al. separated and identified several volatile components from the flowers of M. integrifolia. However, there are no reports on the phenolic composition and antioxidant property of macadamia flowers. Therefore, the present study analyzed the influence of several solvents on the phenolic content and antioxidant property of Macadamia flower extracts. In addition, the study assessed the correlation between the phenolic compounds and their antioxidant capacities. The findings of this study will provide helpful information for further research and exploitation of macadamia flowers.

Results and Discussion

Total Phenolic Content

The total phenolic content (TPC) of the different solvent extracts of the 2 macadamia taxa is presented in Table 1. The values varied from 13.8 to 23.0 mg gallic acid equivalent (GAE)/g fresh weight (FW) for “Nanya No.2” and 5.4 to 20.1 mg GAE/g FW for “HAES695”, with about 1.7 and 3.7 times difference, between water and acetone extracts, respectively. The TPC values detected in this study are within the range reported by Zheng et al. for 65 edible flowers. Several studies have shown that the TPC of flowers depends on the species, the cultivar, and the solvent. In this study, the TPC of flowers depended on the cultivar, the solvent, and the genotype and the solvent polarity caused the differences in the TPC of macadamia flowers.

Total Flavonoid Content

Flavonoids are a group of bioactive substances present abundantly in flowers. Xiong et al. reported that the total flavonoid content (TFC) of 10 edible flowers, extracted with 80% acetone, ranged from 7.7 to 89.4 mg rutin equivalent (RE)/g dry weight (DW). Chen et al. found that the TFC of 23 edible flowers in the water extract varied from 0.5 to 71.5 mg RE/g DW. Meanwhile, the 75% ethanol extract contained more TFC than the water extract of the fresh daylily flower. Similar to the changes in TPC in the present study, the TFC in the flowers varied markedly between the 2 cultivars in the 4 solvent extracts, and the TFC ranged from 9.7 to 17.4 mg RE/g FW for “Nanya No.2” and 4.4 to 10.9 mg RE/g FW for “HAES695”, with about 1.8 and 2.4-fold differences between water and acetone extracts, respectively (Table 1). For each solvent, the TFC of “Nanya No.2” was significantly higher than that of “HAES695”. Furthermore, the acetone extract had the highest TFC, while the water extract had the lowest ($P < .05$). For each cultivar, no significant difference in TFC was observed between the methanol and ethanol extracts. These results indicated that the flavonoid levels in macadamia flowers are similar to the abovementioned edible flowers. Thus, the differences in the genotype and the solvent polarity caused the differences in the TFC of macadamia flowers between 2 taxa and across solvents.

Phenolic Compounds

The content of individual phenolic compounds in the different solvent extracts of the 2 taxa of macadamia flowers is presented in Table 2. Thirteen phenolic compounds, including flavonoids (eg, catechin, epicatechin, rutin, naringenin, myricetin, phlorizin, quercetin, and kaempferol) and phenolic acids (eg protocatechuic, ellagic, gallic, chlorogenic, and ferulic acids), were initially identified and quantified through high-performance liquid chromatography (HPLC) by comparing their retention times and peak areas with those of the authentic standards. All the extracts had these compounds with differences between the 2

### Table 1. TPC and TFC in the Extracts of “Nanya No.2” and “HAES695” Macadamia Flowers Prepared With Different Solvents.

| Solvent | TPC (mg GAE/g FW) | TFC (mg RE/g FW) |
|---------|------------------|------------------|
| Acetone | Ethanol | Methanol | Water |
| “Nanya No.2” | 23.0 ± 0.9 aA | 16.8 ± 0.3 aB | 17.7 ± 1.3 aB | 13.8 ± 0.5 aC |
| “HAES695” | 20.1 ± 0.1 bA | 10.5 ± 0.5 bC | 12.9 ± 0.7 bB | 5.4 ± 0.2 bD |
| “Nanya No.2” | 17.4 ± 0.6 aA | 11.1 ± 0.3 aB | 11.3 ± 0.1 aB | 9.7 ± 0.6 aC |
| “HAES695” | 10.9 ± 0.3 bA | 5.8 ± 0.2 bBC | 6.8 ± 0.8 bB | 4.4 ± 0.8 bC |

Values are the means of three replicates ± SE (n = 3). Data are followed by different capital letters for the solvents, and small letters for the cultivars indicate significant difference at $P < .05$ (Duncan’s test).

Abbreviations: FW, fresh weight; GAE, gallic acid equivalent; RE, rutin equivalent; TFC, total flavonoid content; TPC, total phenolic content.
macadamia taxa and within the extraction solvents. Similarly, Kelebek et al.\textsuperscript{25} elucidated that the phenolic compounds of the extracts were influenced by the type of extraction solvent. Rutin and catechin are the flavonoids widely present in flowers and detected at high levels in edible flowers.\textsuperscript{4,9,26} Researchers have reported rutin as the most abundant flavonoid in capuzin (\textit{Tropaeolum majus}) flowers,\textsuperscript{11} while catechin is the highest in the daylily.\textsuperscript{27} In this study, rutin and catechin were the predominant phenolics identified in the 4 solvent extracts of macadamia flowers, contributing 63.9\% to 72.2\% and 65.1\% to 85.0\% of the total phenolic compounds of “Nanya No.2” and “HAES695”, respectively. For each solvent extract of the “HAES695” flower, catechin was the most abundant (769.0-1057.0 \( \mu \)g/g FW) flavonoid, and was significantly higher than rutin in the content (40.2-457.4 \( \mu \)g/g FW). On the contrary, the predominant compound in “Nanya No.2” was rutin, detected in the three organic solvent extracts. The amount of rutin (1049.9-1230.8 \( \mu \)g/g FW) was markedly greater than catechin (828.1-910.8 \( \mu \)g/g FW). Additionally, rutin was less than one-fifth that of catechin in the aqueous extract (636.5 \( \mu \)g/g FW). The levels of rutin and catechin detected in the 2 taxa of macadamia flowers were comparable to those reported by Chen et al.\textsuperscript{9} for the edible flowers. Barros et al.\textsuperscript{11} reported that the rutin content in the red flowers of capuzin was significantly greater than that in the orange ones. In this study, the white flowers of “Nanya No.2” had more rutin than the pink flowers of “HAES695” (\( P < .05 \)), while catechin showed an opposite pattern, which suggested that the differences in these 2 compounds were probably due to the differences in flower color. In addition, significant differences were detected in the rutin content among the 4 solvent extracts. However, no significant difference was detected in the catechin among all the test extracts, except for the aqueous extract, which showed the lowest catechin compared with the other three solvent extracts.

