Comparison of Chemical Compositions and Antioxidant Activities of Fresh and Dried Rosa roxburghii Tratt Fruit

Guanyu Yan1,*, Peiyian Zheng1,*, Shaoquan Weng2,*, Yida Zhang1,*, Wenliu Xu2, Jiaying Luo1, Jianjun Fei3, Jingxian Wang1, Hui Zhang2, Haisheng Hu1 and Baoqing Sun1

Abstract

Fresh fruit of Rosa roxburghii Tratt has attracted great interest and is used in many functional products in China. However, fresh fruits are perishable products with quite short shelf lives and few studies have focused on dried fruits. Therefore, this study aimed to explore whether the drying process can be used to preserve bioactive components of R. roxburghii fruits by comparing phytochemical profiles and antioxidant activities between fresh and dried fruit. As a result, a total of 95 compounds, mainly including organic acids, phenols, and flavonoids, were identified in fresh and dried fruits by using ultrahigh-performance liquid chromatography-quadrupole-time of flight mass spectrometry. The relative quantitative result showed that contents of phenols and acylamide were significantly higher (p < .05) in dried fruit. Furthermore, dried fruit showed stronger antioxidant activity by using 1,1-diphenyl-2-picrylhydrazyl radical scavenging ability and ferric reducing antioxidant power. This research suggested that dried R. roxburghii fruit could be considered a more effective and economical health and functional source for functional food and industry.

Keywords

Rosa roxburghii Tratt, ultrahigh-performance liquid chromatography-quadrupole-time of flight mass spectrometry (UHPLC-Q-ToF/MS), fresh and dried fruits, antioxidant activities, chemical constituents

Received: October 14th, 2021; Accepted: March 31st, 2022.

Introduction

Rosa roxburghii Tratt is mainly found in the south and southwest of China. Over recent decades, many research studies have shown that the fruit of R. roxburghii owns significant radiation protection, antitumor, antioxidant, and antiinflammatory properties. It has been widely used in functional foods and cosmetic products. These health benefits are attributable to the biologically active components, including L-ascorbic acid, superoxide dismutase, flavonoids, phenols, polysaccharides, organic acids, and amino acids.1 However, fresh fruit can only be stored for up to 15 days at room temperature because of high respiration and water loss rates after harvest.2 Furthermore, common low-temperature storage techniques are expensive and need specialized equipment, which has limitations in some areas.3 Hence, an appropriate drying method is a suitable alternative to reduce the loss and preserve the fruit quality. Drying process could reduce moisture, weight, and volume of fresh materials, largely increasing their shelf-life and facilitating their transportation in a mountainous area.4 According to previous studies, drying can lead to composition changes, such as degradation of the total polyphenolic compounds, carotenoids, and total anthocyanin content.5,6 To date, there are few in-depth studies on the active components of dried R. roxburghii fruit. And, in previous studies, components

1Department of Allergy and Clinical Immunology, National Center for Respiratory Medicine, National Clinical Research Center for Respiratory Disease, State Key Laboratory of Respiratory Disease, Guangzhou Institute of Respiratory Health, The First Affiliated Hospital of Guangzhou Medical University, Guangzhou, China
2Research & Development Institute, Guangzhou Wanglaoji Health Industry Co., Ltd, Guangzhou, China
3Guizhou Hengliyuan Natural Biotechnology Co. Ltd, Guizhou, China

*These authors contributed equally to the study

Corresponding Author:

Baoqing Sun, Department of Allergy and Clinical Immunology, National Center for Respiratory Medicine, National Clinical Research Center for Respiratory Disease, State Key Laboratory of Respiratory Disease, Guangzhou Institute of Respiratory Health, The First Affiliated Hospital of Guangzhou Medical University, No. 151 Yanjiang Xi Lu, Yuexiu District, Guangzhou, China. Email: sunbaoqing@vip.163.com
in the dried fruits were mainly evaluated by high-performance liquid chromatography with diode-array detection, refractive index detector, ultraviolet spectrophotometer, and atomic absorption spectrophotometer. However, these methods are either time-consuming or have low sensitivity. In recent years, ultrahigh-performance liquid chromatography-quadrupole-time of flight mass spectrometry (UHPLC-Q-ToF/MS) has been widely used to identify constituents in complex extract due to its high sensitivity, selectivity, and separation efficiency.

To explore the effect of drying on the composition and efficacy of fruits, in this paper, the components of fresh and dried R. roxburghii fruits were identified and compared by using UHPLC-Q-ToF/MS. Besides, in vitro antioxidant activity was also investigated by using 1,1-diphenyl-2-picrylhydrazyl radical (DPPH•) scavenging ability and ferric reducing antioxidant power (FRAP).

Results and Discussions

Component Difference Between Fresh and Dried R. roxburghii Fruits by Using UHPLC-Q-ToF/MS

In this study, a total of 95 compounds were identified in 2 fruits. The representative chromatograms and information on identified compounds are shown in Figure 1 and Table 1, respectively.

Organic acids were the most abundant components in R. roxburghii. In the present study, 10 compounds (5-8, 10, 12, 15, 24-25, 43) were annotated as organic acids. Among them, compound 5 was identified as L-ascorbic acid by comparing the MS and MS² data with standard (Figure S1A). Other 9 compounds were identified by comparing the molecular formula of the deprotonated molecule [M + H]⁺ and [M − H]⁻ and neutral loss (H₂O, HCOOH, CO₂, and glucosyl groups) during fragmentation to previous reports.

Flavonoids also were important constituents. Thirty-one compounds were identified as flavonoids (31, 33, 34-36, 39, 40, 46-49, 53-56, 58-60, 63-69, 73, 77-79, 81, 82) in fresh and dried fruits. Compounds 36, 40, 46, 49, and 82 were identified as procyanidin B1, eriodictyol, isoquercitrin, catechin, and quercetin, respectively, by comparing with the reference standards (Figure S1C-F and H). And, compounds 31, 53, and 66 were tentatively identified as catechins and their isomers, while compounds 34, 35, 39, 47, 59, 63, 65, 68, 69, and 77, which contained catechin unit, were further identified by comparing with database and previous reports. Furthermore, compounds 48, 54, 58, 60, and 64 could generate procyanidin B1 and eriodictyol unit, and compounds 55 and 67 contained a quercetin unit in MS² spectra, which were characteristic ions and as a basis of identification.