Kaempferol is another important flavonol that showed huge differences among the 4 extracts, the content varying from 160.6 to 276.9 \( \mu \)g/g FW for “Nanya No.2” and 92.7 to 223.6 \( \mu \)g/g FW for “HAES695”, consistent with those for nasturtium flowers\textsuperscript{13} and higher than those of the four edible flowers from Brazil.\textsuperscript{11} Naringenin and myricitin levels were roughly the same among the 4 solvent extracts, apart from the ethanol extract of “Nanya No.2” and the acetone and methanol extracts of “HAES695”, which displayed more naringenin than myricitin. Notably, naringenin and myricitin in the macadamia flowers were less than those in daylily flowers.\textsuperscript{14} Meanwhile, the content of chlorizin in the 2 macadamia taxa was greatly lower than that in apple flowers.\textsuperscript{28} Quercetin and epicatechin were detected in small quantities in all the extracts, unlike most edible flowers.\textsuperscript{9} In addition, the 6 flavonoids in “Nanya No.2” were remarkably greater than those in “HAES695” (\( P < .05 \)).

Phenolic acids are one of the major classes of plant phenolic compounds with better antioxidant properties than vitamins.\textsuperscript{29} Among the 5 phenolic acids tested in this study, protocatechuic and ellagic acids were predominant in both cultivars. “Nanya No.2” flowers had 53.4 to 465.6 \( \mu \)g/g FW of protocatechuic acid, which was significantly higher than that in “HAES695” (3.5-333.5 \( \mu \)g/g FW; \( P < .05 \)); both values were consistent with those reported by Chen et al.\textsuperscript{9} for 23 edible flowers. Besides, a significant difference was observed in protocatechuic acid content among the 4 solvent extracts for each cultivar. As a hydrolytic product of ellagitannins, ellagic acid with marked pharmacological activities was detected in the edible flower of \textit{Tagetes erecta} (7.4 \( \mu \)g/g FW).\textsuperscript{10,30} A higher content of ellagic acid was detected in this study; ellagic acid in “Nanya No.2” ranged from 16.5 to 89.4 \( \mu \)g/g FW with significant differences among the extracts, while that in “HAES695” ranged from 11.1 to 81.9 \( \mu \)g/g FW, with no significant variation among the extracts, except for the aqueous extract with the lowest. The ellagic acid content of “Nanya No.2” was significantly greater than that of “HAES695” only in the acetone extract (\( P < .05 \)). In addition, the levels of gallic, chlorogenic, and ferulic acids in the present study were lower in all the tested extracts than in the few edible flowers.\textsuperscript{9,18} Moreover, significant differences were detected in gallic and chlorogenic acids among the 4 extracts of each cultivar, while no difference was seen in ferulic acid, except for the aqueous extract with the lowest.

Overall, the total amount of the individual phenolic compounds varied greatly among the 4 extracts, which ranged from 1098.6 to 3353.9 \( \mu \)g/g FW and 952.3 to 2291.9 \( \mu \)g/g FW in “Nanya No.2” and “HAES695”, respectively (Table 2). The highest content of phenolic compounds was observed in the acetone extract of both flowers, followed by methanol and ethanol extracts, similar to TPC (Table 1), while the lowest was in the aqueous extract. Thus, the differences in the chemical properties and polarities of phenolic compounds resulted in the differences in the yield of phenolics among the various solvent extracts,\textsuperscript{31,32} suggesting that most polyphenols had better solubility in acetone than in the other 3 solvents. The total amount of phenolic compounds in the different solvent extracts of “Nanya No.2” was greater than that of “HAES695”, consistent with the reports that the flowers with pale petals possess more phenolic compounds than those with colorful petals.\textsuperscript{13,33} Additionally, flavonoids, accounting for more than 80\% of the total amount of phenolic compounds, seem to be the dominant compounds in each solvent extract, as reported by Pires et al.\textsuperscript{7} and Chen et al.\textsuperscript{9} in a few edible flowers.

**Antioxidant Capacity**

The antioxidant capacity of plant extracts is chiefly attributed to the phenolic compounds and is dependent on their redox properties and concentrations. Therefore, if phenolics with strong antioxidant potential are present at higher levels, the extracts would exhibit a robust antioxidant activity. The present study performed 3 assays (2,2-diphenyl-1-picrylhydrazyl [DPPH], 2,2’-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt [ABTS], and ferric reducing antioxidant power [FRAP]) to evaluate the antioxidant capabilities of the extracts. As shown in Table 3, the DPPH, ABTS, and FRAP values of
Table 2. The Contents of Phenolic Compounds in Extracts of Macadamia Flowers Detected by RP-HPLC Analysis.

| Compounds            | "Nanya No.2" |            |            |            | "HAES695" |            |            |            |
|----------------------|--------------|------------|------------|------------|------------|------------|------------|------------|
|                      | Acetone (70%)| Ethanol (70%)| Methanol (70%)| Water | Acetone (70%)| Ethanol (70%)| Methanol (70%)| Water |
| Gallic acid          | 20.8 ± 0.5Ha | 4.0 ± 0.1Kc | 5.9 ± 0.8FGb | 6.3 ± 0.9Fb | 16.2 ± 0.9Hb | 32.2 ± 0.5Fa | 4.0 ± 0.1Kc | 32.2 ± 0.5Fa |
| Chlorogenic acid     | 6.7 ± 0.2Jb  | 8.1 ± 0.3Ha | 7.0 ± 0.8Fab | 2.72 ± 0.4Gc | 6.6 ± 0.6Ja | 2.0 ± 0.1Jc | 1.5 ± 0.0Fi | 4.1 ± 0.4Ja |
| Ferulic acid         | 5.8 ± 1.0Ja  | 4.9 ± 0.2Ja | 4.8 ± 0.0Ga  | 1.5 ± 0.0Hb | 3.7 ± 0.3Ka | 4.2 ± 0.1Ja | 1.7 ± 0.0Hb | 4.1 ± 0.4Ja |
| Ellagic acid         | 89.4 ± 1.6Fa | 78.0 ± 1.1Fb | 80.4 ± 6.2Eab | 16.5 ± 4.4Ec | 81.9 ± 2.6Da | 74.2 ± 2.8Da | 70.4 ± 9.1Da | 11.1 ± 0.6Dc |
| Protocatechuic acid  | 465.6 ± 27.6Ca | 76.0 ± 5.2Fc | 116.9 ± 11.9Db | 53.4 ± 2.1Dd | 333.5 ± 75.6Ba | 39.1 ± 0.7Ec | 85.9 ± 3.7Db | 3.5 ± 0.1Gd |
| Catechin             | 910.8 ± 36.0Ba | 888.0 ± 52.5Ba | 828.1 ± 63.9Ba | 636.5 ± 23.4Ab | 1033.9 ± 95.6Ba | 997.5 ± 1.9Aa | 1057.0 ± 75.4Aa | 769.0 ± 9.9Ab |
| Epicatechin          | 2.0 ± 0.1Kb  | 2.2 ± 0.1Lb | 2.8 ± 0.2Ha  | 1.5 ± 0.1Hc | 2.9 ± 0.3Ka | 1.5 ± 0.1Kb | 2.0 ± 0.2Ja | 1.4 ± 0.0lb |
| Rutin                | 1230.8 ± 19.3Aa | 1049.9 ± 27.8Ab | 1090.7 ± 68.7Aab | 1181.8 ± 1.5Cc | 457.4 ± 18.4Ba | 364.9 ± 21.3Bb | 408.9 ± 27.1Bab | 40.2 ± 2.4Cc |
| Naringenin           | 134.4 ± 2.6Ea | 132.0 ± 4.7Da | 117.0 ± 8.0Da | 37.3 ± 9.8Db | 56.1 ± 2.6Ea | 40.6 ± 1.6Ee | 46.9 ± 4.4Eab | 8.2 ± 1.3Ec |
| Myricetin            | 126.4 ± 3.4Ea | 105.7 ± 3.0Eeb | 110.0 ± 7.3Dab | 47.4 ± 13.6Dc | 43.0 ± 1.1Fa | 43.2 ± 3.8Ea | 21.9 ± 4.4Fb | 8.9 ± 0.4Ee |
| Phlorizin            | 77.8 ± 2.9Ga  | 51.4 ± 2.2Gb | 62.6 ± 6.3Eab | 11.8 ± 0.7Ec | 24.9 ± 0.7Ga | 10.5 ± 1.2Gb | 9.4 ± 0.3Gb  | 5.0 ± 0.0Fc |
| Quercetin            | 11.9 ± 0.9fa  | 6.7 ± 0.2Gb | 6.3 ± 0.4Fb  | 5.1 ± 0.2Fe | 8.3 ± 0.1Fa | 6.0 ± 0.4Gh | 5.4 ± 0.3Hbc | 4.9 ± 0.1Fb |
| Kaempferol           | 271.2 ± 7.7Da | 276.9 ± 3.6Ca | 237.8 ± 2.5Cb | 160.6 ± 10.6Bc | 223.6 ± 3.5Ca | 158.2 ± 16.9Cb | 138.1 ± 17.3Cb | 92.7 ± 2.2Bc |
| Total                | 3353.9        | 2683.7      | 2670.3      | 1098.6     | 2291.9      | 1774.0      | 1864.9      | 952.3      |

Values are the means of 3 replicates ± SE (n = 3). Data are followed by different capital letters for the phenolic compounds, and small letters for the solvents in the same cultivar, indicate significant difference at $P < .05$ (Duncan’s test).

Abbreviations: FW, fresh weight; HPLC, high-performance liquid chromatography.
the 4 solvent extracts of “Nanya No.2” were 69.6 to 102.0 μmol trolox equivalent (TE)/g FW, 213.4 to 293.4 μmol TE/g FW, and 194.8 to 256.8 μmol Fe^{2+}/g FW, respectively, while the values of “HAES695” were remarkably lower (P < .05) (22.9-93.0 μmol TE/g FW, 111.7-280.3 μmol TE/g FW, and 84.0-185.0 μmol Fe^{2+}/g FW, respectively). These values were within the range reported by Zheng et al. for edible flowers. Among the different solvent extracts, the 70% acetone extract showed the highest DPPH, ABTS, and FRAP values, whereas the water extract exhibited the lowest (P < .05), except for the DPPH and FRAP values of “Nanya No.2”, which were compared to the methanol and ethanol extracts. Meanwhile, no significant differences were found between the methanol and ethanol extracts in the DPPH, ABTS, and FRAP values. The differences in the phenolic and flavonoid content explained the differences in the antioxidant activity among the different solvents and cultivars, consistent with the study on eggplant peel. Indeed, the 70% acetone extract of macadamia flowers possessed the highest antioxidant activity, similar to the aqueous acetone extract of banana peel that had the highest phenolic content and high antioxidant capability.

**Correlation Analysis**

The antioxidant activity based on DPPH, ABTS, and FRAP assays was positively correlated with the levels of phenolic compounds. Similar results were obtained in this study, and the Pearson’s correlation coefficients are presented in Table 4. Highly significant positive correlations were detected between TPC and the DPPH, ABTS, and FRAP values (0.865, 0.840, and 0.884, respectively; P < .01), while the corresponding correlation coefficients for TFC were larger (0.930, 0.975, and 0.963, respectively). In addition, TFC positively correlated with TPC (r = 0.888). These results indicated that the phenolics and flavonoids were mainly responsible for the antioxidant capacity of the extracts. Moreover, the flavonoids might be a more important contributor to the antioxidant activity of macadamia flowers, as reported by Tai et al. for *Sophora viciifolia* edible flowers.