Compounds 1, 16, 17, 19, 21, 27, and 32 were identified as amino acids. The characteristic fragment ions were produced by neutral losses of H₂O, HCOOH, and NH₃ groups. For example, compound 27 with protonated [M + H]⁺ ion at m/z 166.08, suggests the molecular formula of C₈H₁₄NO₃. Fragment ions at m/z 149.05, 131.04, 120.08 correspond to the neutral losses of NH₃, H₂O, and HCOOH groups. Then, by referring to the literature, it was identified as phenylalanine—an essential amino acid (Figure S1B).

Seventeen phenols, including 2, 18, 20, 23, 28, 29, 30, 41, 44, 45, 50, 51, 57, 62, 73, 75, and 85, were annotated. Among them, compound 75 was identified as ellagic acid by comparing to standard (Figure S1G). In addition, compounds 29, 44, 62, and 73 produced base peak ions at m/z 300.99 in MS² spectra, which indicated an ellagic acid unit. Finally, these compounds were further identified by comparing to a database and previous reports.

Compound 87 was identified as Kaji-ichigoside F1 comparing to standard (Figure S1I, which was a characteristic and main triterpenoid in R. roxburghii fruit. Compounds 71, 88, 89, 91-94, 70, and 83 yield characteristic ions (neutral losses of glucosyl group, H₂O, and HCOOH groups) in MS/MS spectra and were identified as triterpenoids and sesquiterpenes. Compound 95 was identified as an acylamide. It showed [M + H]⁺ at m/z 248.20, [M + Na]⁺ at 270.18 in MS spectra, and produced MS/MS ions at m/z 230.18, 175.11, 167.12, 152.10, 81.06, 72.08, and 57.07 (Figure S1J). Then, it was tentatively identified as (2E,4E,8Z,10Z)-nisobutyl-dodeca-2,4,8,10-tetraenamide or an isomer.

The chemical profiles were quite similar between fresh and dried fruits (Table 1). More specifically, L-ascorbic acid, flavonoids, and phenols, which contribute more to the antioxidant activities, were identified in both fresh and dried fruits. These results indicated that functional components might be preserved in the dried fruit. However, considering the antioxidant capacity was influenced by not only component difference but also their amount, it is still necessary to know the difference in the content of these components between fresh and dried fruits.

Component Content Difference Between Fresh and Dried R. roxburghii Fruits

Relative quantification was performed to compare the difference of identified compounds between fresh and dried fruits by using UPLC-MS peak areas. Ionization mode with the best MS response was selected for the calculation of the detected compounds: [M − H]⁻ ions were used for phenols, catechins, flavonoids, terpenoids, and organic acids, while [M + H]⁺ ions for amino acids and acylamides. As shown in Table 2, relative contents of each type of compound in fresh and dried fruits are: amino acids (21.34% and 34.39%), acylamide (0% and 11.29%), flavonoids (35.00% and 22.13%), organic acids (60.37% and 52.81%), phenols (3.88% and 19.10%), terpenoids (16.56% and 13.30%), respectively. Among these compounds, there was no significant difference between fresh and dried fruits, except for acylamide (p < .001) and phenols (p < .05).
The high content of L-ascorbic acid (compound 5) in R. roxburghii was known to provide noticeable antioxidant activities. In Table 2, L-ascorbic acid showed no significant difference between the 2 fruits (fold change <1.5), which indicated that the antioxidant activities in the dried fruit could not be significantly diminished.