Studies have revealed the correlation between phenolic composition and antioxidant capacity of plant extracts, with differences in the contribution of individual phenolic compounds to the antioxidant activity. In this study, 5 phenolic compounds (e.g., ferulic acid, catechin, phlorizin, quercetin, and kaempferol) exhibited significant or extremely significant positive correlations with the DPPH, ABTS, and FRAP values. The highest correlation coefficient was detected for quercetin in DPPH (r = 0.886), catechin in ABTS (r = 0.839), and ferulic acid in FRAP (r = 0.838). Hence, these 5 phenolic compounds could be largely responsible for the antioxidant activity of macadamia flower extracts. Additionally, naringenin and myricetin content positively correlated with the DPPH and FRAP values, and ellagic acid and protocatechuic acid with the FRAP values, indicating that these 4 compounds might have synergistic effects on its antioxidant power. Surprisingly, no significant correlation was observed between the rutin content and the 3 antioxidant assays, although rutin was the main compound in the tested extracts. This observation suggests that rutin contributed less to the antioxidant property of macadamia flowers, consistent with the reports of Chen et al. for 23 edible flowers. However, several previous studies on wild rice and other edible flowers emphasized that rutin strongly contributed to the antioxidant activities of extracts. In addition, the DPPH, ABTS, and FRAP assays revealed positive and highly significant correlations among these three assays, suggesting these three methodologies are efficient in evaluating the antioxidant capacity of macadamia flowers, consistent with the reports in guava and loquat.

**Conclusion**

The present study analyzed the total and individual phenolic content, flavonoid content, and antioxidant capacities of macadamia flowers. Significant differences were detected in the phenolic content and the antioxidant activities between the 2 macadamia taxa and among the 4 solvent extracts. “Nanya No.2” possessed more phenolics and flavonoids and stronger antioxidant activity than “HAES695”, and the 70% acetone extract had maximum phenolics and flavonoids and the highest antioxidant properties. Among the phenolic compounds identified, rutin and catechin were the most abundant, followed by kaempferol, naringenin, myricetin, protocatechuic acid, and

| Table 3. Antioxidant Capacity of the Extracts of “Nanya No.2” and “HAES695” Macadamia Flowers Prepared by Different Solvents. |
|---------------------------------------------------------------|
| Acetone (70%) | Ethanol (70%) | Methanol (70%) | Water |
| DPPH (μmol TE/gFW) | “Nanya No.2” | 102.0 ± 1.9 aA | 70.2 ± 1.3 aB | 74.7 ± 1.5 aB | 69.6 ± 2.7 aB |
| | “HAES695” | 93.0 ± 3.0 bA | 38.5 ± 3.4 bB | 46.5 ± 2.8 bB | 22.9 ± 3.1 bC |
| ABTS (μmol TE/gFW) | “Nanya No.2” | 293.4 ± 2.1 aA | 256.9 ± 5.7 aB | 257.6 ± 6.7 aB | 213.4 ± 3.3 aC |
| | “HAES695” | 280.3 ± 8.1 aA | 211.9 ± 8.4 bB | 218.9 ± 6.3 bB | 111.7 ± 3.1 bC |
| FRAP (μmol Fe^{2+}/gFW) | “Nanya No.2” | 256.8 ± 1.1 aA | 184.1 ± 6.6 aB | 187.5 ± 1.3 aB | 194.8 ± 4.3 aB |
| | “HAES695” | 184.9 ± 3.6 bA | 124.0 ± 2.8 bB | 133.6 ± 5.2 bB | 84.0 ± 2.8 bC |

Values are the means of 3 replicates ± SE (n = 3). Data are followed by different capital letters for the solvents, and small letters for the cultivars indicate significant difference at P < .05 (Duncan’s test).

Abbreviations: ABTS, 2,2'-azino-bis(3-ethyl-benzothiazoline-6-sulfonic acid) diammonium salt; DPPH, 2,2-diphenyl-1-picrylhydrazyl; FRAP, ferric reducing antioxidant power; TE, Trolox equivalent.
Table 4. Pearson’s Correlation Matrix for Phenolic Compounds, Total Polyphenols, Total Flavonoids, and Antioxidant Capacity of Macadamia Flowers Extracts.

| Variables             | Gallic acid | Chlorogenic acid | Ferulic acid | Ellagic acid | Protocatechuic acid | Catechin | Epicatechin | Rutin | Naringenin | Myricetin | Phlorizin | Quercetin | Kaempferol | TPC   | TFC   | DPPH | ABTS | FRAP |
|-----------------------|------------|------------------|--------------|--------------|--------------------|----------|--------------|-------|------------|-----------|-----------|-----------|------------|-------|-------|------|------|------|
| Gallic acid           | 1          |                  |              |              |                    |          |              |       |            |           |           |           |            |       |       |      |      |      |
| Chlorogenic acid      | 0.097      | 1                |              |              |                    |          |              |       |            |           |           |           |            |       |       |      |      |      |
| Ferulic acid          | 0.431      | −0.181           | 1            |              |                    |          |              |       |            |           |           |           |            |       |       |      |      |      |
| Ellagic acid          | 0.660      | 0.364            | 0.742*       | 1            |                    |          |              |       |            |           |           |           |            |       |       |      |      |      |
| Protocatechuic acid   | 0.681      | 0.446            | 0.746*       | 0.945**      | 1                    |          |              |       |            |           |           |           |            |       |       |      |      |      |
| Catechin              | −0.090     | 0.339            | 0.564        | 0.552        | 0.583              | 1        |              |       |            |           |           |           |            |       |       |      |      |      |
| Epicatechin           | 0.576      | 0.550            | 0.280        | 0.592        | 0.736*             | 0.334    |              |       |            |           |           |           |            |       |       |      |      |      |
| Rutin                 | 0.470      | −0.154           | 0.805*       | 0.506        | 0.655              | 0.473    | 0.402        | 1     |            |           |           |           |            |       |       |      |      |      |
| Naringenin            | 0.484      | 0.025            | 0.859**      | 0.892**      | 0.769*             | 0.548    | 0.203        | 0.541 | 1          |           |           |           |            |       |       |      |      |      |
| Myricetin             | 0.413      | −0.058           | 0.883**      | 0.831*       | 0.706              | 0.513    | 0.103        | 0.511 | 0.983**    | 1         |           |           |            |       |       |      |      |      |
| Phlorizin             | 0.279      | −0.003           | 0.779*       | 0.746*       | 0.605              | 0.512    | −0.069       | 0.407 | 0.945**    | 0.966**   | 1         |           |            |       |       |      |      |      |
| Quercetin             | 0.265      | −0.028           | 0.807*       | 0.771*       | 0.631              | 0.633    | 0.011        | 0.496 | 0.962**    | 0.953**   | 0.967**   | 1         |            |       |       |      |      |      |
| Kaempferol            | −0.061     | 0.397            | 0.573        | 0.671        | 0.621              | 0.950**  | 0.289        | 0.332 | 0.680      | 0.647     | 0.662     | 0.751**   | 1         |       |       |      |      |      |
| TPC                   | 0.274      | 0.036            | 0.922**      | 0.769*       | 0.735*             | 0.625    | 0.157        | 0.613 | 0.900**    | 0.938**   | 0.911**   | 0.887**   | 0.707*    | 1     |       |      |      |      |
| TFC                   | 0.199      | 0.133            | 0.849**      | 0.686        | 0.724*             | 0.844**  | 0.246        | 0.681 | 0.766*     | 0.783*    | 0.763*    | 0.793*    | 0.812*    | 0.888** | 1     |       |      |      |      |
| DPPH                  | 0.009      | 0.054            | 0.755*       | 0.621        | 0.550              | 0.831*   | −0.009       | 0.452 | 0.799*     | 0.827*    | 0.857**   | 0.886**   | 0.870**   | 0.865** | 0.930** | 1     |       |      |      |      |
| ABTS                  | 0.000      | 0.065            | 0.777*       | 0.517        | 0.566              | 0.839**  | 0.081        | 0.628 | 0.657      | 0.697     | 0.711*    | 0.735*    | 0.785*    | 0.840** | 0.975** | 0.931** | 1     |       |      |      |      |
| FRAP                  | 0.366      | 0.255            | 0.838**      | 0.753*       | 0.826*             | 0.736*   | 0.377        | 0.681 | 0.753*     | 0.770*    | 0.732*    | 0.718*    | 0.718*    | 0.864** | 0.963** | 0.831* | 0.905** | 1     |

*Significant correlation at P < .05, **Significant correlation at P < .01.

Abbreviations: ABTS, 2,2'-azino-bis(3-ethyl-benzothiazoline-6-sulfonic acid) diammonium salt; DPPH, 2,2-diphenyl-1-picrylhydrazyl; FRAP, ferric reducing antioxidant power; TFC, total flavonoid content; TPC, total phenolic content.
ellagic acid. Correlation analysis attributed the antioxidant activities of the extracts to TPC and TFC, and ferulic acid, catechin, phlorizin, quercetin, and kaempferol were the main contributors. These findings suggested macadamia flowers as a potential resource of natural antioxidants, which could be exploited to generate bioactive products.

Materials and methods

Materials

Two representative macadamia cultivars, namely “Nanya No.2” (M. integrifolia) and “HAES695” (a hybrid of M. integrifolia and M. tetraphylla), were grown in Xingyi, China (104°59′E, 24°52′N, 780 m a.s.l.), under the same agronomic conditions. “Nanya No.2” is a white-flowered cultivar bred by South Subtropical Crops Research Institute (Zhanjiang, China) and approved by Guangdong Crop Variety Approval Committee (Guangzhou, China). “HAES695” is a pink-flowered cultivar introduced to China from Hawaii. In March 2019, fresh flowers were collected at the initial opening stage from both cultivars, immediately ground into powder in liquid nitrogen, and stored at −80 °C until further analysis.

Reagents and Standards

Folin–Ciocalteu’s phenol reagent, ABTS, DPPH, and 2,4,6-tripyridyl-1-triazine (TPTZ) were purchased from Sigma-Aldrich Chemicals Pvt. Ltd (St. Louis, USA), and HPLC grade chemicals (eg methanol, acetone, and anhydrous ethanol) and other analytical grade chemicals from Sinopharm Chemical Reagent Co., Ltd (Shanghai, China).

The standards were supplied as follows by Sigma-Aldrich: gallic acid, protocatechuic acid, chlorogenic acid, ferulic acid, ellagic acid, catechin, epicatechin, rutin, naringin, myricetin, phlorizin, quercetin, and kaempferol, and 6-hydroxy-2,5,7,8-tetramethylechroman-2-carboxylic acid (Trolox).

Preparation of Extracts

For the extraction of phenolics, a protocol similar to that described by Boulekbache-Makhlof et al. was followed. Briefly, 1.0 g of the flower powder was mixed with 10 mL of the solvent (water, 70% (v/v) methanol, 70% (v/v) ethanol, or 70% (v/v) acetone) and shaken for 1 h at 37 °C. The mixture was centrifuged for 20 min at 4000 × g, and the supernatant was collected to determine the total phenolic and flavonoid content and antioxidant capacity.

Similarly, 2.0 g of the flower samples was extracted with 10 mL of each solvent, and the supernatant was evaporated to near dryness under vacuum at 40 °C using a rotary evaporator (Models RE-201D, Beilun Instruments Co., Shanghai, China). The residue was dissolved in 1% (v/v) of the corresponding solvent to 1 mL, and filtered through a 0.45 μm Nylon Syringe Filter. The filtrate was used for HPLC analysis.