Flavonoids are also known for their antioxidant activity in R. roxburghii. As shown in Table 2, total flavonoid was lower in...
| No. | Rt (min) | Molecular formula | Selected ion | Experimental m/z | MS/MS ions | Identification | Chemical type | Source |
|-----|---------|-------------------|--------------|-----------------|------------|---------------|---------------|--------|
| 1   | 0.77    | C₆H₁₄N₄O₂        | [M + H]⁺     | 175.1186        | 175.0927, 158.0927, 130.0986, 116.0807 | Arginine | Amino acid | FF, DF |
| 2   | 0.85    | C₁₀H₁₅O₁₀        | [M + H]⁺     | 381.0781        | 321.0262, 263.0784, 245.0657, 130.0856, 118.0862 | 1,1′-(1,3-Propanediyl)-bis(3,4,5-trihydroxybenzoate) | Phenol | FF, DF |
| 3   | 0.89    | C₆H₁₂O₆          | [M − H]⁻     | 179.0557        | 161.0454, 149.0451, 125.0241, 119.0334, 89.0224, 71.0140, 59.0143 | Glucose | Monosaccharide | FF |
| 4   | 0.91    | C₁₀H₁₆O₁₁        | [M − H]⁻     | 341.1082        | 179.0567, 119.0354, 89.0249 | Sucrose | Disaccharide | FF |
| 5   | 0.92    | C₆H₁₄O₆          | [M + H]⁺     | 177.0392        | 141.0182, 129.0182, 113.0233 | Ascorbic acid | Organic acid | FF, DF |
| 6   | 0.93    | C₄H₆O₃           | [M − H]⁻     | 135.029         | 117.0194, 89.0246, 75.0092 | Threonic acid | Small molecule | FF |
| 7   | 0.93    | C₆H₁₂O₆          | [M − H]⁻     | 191.0561        | 173.0446, 127.0381, 85.0724 | Quinic acid | Small molecule | FF, DF |
| 8   | 0.93    | C₆H₁₀O₆          | [M − H]⁻     | 165.0394        | 147.0287, 135.6368, 129.0191, 75.0088 | Xylonic acid | Small molecule | FF, DF |
| 9   | 0.97    | C₅H₈NO₂          | [M + H]⁺     | 118.0851        | 72.0809, 59.0493, 43.0546 | Valine | Amino acid | FF, DF |
| 10  | 1.01    | C₄H₆O₃           | [M − H]⁻     | 191.0173        | 173.0071, 129.0166, 85.0276 | Citric acid | Small molecule | FF, DF |
| 11  | 1.07    | C₆H₁₀N₂          | [M + H]⁺     | 136.0167        | 119.0353, 92.0245, 81.0700 | Adenine | Nucleobases | FF, DF |
| 12  | 1.1     | C₁₂H₁₆O₁₂        | [M − H]⁻     | 351.0751        | 157.0120, 127.0018, 115.0014, 87.0068 | 4-O-(4-Deoxy-α-L-erythro-hex-4-enopyranuronosyl)-α-L-gulopyranuronic acid | Organic acid | FF |
| 13  | 1.14    | C₄H₆O₃           | [M − H]⁻     | 133.0132        | 115.0013, 89.0223, 71.0117 | Malic acid | Small molecule | FF, DF |
| 14  | 1.2     | C₁₂H₁₄O₁₄        | [M − H]⁻     | 481.0608        | 445.5222, 300.9696, 275.0181 | 2,3-(S)-hexahydroxydiphenoyl-D-glucose | Organic acid | FF, DF |
| 15  | 1.21    | C₆H₁₂O₇          | [M − H]⁻     | 191.0176        | 173.0066, 154.9971, 111.0063, 87.0064 | Isocitric acid | Small molecule | FF, DF |
| 16  | 1.22    | C₅H₁₁NO₃        | [M + H]⁺     | 182.081         | 165.0442, 147.0335, 136.0656 | Tyrosine | Amino acid | FF, DF |
| 17  | 1.25    | C₁₃H₁₃NO₇        | [M + H]⁺     | 294.1538        | 276.1446, 258.1388, 248.1497, 230.1391, 212.1277, 88.0394 | Fructose-leucine | Amino acid | FF, DF |
| 18  | 1.3     | C₁₃H₁₄O₁₀        | [M − H]⁻     | 331.0657        | 169.0127, 125.0225 | Galloyl-glucose | Phenol | FF, DF |
| 19  | 1.39    | C₁₂H₁₄NO₂        | [M + H]⁺     | 132.1019        | 115.0744, 105.0698 | Isoleucine or isomer | Amino acid | FF, DF |
| 20  | 1.45    | C₇H₆O₃           | [M − H]⁻     | 169.0145        | 151.0018, 125.0243, 107.0133, 97.0293 | Gallic acid | Phenolic acid | FF, DF |
| 21  | 1.5     | C₆H₁₂O₃          | [M + H]⁺     | 132.1019        | 115.0744, 105.0698 | Isoleucine or isomer | Amino acid | FF, DF |
| 22  | 1.55    | C₁₀H₁₄N₂O₄       | [M + H]⁺     | 203.1385        | 185.0429, 162.1020, 86.0963 | L-Alanyl-L-leucine | Amino acid | FF, DF |
| 23  | 1.67    | C₁₃H₁₄O₉        | [M + H]⁺     | 303.0709        | 285.0594, 267.0495, 257.0647, 127.0382 | β-D-Glucopyranosiduronic acid, 2,3-dihydroxyphenyl | Phenol | FF, DF |
| No. | Rt (min) | Molecular formula | Selected ion | Experimental m/z | MS/MS ions | Identification | Chemical type | Source |