Determination of TPC

TPC was determined following the Folin–Ciocalteu assay described by Garzón et al. with slight modifications. Here, 2.5 mL of Folin–Ciocalteu’s reagent (10% v/v) was added to 0.5 mL of the diluted sample extract and allowed to stand for 5 min. Then, the solution was mixed with 2.0 mL of 20% sodium carbonate solution (Na2CO3) and heated in a water bath at 30 °C for 1 h. Finally, the absorbance of the mixture was measured at 765 nm using a Shimadzu UV-1600 spectrophotometer (Kyoto, Japan). TPC in the extract was calculated based on calibration curve of gallic acid (2.5 to 150 μg/mL) standard and expressed as mg GAE per g FW (mg GAE/g FW).

Assessment of TFC

TFC was measured based on the method of Benamar et al. with slight modifications. Approximately 0.5 mL of the diluted sample extract was mixed with 0.5 mL of 5% sodium nitrite (NaNO2). After 5 min, 0.5 mL of 10% aluminum chloride (AlCl3) was added, and the mixture was allowed to stand for 6 min. Then, the solution was mixed with 1.5 mL of 1.0 mol/L sodium hydroxide (NaOH) and heated in a water bath at 40 °C for 15 min. Finally, the absorbance was determined spectrophotometrically at 510 nm. TFC of the extract was calculated based on a calibration curve obtained from the rutin (5-500 μg/mL) standard and expressed as mg GAE per g FW (mg RE/g FW).

Determination of DPPH Radical Scavenging Activity

The DPPH scavenging activity was evaluated using the modified method of Vieira et al. DPPH solution (0.05 mmol/L) was prepared with the buffered methanol mixture (60 mL methanol and 40 mL sodium acetate buffer; 0.1 mol/L, pH 5.5). At t = 0 min (t0), the absorbance of 2.9 mL DPPH solution was recorded at 517 nm. Then, 0.1 mL of either the diluted extract or Trolox standard (0, 0.025, 0.05, 0.1, 0.25, or 0.5 mmol/L) was added, and the mixture was incubated at 30 °C for 15 min (t15) in the dark. Immediately, the absorbance was measured against a buffered methanol blank. The DPPH radical scavenging activity (RSA) was calculated according to the following equation:

\[
RSA(%) = \left(1 - \frac{\text{Absorbance}_{t15}}{\text{Absorbance}_{t0}}\right) \times 100.
\]

The final results were obtained based on the calibration curve of Trolox and reported as micromoles TE per g FW (μmol TE/g FW).

Determination of ABTS Radical Scavenging Activity

The ABTS RSA was carried out according to the method reported by Re et al. The ABTS radical cation (ABTS•+) solution was prepared by mixing ABTS (7 mmol/L) with 2.45 mmol/L potassium persulfate (K2S2O8) and incubating at room temperature for 16 h.
temperature for 16 h in the dark. At \( t = 0 \) min \( (t_0) \), the ABTS\( ^{++} \) solution was diluted with 80% ethanol to an absorbance of 0.700 ± 0.020 (734 nm). Then, 2.9 mL of the diluted ABTS\( ^{++} \) solution was added to 0.1 mL of either the diluted extract or Trolox standard, as described above. After moderate shaking, the mixture was left standing at 30 °C for 7 min \( (t_c) \) in the dark, and the absorbance was measured against the 80% ethanol blank. The ABTS\( ^{++} \) RSA was evaluated using the following equation:

\[
\text{RSA(\%)} = \left(1 - \frac{\text{Absorbancet}}{\text{Absorbancet}_0}\right) \times 100
\]

The final results were obtained based on the calibration curve of Trolox and expressed as micromoles of TE per g FW (\( \mu \text{mol TE/g FW} \)).

**Determination of Ferric Reducing Antioxidant Power**

FRAP was measured as described by Benzie and Strain.\(^{42}\) The FRAP reagent was prepared by mixing sodium acetate buffer (300 mmol/L, pH 3.6), TPTZ (10 mmol/L) in 40 mmol/L hydrochloric acid (HCl), and 20 mmol/L iron(III) chloride (FeCl\(_3\)) in 10:1:1 proportion (\( \nu/\nu/\nu \)). Then, 2.85 mL of the FRAP reagent was allowed to react with 0.15 mL of the diluted extract in the dark at 37 °C. After 20 min, the absorbance of the mixture was recorded at 593 nm. The FRAP values were obtained based on the calibration curve of iron(II) sulfate heptahydrate \( (\text{FeSO}_4\cdot7\text{H}_2\text{O}) \) (0.05-2.0 mmol/L) and expressed as micromoles of \( \text{Fe}^{2+} \) per g FW (\( \mu \text{mol Fe}^{2+}/\text{g FW} \)).

**Identification and Quantification of Phenolic Compounds**

The phenolic compounds were analyzed on a reversed-phase HPLC system (LC-20A, Shimadzu, Japan) coupled with a UV-vis multiwavelength detector. These compounds were separated on a Zorbax Eclipse SB-C18 column (250 mm × 4.60 mm, 5 μm, Agilent, USA) using a gradient elution program with the mobile phase consisting of solvent A (0.5% formic acid in deionized water) and solvent B (methanol). A sample injection volume of 10 μL, a flow speed of 1.0 mL/min, and a column temperature of 40 °C were applied for the elution. The elution conditions were as follows: 0-20 min, 5% B and 95% A; 20-30 min, 9% B and 91% A; 30-40 min, 24% B and 76% A; 40-46 min, 44% B and 56% A; 46-52 min, 60% B and 40% A; and 52-60 min, 100% A. Finally, the peaks (280 nm) were identified by comparing the retention time and the spectra with authentic standards. Each phenolic compound was quantified according to the peak area and the standard calibration.\(^{43}\)

**Statistical Analysis**

All extracts were conducted in triplicates. Data are presented as mean ± standard error (SE). One-way analysis of variance (ANOVA) and a Pearson correlation test were performed with SPSS 16.0 software (SPSS Inc., USA). The significant differences \( (P < .05) \) between the mean values were established by Duncan’s multiple range test, and the correlation coefficients \( (r) \) were used to show correlations among different variables.

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**Declaration of Conflicting Interests**

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**Author Contributions (Roles)**

Wei-hai Yang performed the experimental work and drafted the manuscript. Chao-zhong Lu participated in the experimental design and analyzed the data. All authors have read and approved the final text.

**Ethical Approval**

Ethical approval is not applicable for this article.

**Informed Consent**

Not applicable, because this article does not contain any studies with human or animal subjects.

**Trial Registration**

Not applicable, because this article does not contain any clinical trials.

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**References**

1. Yang W, Zeng L, Zeng H, et al. Investigation and analysis on leaf morphological characters of macadamia germplasm resources. *Chinese Journal of Tropical Crops*. 2020;41(1):069-076. doi:10.3969/j.issn.1000-2561.2020.01.010
2. Olesen T, Huett D, Smith G. The production of flowers, fruit and leafy shoots in pruned macadamia trees. *Funct. Plant Biol*. 2011;38(4):327-336. doi:10.1071/FP11011
3. Trueman SJ, Turnbull CGN. Effects of cross-pollination and flower removal on fruit set of Macadamia. *Ann. Bot.* 1994;73(1):23-32. doi:10.1006/anbo.1994.1003

4. Fernandes L, Casal S, Pereira JA, Saravia JA, Ramalhosa E. Edible flowers: a review of the nutritional, antioxidant, antimicrobial properties and effects on human health. *J. Food Compos. Anal.* 2017;60:38-50. doi:10.1016/j.jfca.2017.03.017

5. Pires TCSP, Dias MI, Barros L, et al. Edible compounds by HPLC-DAD-ESI/MS n. *Food Res. Int.* 2018;105:580-588. doi:10.1016/j.foodres.2017.11.014

6. Nowicka P, Wojdyla A. Anti-hyperglycemic and antimicrobial effects of natural antioxidant contents in edible flowers. *Antioxidants.* 2019;8(8):308-319. doi:10.3390/antiox8080308

7. Pires TCSP, Dias MI, Barros L, et al. Edible flowers as sources of phenolic compounds with bioactive potential. *Food Res. Int.* 2018;105:580-588. doi:10.1016/j.foodres.2017.11.014

8. Shahidi F, Naczk M. *Phenolics in Food and Nutraceuticals.* CRC Press LLC; 2004:132-237. https://www.doc88.com/p-63970173100.html.

9. Chen G, Chen S, Xie Y, et al. Total phenolic, flavonoid and antioxidant activity of 23 edible flowers subjected to *in vitro* digestion. *J. Funct. Foods.* 2015;17:243-259. doi:10.1016/j.jff.2015.05.028

10. Navarro-González I, González-Barrio R, García-Valverde V, Bautista-Ortíz AB, Periago MJ. Nutritional composition and antioxidant capacity in edible flowers: characterisation of phenolic compounds by HPLC-DAD-ESI/MS n. *Int. J. Mol. Sci.* 2015;16:805-822. doi:10.3390/ijms16010805

11. Barros RGC, Andrade JKS, Pereira CU, et al. Phytochemical screening, antioxidant capacity and chemometric characterization of four edible flowers from Brazil. *Food Res. Int.* 2020;130:108899. doi:10.1016/j.foodres.2019.108899

12. Khodadami A, Wilkes MA, Roberts TH. Techniques for analysis of plant phenolic compounds. *Molecules.* 2013;18(3):2328-2375. doi:10.3390/molecules18022328

13. Garzón GA, Manso DC, Riedl K, Schwartz SJ, Padilla-Zakour O. Identification of phenolic compounds in petals of nasturtium flowers (*Tropaeolum majus*) by high-performance liquid chromatography coupled to mass spectrometry and determination of oxygen radical absorbance capacity (ORAC). *J. Agric. Food Chem.* 2015;63(8):1803-1810. doi:10.1021/jf503366c

14. Wu WT, Mong M, Yang Y, Wang Z, Yin M. Aqueous and ethanol extracts of daylily flower (*Hemerocallis fulva* L.) protect HUVEls against high glucose. *J Food Sci.* 2018;83(5):1463-1469. doi:10.1111/1750-3841.14137

15. Martins N, Barros I, Henriques M, Silva S, Ferreira ICFR. Activity of phenolic compounds from plant origin against *Candida* species. *Ind. Crop. Prod.* 2015;74:648-670. doi:10.1016/j.indcrop.2015.05.067

16. Liu J, Yin G, Zhang H, Wu Y, Xu S, Wei J. Comparison of essential oils from *Macadamia ternifolia* flowers by supercritical carbon dioxide fluid extraction and simultaneous distillation extraction. *J. Yunnan University (Nat. Sci. Ed.).* 2013;35(5):678-684. doi:10.7540/j.yu.20120706

17. Zheng J, Yu X, Maninder M, Xu B. Total phenolics and antioxidants of commonly consumed edible flowers in China. *Int. J. Food Prop.* 2018;21(1):1524-1540. doi:10.1080/10942912.2018.1494195

18. Xiong J, Yang J, Jiang Y, et al. Phenolic compounds and antioxidant capacities of 10 common edible flowers from China. *J Food Sci.* 2014;79(4):517-525. doi:10.1111/1750-3841.12404

19. Hajimahmoodi M, Moghaddam G, Ranjbar AM, et al. Total phenolic, flavonoid, tannin content and antioxidant power of some Iranian pomegranate flower cultivars (*Punica granatum* L.). *Am. J. Plant Sci.* 2013;4(9):1815-1820. doi:10.4236/ajps.2013.49223

20. Li W, Gao YX, Zha J, Wang Q. Phenolic, flavonoid, and lutein ester content and antioxidant activity of 11 cultivars of Chinese marigold. *J. Agric. Food Chem.* 2007;55(21):8478-8484. doi:10.1021/jf071696]

21. Zhou CH, Sun CD, Chen K S, Li X. Flavonoids, phenolics, and antioxidant capacity in the flower of *Eriobotrya japonica* Lindl. *Int. J. Mol. Sci.* 2011;12(5):2935-2945. doi:10.3390/ijms12052935