|-----|----------|-------------------|--------------|-----------------|------------|----------------|---------------|--------|
| 24  | 1.72     | C₅H₆O₃           | [M+H]⁺       | 115.0855        | 87.0483, 59.0491, 43.0180 | β-Acetylacrylic acid | Organic acid | FF, DF |
| 25  | 1.79     | C₆H₁₀N₂O₇        | [M+H]⁺       | 217.154         | 121.0505, 86.0599, 72.0808 | L-valine anhydride | Small molecule | Organic acid |
| 26  | 1.89     | C₇H₁₂NO₇         | [M+H]⁺       | 328.1393        | 310.1279, 292.1175, 264.1217, 246.1116, 178.0856 | Fructose-phenylalanine | Small molecule | Organic acid |
| 27  | 2.05     | C₈H₁₁NO₂         | [M+H]⁺       | 166.086         | 149.0592, 131.0484, 120.0804, 107.0485, 103.0537 | Phenylalanine | Amino acid | FF, DF |
| 28  | 2.3      | C₆H₆O₄           | [M⁻]⁻       | 153.0191        | 123.0449, 109.0296, 81.0351 | Protocatechuic acid | Phenolic acid | FF, DF |
| 29  | 2.34     | C₆H₁₂O₁₈         | [M⁻]⁻       | 633.0737        | 481.0609, 463.0512, 343.0098, 300.9990, 275.0192, 169.0136, 125.0237 | Galloyl-hexahydroxydiphenoyl-glucose or isomer | Phenolic acid | FF, DF |
| 30  | 2.39     | C₆H₈O₅           | [M⁻]⁻       | 195.0295        | 179.0346, 165.0198, 151.0405, 123.0455 | 3,4,5-Trihydroxycinnamic acid | Phenolic acid | FF |
| 31  | 2.44     | C₄H₆O₅           | [M+H]⁺       | 291.1071        | 273.0753, 237.1110, 209.1177, 153.0524 | Catechin or isomer | Flavone | FF, DF |
| 32  | 2.63     | C₁₀H₁₆N₂O₇       | [M+H]⁺       | 229.1543        | 211.0513, 190.0498, 167.0704, 116.0704, 86.0963, 70.0648 | L-valine anhydride | Amino acid | FF |
| 33  | 2.65     | C₁₀H₂₀N₂O₁₀      | [M+H]⁺       | 421.1127        | 403.1062, 385.0921, 357.0970, 271.0609 | 3,4,5′,6,8-Penta-Me ether-3,3′,3′,5′,5′,6′,8-Octahydroxyflavone | Flavone | FF, DF |
| 34  | 2.65     | C₁₀H₂₀O₁₂        | [M⁻]⁻       | 577.136         | 540.0766, 520.0717, 490.0667, 460.0618 | Procyanidin B1 or isomer | Flavone | FF, DF |
| 35  | 2.75     | C₁₀H₂₀O₁₂        | [M+H]⁺       | 579.1491        | 541.0832, 521.0783, 490.0734, 460.0685 | Procyanidin B1 or isomer | Flavone | FF, DF |
| 36  | 2.8      | C₁₀H₂₀O₁₂        | [M⁻]⁻       | 577.136         | 540.0766, 520.0717, 490.0667, 460.0618 | Procyanidin B1 or isomer | Flavone | FF, DF |
| 37  | 2.82     | C₁₀H₁₆O₄         | [M+H]⁺       | 265.1432        | 247.1333, 229.1210, 201.1260, 187.1107 | Abscissic acid | Organic acid | FF, DF |
| 38  | 2.82     | C₁₀H₂₀O₁₀        | [M+H]⁺       | 467.1892        | 305.0657, 287.1223, 259.0595, 153.0618 | 2-(4-Hydroxyphenyl)ethyl (2S,3E,4R)-3-ethylidene-2-(β-D-glucopyranosyloxy)-3,4-dihydro-2H-pyran-4-acetate | Ester | FF, DF |
| 39  | 2.9      | C₁₀H₂₀O₁₂        | [M+H]⁺       | 579.1491        | 541.0832, 521.0783, 490.0734, 460.0685 | Procyanidin B1 or isomer | Flavone | FF, DF |
| 40  | 2.9      | C₁₀H₂₀O₁₂        | [M+H]⁺       | 289.0706        | 259.0598, 179.0329, 163.0390, 151.0382, 149.0235, 139.0390, 135.0436 | Eriodictyol or isomer | Flavone | FF, DF |
| 41  | 2.9      | C₁₀H₂₀O₁₂        | [M+H]⁺       | 317.0872        | 299.0762, 253.0684, 141.0543 | 2,6-anhydro-1-O-(34,5-trihydroxybenzoyl)-D-mannitol or isomer | Phenolic acid | FF, DF |
| 42  | 2.9      | C₁₀H₂₀O₁₂        | [M+H]⁺       | 289.0706        | 188.0700, 159.0912, 146.0600 | Tryptophan | Amino acid | FF |
| 43  | 2.95     | C₁₀H₂₀O₁₂        | [M⁻]⁻       | 341.0879        | 179.0352, 135.0452 | Caffeic acid hexoside | Organic acid | FF |
| 44  | 2.96     | C₁₀H₂₀O₁₈        | [M⁻]⁻       | 633.0737        | 481.0609, 463.0512, 343.0098, 300.9990, 275.0192, 169.0136, 125.0237 | Galloyl-hexahydroxydiphenoyl-glucose or isomer | Phenolic acid | FF, DF |
| 45  | 2.98     | C₁₀H₂₀O₁₂        | [M+H]⁺       | 317.0865        | 299.0762, 253.0684, 141.0543 | 2,6-anhydro-1-O-(34,5-trihydroxybenzoyl)-D-mannitol or isomer | Phenolic acid | FF |
| 46  | 3        | C₁₂H₂₀O₁₂        | [M+H]⁺       | 465.1027        | 303.0124 | Isosquercetin | Flavone glycoside | FF |

(Continued)
| No. | Rt (min) | Molecular formula | Selected ion | Experimental m/z | MS/MS ions | Identification | Chemical type | Source |
|-----|---------|-------------------|--------------|------------------|------------|---------------|---------------|--------|
| 47  | 3       | C₁₅H₁₂O₁₁        | [M + H]⁺      | 563.155          | 427.1002, 411.1053, 393.0955, 291.0852, 273.0753, 255.0624 | Epiafzelechin-(4β→8)-epicatechin or isomer | Flavone | FF, DF |
| 48  | 3       | C₁₅H₁₂O₁₈        | [M + H]⁺      | 867.2134         | 579.1528, 425.0884, 409.0947, 397.0918, 289.0717 | Procyanidin C₁ | Flavone | FF, DF |
| 49  | 3       | C₁₅H₁₂O₅         | [M – H]⁻      | 289.072          | 247.0248, 191.0349, 173.0242, 151.0398, 145.1096, 123.0296, 109.0294 | Catechin or isomer | Flavone | FF, DF |
| 50  | 3.04    | C₃H₆O₃           | [M + H]⁺      | 139.0387         | 111.0435, 93.0331, 72.9352, 65.0377, 56.9644 | 4-Hydroxybenzoic acid | Phenolic acid | FF, DF |
| 51  | 3.07    | C₃H₆O₆           | [M – H]⁻      | 291.0149         | 247.0240, 219.0294, 191.0344 | Brevifolincarboxylic acid | Phenolic acid | FF, DF |
| 52  | 3.1     | C₃H₆O₆           | [M + H]⁺      | 265.1429         | 247.1330, 229.1219, 217.1225, 201.1268, 187.1119 | Abscisic acid | Organic acid | FF, DF |
| 53  | 3.17    | C₁₅H₁₂O₅         | [M + H]⁺      | 291.1071         | 273.0753, 237.1110, 209.1177, 153.0524 | Catechin or isomer | Flavone | FF, DF |
| 54  | 3.2     | C₁₅H₁₂O₁₈        | [M + H]⁺      | 867.2126         | 579.1475, 289.0709 | Procyanidin C₁ | Flavone | FF, DF |
| 55  | 3.2     | C₂₁H₂₀O₁₂        | [M + H]⁺      | 465.1021         | 303.0501 | Isoquercetin | Flavone glycoside | FF, DF |
| 56  | 3.2     | C₁₅H₁₂O₅         | [M + H]⁺      | 289.0705         | 259.0598, 179.0329, 163.0390, 151.0382, 149.0235, 139.0390, 135.0436 | Eriodictyol | Flavone | FF, DF |
| 57  | 3.38    | C₃H₆O₃           | [M + H]⁺      | 165.0543         | 147.0438, 123.0389, 119.0484 | p-Hydroxy-cinnamic acid | Phenolic acid | FF, DF |
| 58  | 3.38    | C₁₅H₁₂O₈         | [M + H]⁺      | 349.0895         | 303.0883, 289.9267 | Dryopic acid | Flavone | FF, DF |
| 59  | 3.39    | C₂₁H₂₀O₉         | [M – H]⁻      | 401.0878         | 301.0696, 289.0699, 203.0703, 151.0394, 137.0236, 109.0290 | (Epi)catechin derivative | Flavone | FF, DF |
| 60  | 3.4     | C₁₅H₁₂O₁₈        | [M + H]⁺      | 867.2107         | 579.1475, 289.0709 | Procyanidin C₁ | Flavone | FF, DF |
| 61  | 3.4     | C₃H₆O₃           | [M + H]⁺      | 165.0545         | 147.0389, 123.0389, 119.0441 | p-Hydroxy-cinnamic acid or isomer | Phenolic acid | FF, DF |
| 62  | 3.45    | C₂₁H₂₀O₁₃        | [M – H]⁻      | 469.005          | 300.9978, 270.9899, | Flavogallonic acid | Phenol | FF, DF |
| 63  | 3.5     | C₃₀H₂₆O₁₁        | [M + H]⁺      | 563.155          | 427.1002, 411.1053, 393.0955, 291.0852, 273.0753, 255.0624 | Epiafzelechin-(4β→8)-epicatechin or isomer | Flavone | FF |
| 64  | 3.5     | C₁₅H₁₂O₁₈        | [M + H]⁺      | 867.2122         | 579.1475, 289.0709 | Procyanidin C₁ | Flavone | FF, DF |
| 65  | 3.55    | C₃₀H₂₆O₁₂        | [M – H]⁻      | 577.136          | 407.0776, 339.0887, 289.0720, 245.0824, 161.0241, 125.0245 | Procyanidin B₁ or isomer | Flavone | FF, DF |
| 66  | 3.57    | C₁₅H₁₂O₅         | [M – H]⁻      | 289.0719         | 271.0618, 245.0817, 189.0527, 151.0398, | Catechin or isomer | Flavone | FF, DF |
| 67  | 3.73    | C₃₀H₂₆O₁₂        | [M + H]⁺      | 465.1025         | 303.0501 | Isoquercetin | Flavone glycoside | FF |
| 68  | 3.75    | C₁₅H₁₂O₁₂        | [M + H]⁺      | 579.1491         | 561.1391, 427.1028, 409.0917, 291.0866, 289.0705 | Procyanidin B₁ or isomer | Flavone | FF, DF |
| 69  | 3.8     | C₁₅H₁₂O₁₆        | [M – H]⁻      | 729.1458         | | Gallocatechin-(4α→8)-catechin | Flavone | FF |