22. Michiels JA, Kevers C, Pinçemail J, Defraigne JO, Dommes J. Extraction conditions can greatly influence antioxidant capacity assays in plant food matrices. *Food Chem.* 2012;130(4):986-993. doi:10.1016/j.foodchem.2011.07.117

23. Boulekbache-Makhlouf I, Medouni I, Medouni-Adrar S, Arkoub I, Madani K. Effect of solvents extraction on phenolic content and antioxidant activity of the byproduct of eggplant. *Ind. Crop. Prod.* 2013;49:668-674. doi:10.1016/j.indcrop.2013.06.009

24. Repay IB, Bourouj S, Debez IBS, et al. Effects of extraction solvents and provenances on phenolic contents and antioxidant activities of cumin (*Cuminum cyminum* L.) seeds. *Food Bioprocess Tech.* 2012;5(7):2827-2836. doi:10.1007/s11947-011-0625-4

25. Kelebek H, Selli S, Sevindik Ö. Screening of phenolic content and antioxidant capacity of Okitsu mandarin (*Citrus unshiu* Marc.) juice extracted with various solvents. *J. Raw Mater. Process Foods.* 2020;1:7-12.

26. Li AN, Li S, Li HB, et al. Total phenolic contents and antioxidant capacities of 51 edible and wild flowers. *J. Funct. Foods.* 2014;6:319-330. doi:10.1016/j.jff.2013.10.022

27. Fu MR, He ZP, Zhao YY, Yang J, Mao LC. Antioxidant properties and involved compounds of daylily flowers in relation to maturity. *Food Chem.* 2009;114(4):1192-1197. doi:10.1016/j.foodchem.2008.10.072

28. Hou X, Li X, Song R, Yang D, Kang W, Cui L. Dynamic changes of phlorizin in *Malus pumila* Mill. leaves and flowers during flower blooming. *Chem. Res.* 2019;30(5):478-482. doi:10.14002/j.hxya.2019.05.006

29. Tsao R, Deng Z. Separation procedures for naturally occurring antioxidant phytochemicals. *J. Chromatogr. A.* 2004;1041(1-2):85-99. doi:10.1016/j.chroma.2004.09.028

30. García-Niño WR, Zazueta C. Ellagic acid: pharmacological activities and molecular mechanisms involved in liver protection. *Pharmaz. Res.* 2015;27:84-103. doi:10.1007/s11095-014-1408-1

31. Liu SC, Lin JT, Wang CK, Chen HY, Yang DJ. Antioxidant properties of various solvent extracts from lychee (*Litchi chinensis zonin*) flowers. *Food Chem.* 2009;114(2):577-581. doi:10.1016/j.foodchem.2008.09.088
32. Sultana B, Anwar F, Ashraf M. Effect of extraction solvent/technique on the antioxidant activity of selected medical plant extracts. *Molecules*. 2009;14:2167-2180. doi:10.3390/molecules14062167

33. González-Barrio R, Peraigo M J, Luna-Recio C, Javier GF, Navarro-González I. Chemical composition of the edible flowers, pansy (*Viola wittrockiana*) and snapdragon (*Antirrhinum majus*) as new sources of bioactive compounds. *Food Chem*. 2018;252:373-380. doi:10.1016/j.foodchem.2018.01.102

34. González-Montelongo R, Lobo MG, Gonzalez M. Antioxidant activity in banana peel extracts: testing extraction conditions and related bioactive compounds. *Food Chem*. 2010;119(3):1030-1039. doi:10.1016/j.foodchem.2009.08.012

35. Thaipong K, Boonprakob U, Crosby K, Cisneros-Zevallos L, Byrne DH. Comparison of ABTS, DPPH, FRAP, and ORAC assays for estimating antioxidant activity from guava fruit extracts. *J. Food Compos. Anal.* 2006;19(6-7):669-675. doi:10.1016/j.jfca.2006.01.003

36. Tai Z, Cai L, Dai L, et al. Antioxidant activity and chemical constituents of edible flower of *Sophora viciifolia*. *Food Chem*. 2011;126(4):1648-1654. doi:10.1016/j.foodchem.2010.12.048

37. Raudone L, Raudonis R, Liaudanskas M, Viskelis J, Pakalnskas A, Janulis V. Phenolic profiles and contribution of individual compounds to antioxidant activity of apple powders. *J Food Sci*. 2016;81(5):1055-1061. doi:10.1111/1750-3841.13277

38. Sumczynski D, Kotásková E, Orsavová J, Valášek P. Contribution of individual phenolics to antioxidant activity and in vitro digestibility of wild rices (*Zizania aquatica L*). *Food Chem*. 2017;218:107-115. doi:10.1016/j.foodchem.2016.09.060

39. Benamar H, Rached W, Derdour A, Marouf A. Screening of Algerian medicinal plants for acetylcholinesterase inhibitory activity. *J. Biol. Sci*. 2010;10(1):1-9. doi:10.3923/jbs.2010.1.9

40. Vieira FGK, Borges GSC, Copetti C, Pietro PF, Nunes EC, Fett R. Phenolic compounds and antioxidant activity of the apple flesh and peel of eleven cultivars grown in Brazil. *Sci. Hortic.* 2011;128(3):261-266. doi:10.1016/j.scienta.2011.01.032

41. Re R, Pellegreti N, Proteggente A, Pannala A, Yang M, Rice-Evans C. Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Bio. Med.* 1999;26(9-10):1231-1237. doi:10.1016/S0891-5849(98)00315-3

42. Benzie IFF, Strain JJ. The ferric reducing ability of plasma (FRAP) as a measure of “antioxidant power”: the FRAP assay. *Anal. Biochem.* 1996;239(1):70-76. doi:10.1006/abio.1996.0292

43. Kelebek H, Selli S. Characterization of phenolic compounds in strawberry fruits by RP-HPLC-DAD and investigation of their antioxidant capacity. *J Liquid Chromat Rel Technol*. 2011;34(20):2495-2504. doi:10.1080/10826076.2011.591029