(Continued)
| No. | Rt (min) | Molecular formula | Selected ion m/z | Experimental MS/MS ions | Identification | Chemical type | Source |
|-----|----------|--------------------|------------------|-------------------------|---------------|--------------|--------|
| 70  | 3.8      | C_21_H_28_O_8     | [M + H]^+        | 407.0780, 289.0729, 169.0149, 125.0251 | Vomoflexoside  | Sesquiterpene | FF, DF |
| 71  | 3.82     | C_24_H_36_O_16   | [M + H]^+        | 795.3782, 303.0141 | 6β-carboxy-2-[(11-carboxy-6a,6β,8a,11,14β-pentamethyl-14-oxo-1,2,3,4,4a,5,6,7,8,9,10,12,12a,14a-tetradecahydropicen-3-yl)oxy]-4,5-dihydroxyoxan-3-yl]oxy-34,5-trihydroxyoxan-2-carboxylic acid | Triterpenoid glycoside | FF, DF |
| 72  | 4.15     | C_61_H_90_O_22  | [M + Na]^+       | 207.1375* | Xiγ-Undecalactone  | Ester | FF, DF |
| 73  | 4.16     | C_62_H_90_O_22  | [M − H]^-       | 447.0873 | Ellagic acid-4-O-L-rhamnoside  | Flavone glycoside | FF, DF |
| 74  | 4.27     | C_11_H_20_O_2   | [M + H]^+        | 529.1358, 489.1044, 447.0942, 285.0418 | Kaempferol 3-O-[X-O-3-hydroxy-3-methylglutaryl]-β-glucoside or isomer | Flavone glycoside | FF, DF |
| 75  | 4.32     | C_41_H_64_O_12  | [M − H]^-       | 300.9997 | Ellagic acid  | Phenol | FF, DF |
| 76  | 4.78     | C_22_H_36_O_11  | [M + H]^+        | 525.231 | Secoisolariciresinol 4-O-β-D-glucopyranoside  | Lignan | FF, DF |
| 77  | 4.82     | C_22_H_36_O_16  | [M − H]^-       | 607.1309 | Quercetin  | Flavone | FF, DF |
| 78  | 5.17     | C_61_H_90_O_22  | [M − H]^-       | 591.1358 | Quercetin 3-O-[X-O-3-hydroxy-3-methyl]glucosid | Flavone glycoside | FF, DF |
| 79  | 5.37     | C_61_H_90_O_22  | [M − H]^-       | 591.1358 | Quercetin 3-O-[X-O-3-hydroxy-3-methyl]glucosid | Flavone glycoside | FF, DF |
| 80  | 5.66     | C_61_H_90_O_22  | [M + Na]^+       | 209.1531* | Methyl decanoate  | Ester | FF, DF |
| 81  | 6.46     | C_62_H_90_O_22  | [M − H]^-       | 593.1303 | Kaempferol-3-O-b-D-(6'-O-coumaroyl)-glucopyranoside  | Flavone glycoside | FF, DF |
| 82  | 6.53     | C_41_H_64_O_12  | [M − H]^-       | 301.0355 | Quercetin  | Flavone | FF, DF |
| 83  | 6.56     | C_22_H_36_O_12  | [M + H]^+        | 425.1802 | Crepidiaside B  | Sesquiterpene | FF |
| 84  | 6.56     | C_62_H_90_O_22  | [M + H]^+        | 407.1706 | 3,4-Deoxysalicyclic acid-3-sinapyl ether  | Lignan | FF, DF |
| 85  | 6.81     | C_62_H_90_O_22  | [M + H]^+        | 609.2604 | 3,4-Deoxysalicyclic acid-3-sinapyl ether  | Phenolic acid | DD |
| 86  | 6.91     | C_62_H_90_O_22  | [M + H]^+        | 689.3877 | 3,4-Deoxysalicyclic acid-3-sinapyl ether  | Steroidal glycoside | DD |
| 87  | 7.31     | C_60_H_92_O_20  | [M+COOH]^−      | 695.4012  | Kaji-ichigoside F1 or isomer | Triterpenoid glycoside | FF, DF |
| 88  | 7.43     | C_60_H_92_O_20  | [M+COOH]^−      | 695.4012  | Kaji-ichigoside F1 or isomer | Triterpenoid glycoside | FF, DF |
| 89  | 7.58     | C_60_H_92_O_20  | [M+COOH]^−      | 695.4012  | Kaji-ichigoside F1 or isomer | Triterpenoid glycoside | FF, DF |
| 90  | 8.05     | C_60_H_92_O_20  | [M+COOH]^−      | 673.3933  | Chol-4-en-6-one, 3-(β-D-glucopyranosyloxy)- | Steroidal glycoside | FF, DF |
| No. | Rt (min) | Molecular formula | Selected ion | Experimental m/z | MS/MS ions | Identification                                                                 | Chemical type       | Source |
|-----|----------|-------------------|--------------|-----------------|------------|--------------------------------------------------------------------------------|---------------------|--------|
| 91  | 8.44     | C_{36}H_{56}O_{10} | [M + H]^+   | 671.3792        | 509.3234   | 20-hydroxy-16-(6-methoxy-3-oxo-1,5-cyclohexadien-1-yl)-23-methyl-,(20ξ)-(9CI) | Oligoporin C        | FF, DF |
| 92  | 9.35     | C_{30}H_{46}O_{5}  | [M – H]^-   | 485.3272        | 467.3164, 425.3049, 375.3079 | 2α,19α-Dihydroxy-3-oxo-urs-12-en-28-oic acid or isomer | Triterpenoid glycoside | FF, DF |
| 93  | 9.65     | C_{30}H_{48}O_{5}  | [M – H]^-   | 487.3429        | 469.3320, 443.3518, 423.3228, 407.3309, 371.2963 | Euscaphic acid or isomer | Triterpenoid | FF, DF |
| 94  | 10.68    | C_{30}H_{46}O_{5}  | [M – H]^-   | 485.3272        | 467.3156, 425.3061, 375.3079 | 2α,19α-Dihydroxy-3-oxo-urs-12-en-28-oic acid or isomer | Triterpenoid | FF, DF |
| 95  | 10.78    | C_{16}H_{25}NO     | [M + H]^+   | 248.2018        | 230.1886, 194.1530, 180.1378, 175.1194, 167.1298, 152.1066, 81.0698, 72.0806, 57.0700 | (2E,4E,8Z,10Z)-Nisobutyl-dodeca-2,4,8,10-tetraenamide or isomer | Acylamide | FF, DF |

Abbreviations: FF, fresh fruit extract; DF, dried fruit extract.
# Table 2. Relative LC-MS Peak Areas of Identified Compounds in Fresh and Dried *Rosa moschata* Fruits.

| No. | Compound                                                                 | Fresh fruit (%) | Dried fruit (%) | Fold change | P value |
|-----|---------------------------------------------------------------------------|-----------------|-----------------|-------------|---------|
| 1   | Arginine                                                                  | 5.54            | 0.17            | -33.07      |         |
| 16  | Tyrosine                                                                  | 1.08            | 4.37            | 4.06        |         |
| 17  | Fructose-leucine                                                          | 0.09            | 0.99            | 11.05       |         |
| 19  | Isoleucine or isomer                                                      | 6.89            | 6.63            | -1.04       |         |
| 21  | Isoleucine or isomer                                                      | 1.89            | 9.90            | 5.25        |         |
| 27  | Phenylalanine                                                             | 0.45            | 6.37            | 14.16       |         |
| 32  | Leucylproline                                                             | 0.04            | 0.49            | 13.66       |         |
|     | **Total amino acid**                                                      | **21.34**       | **34.39**       | **32**      |         |
| 95  | (2E,4E,8Z,10Z)-Nisobutyl-dodeca-2,4,8,10-tetraenamide or isomer         | 0.00            | 11.29           | ∞           |         |
|     | **Total acylamide**                                                      | **0.00**        | **11.29**       | <.001       |         |
| 31  | Catechin or isomer                                                        | 0.34            | 0.10            | -3.28       |         |
| 33  | 3,4',5',6,8-Pent-Me ether-3,3',4',5',6,7,8-Octahydroxyflavone              | 0.06            | 0.49            | 7.90        |         |
| 34  | Procyanidin B1 or isomer                                                  | 1.35            | 0.74            | -1.82       |         |
| 36  | Procyanidin B1 or isomer                                                  | 8.96            | 4.44            | -2.01       |         |
| 46  | Isoquercetin or isomer                                                    | 2.29            | 0.06            | -38.72      |         |
| 47  | Epiafzelechin-(4β→8)-epicatechin or isomer                                | 0.13            | 0.29            | 2.26        |         |
| 48  | Procyanidin C1 or isomer                                                  | 1.72            | 0.41            | -4.16       |         |
| 49  | Catechin or isomer                                                        | 13.25           | 10.32           | -1.28       |         |
| 54  | Procyanidin C1 or isomer                                                  | 0.19            | 0.04            | -4.49       |         |
| 55  | Isoquercetin or isomer                                                    | 0.14            | 0.00            | ∞           |         |
| 56  | Eriodictyol                                                               | 0.13            | 0.09            | -1.52       |         |
| 58  | Dryopteric acid                                                           | 0.00            | 0.22            | ∞           |         |
| 59  | (Ep)catechin derivative                                                   | 0.00            | 0.57            | ∞           |         |
| 60  | Procyanidin C1 or isomer                                                  | 0.37            | 0.06            | -5.81       |         |
| 63  | Epiafzelechin-(4β→8)-epicatechin or isomer                                | 0.62            | 0.01            | -71.04      |         |
| 64  | Procyanidin C1 or isomer                                                  | 0.45            | 0.11            | -3.90       |         |
| 65  | Procyanidin B1 or isomer                                                  | 0.71            | 0.37            | -1.90       |         |
| 66  | Catechin or isomer                                                        | 0.00            | 0.38            | ∞           |         |
| 67  | Isoquercetin or isomer                                                    | 0.31            | 0.10            | -3.20       |         |
| 73  | Ellagic acid-4-O-L-rhamnoside                                              | 1.83            | 0.92            | -1.99       |         |
| 77  | Quercetin 3-O-[[X-O-3-hydroxy-3-methylglutaryl]-β-glucoside]               | 0.11            | 0.55            | 4.81        |         |
| 78  | Kaempferol 3-O-[[X-O-3-hydroxy-3-methylglutaryl]-β-glucoside] or isomer    | 0.00            | 0.21            | ∞           |         |
| 79  | Kaempferol 3-O-[[X-O-3-hydroxy-3-methylglutaryl]-β-glucoside] or isomer    | 0.00            | 0.17            | ∞           |         |
|     | **Total flavonoid**                                                       | **35.00**       | **22.13**       | **.49**     |         |
| 5   | L-ascorbic acid                                                           | 30.80           | 25.28           | -1.22       |         |
| 6   | Threonic acid                                                             | 0.13            | 1.56            | 11.90       |         |
| 7   | Quinic acid                                                               | 2.71            | 4.23            | 1.56        |         |
| No. | Compound                                                                 | Fresh fruit (%) | Dried fruit (%) | Fold change<sup>a</sup> | P value |
|-----|--------------------------------------------------------------------------|-----------------|----------------|--------------------------|---------|
| 8   | Xyloonic acid                                                            | 1.46            | 5.58           | 3.81                     |         |
| 10  | Citric acid                                                              | 7.28            | 7.92           | 1.09                     |         |
| 12  | 4-O-(4-Deoxy-α-L-erythro-hex-4-enopyranuronosyl)-α-L-gulopyranuronic acid| 8.79            | 0.94           | −9.35                    |         |
| 15  | Isocitric acid                                                           | 7.62            | 6.00           | −1.27                    |         |
| 24  | β-Acetylcheryll acid                                                    | 0.37            | 0.10           | −3.55                    |         |
| 25  | L-valine anhydride                                                       | 0.00            | 0.0032         | ∞                         |         |
| 43  | Caffeic acid hexoside                                                    | 0.25            | 0.10           | −2.48                    |         |
|     | **Total organic acid**                                                  | **60.37**       | **52.81**      | **.84**                  |         |
| 2   | 1,1′-(1,3-Propanediyl) bis(34,5-trihydroxybenzoate)                     | 1.20            | 0.07           | −18.38                   |         |
| 18  | Galloyl-glucose                                                          | 0.00            | 0.81           | ∞                         |         |
| 20  | Gallic acid                                                              | 0.00            | 4.54           | ∞                         |         |
| 23  | β-D-Glucopyranosiduronic acid, 2,3-dihydroxyphenyl                       | 0.00            | 0.18           | ∞                         |         |
| 28  | Protocatechuic acid                                                     | 0.00            | 0.31           | ∞                         |         |
| 29  | Galloyl-hexahydroxydiphenoyl-glucose or isomer                           | 0.00            | 2.04           | ∞                         |         |
| 30  | 3,4,5-Trihydroxyphenyl acid                                             | 0.00            | 1.55           | ∞                         |         |
| 50  | 4-Hydroxybenzoic acid                                                   | 0.11            | 0.19           | 1.68                     |         |
| 51  | Brevifolinecarboxylic acid                                              | 0.0065          | 1.73           | 267.20                   |         |
| 62  | Flavogallonic acid                                                      | 0.043           | 1.15           | 26.43                    |         |
| 75  | Ellagic acid                                                            | 1.31            | 4.84           | 3.71                     |         |
|     | **Total phenol**                                                        | **3.88**        | **19.10**      | **.02**                  |         |
| 88  | Kaji-ichigoside F1                                                      | 11.35           | 8.19           | −1.39                    |         |
|     | **Total**                                                               | **16.56**       | **13.30**      | **.81**                  |         |
|     | **Terpenoid**                                                           |                 |                |                          |         |
| 11  | Adenine                                                                 | 0.13            | 1.02           | 7.61                     |         |
| 72  | xi-γ-Undecalactone                                                      | 4.85            | 1.83           | −2.65                    |         |
| 80  | Methyl decanoate                                                        | 1.65            | 0.11           | −15.31                   |         |
| 86  | (4R)-4-(35,7R,8R,9S,10S,13R,14S,17R)-7-Hydroxy-3-(4-methoxybenzoyl)-10,13-dimethyloxan-2-yloxy-1,2,4,5,6,7,8,9,11,12,14,15,16,17-tetradecahydrocyclopenta[a]phenanthren-17-ylpentanoic acid | 0.12 | 0.29 | 2.40 |
|     | **Total others**                                                        | **10.50**       | **6.90**       | **.47**                  |         |

<sup>a</sup>Positive fold change value means a relatively higher content in dried fruit, while negative value means higher content in fresh fruit. All the tests were performed in triplicate.
Table 3. DPPH• Scavenging Capacity and FRAP of Fresh and Dried *R. roxburghii* Fruits.

| Sample          | DPPH (mg AAE/g) | IC50 (mg/mL) | FRAP (mmol Fe2+/100 g) |
|-----------------|----------------|--------------|------------------------|
| FF              | 2.92 ± 0.59    | 4.21 ± 0.13  | 110.62 ± 35.38         |
| DF              | 5.05 ± 0.83    | 3.69 ± 1.25  | 187.30 ± 49.16         |
| L-Ascorbic acid | nt             | 0.026 ± 0.099| 1882.72 ± 202.91       |

Abbreviations: DPPH•, 1,1-diphenyl-2-picrylhydrazyl radical; FRAP, ferric reducing antioxidant power; AAE, L-ascorbic acid equivalents; FF, fresh fruit extract; DF, dried fruit extract; nt, not tested.

All values are expressed as mean ± SD of three independent measurements.

...dried fruit, but with no significant difference (p > .05). More specifically, the most abundant flavonoids are catechin (compound 49), procyanidin B1 (compound 36), and/or their isomers, accounting for 70% of the total flavonoids in both fresh and dried fruits. According to previous studies focusing on the thermal treatment of teas and blueberries, heating could lead to the loss of catechin and procyanidin due to chemical reactions with other compounds or oxidations. In this study, the lower content of catechin and procyanidin in dried fruit might be caused by a similar reason. Catechin was reported to have antioxidant and antitumor activities, and procyanidin B1 also has antioxidant activity. Thus, the reduction of total flavonoid contents might lead to a diminishment of antioxidant activities in dried fruit.

Interestingly, the content of total phenol was significantly higher (p < .05) in dried fruit. More specifically, the content of ellagic acid (compound 75) and gallic acid (compound 20) were the main and characteristic phenols in dried fruit (fold change: 3.75/∞; relative area ratio: 4.84%/4.54%). The increase of the gallic acid content was also reported in a previous study on potato after the heating process, due to the breakdown of complex components. And, the amount of ellagic acid could increase after heating, due to the hydrolysis of the precursors. In our study, the high content of gallic and ellagic acids in dried fruit might come from a similar way. Both gallic acid and ellagic acid are strong antioxidants sourced in plants. Therefore, these results suggested that the higher phenols in dried fruits might enhance their antioxidant activity.

As shown in Figure 1 and Table 2, the content of (2E,4E,8Z,10Z)-Nisobutyl-dodeca-2,4,8,10-tetraenamide (compound 95) was significantly higher in dried fruit (p < .001). This compound is known as the main alkylamide in *Echinacea* species plants, which have immunomodulatory and antiinflammatory actions. Besides, the content of the total amino acid was also higher in dried fruit (34.39%). Among them, the content of essential amino acids, including tyrosine, isoleucine, and phenylalanine, were the main amino acids in dried fruit, which suggested that the nutritional benefits would be improved.

In this study, total organic acid and flavonoid contents were lower, whereas total amino acid, acylamide, and phenol contents were higher in dried fruits. Since L-ascorbic acid, flavonoids, and phenols all contribute to the antioxidant capacities, the difference of the bioactivity between fresh and dried fruit was still unclear. Thus, the DPPH• scavenging assay and FRAP were performed.

**Antioxidant Activities of R. roxburghii Fruits**

Based on the different mechanism-based methods, DPPH• scavenging ability and FRAP are widely used to detect the *in vitro* antioxidant activity of the specific compound or extracts from plants or foods. In this experiment, the DPPH• scavenging activities and FRAP of the fresh and dried fruits were also determined, and L-ascorbic acid was used as a positive control. As shown in Table 3, the scavenging activity of DPPH• assay showed that dried fruit was with slightly higher AAEs and lower IC50 compared to fresh fruit, indicating it had better antioxidant activity. The result of the ferric reducing capacity of dried fruit also gave a higher value.

The above results indicated that dried *R. roxburghii* fruit still has strong antioxidant activity. Previous studies have reported that L-ascorbic acid, flavonoids, and phenols showed strong antioxidant activity. The analysis of relative amounts of identified compounds, phenols in dried fruits were significantly higher, which might explain the strong antioxidant activity of dried *R. roxburghii* fruit.

**Conclusion**

In conclusion, the constituents and in vitro antioxidant activities of fresh and dried *R. roxburghii* fruit were evaluated and compared for the first time. The dried fruit showed stronger antioxidant activities by scavenging free radical and ferric reducing capacity assays. The high content of phenols in dried fruit might explain the above results. Overall, this study suggested that dried *R. roxburghii* fruit could preserve the bioactive and functional compounds. Therefore, dried fruit could be considered a more effective and economical health and functional supplement for food and healthcare industries.

**Experimental**

**Chemicals and Reagents**

Acetonitrile (HPLC grade) and methanol (HPLC grade) were obtained from Anaqua Chemicals Supply Inc., Ltd. Deionized water was prepared using a Millipore water purification system (Millipore Corp.). Formic acid (MS grade), 2, 4, 6-tripirydyl-s-triazine (TPTZ), and other chemical reagents were provided by Sigma-Aldrich. 1,1-Diphenyl-2-picrylhydrazyl radical (DPPH•) was purchased from TCI Development Co., Ltd. Reference substances, (+)-catechin, isoquercitrin, quercetine, kajiichigoside F1, and eriodictyol were obtained from...
Shenzhen hiboled century Biotechnology Co. Ltd), L-ascorbic acid, procyanidin B1, and ellagic acid were supplied by Guangzhou zhuanan Biological Technology Co. Ltd, and their purities were more than 98.0% by high-performance liquid chromatography analysis.

Plant Materials

The variety of *R. roxburghii* is Gui Nong Qi Hao, provided by Guizhou Hengliyuan Natural Biotechnology Co Ltd

Sample Preparation

Dried fruits, which were dried at 37 °C in an oven until the moisture content was <5% (drying time is around 24 h), were exactly weighed and extracted by refluxing with water (1:10, w/v) for 2 h. All supernatant was collected after centrifugation at 15,000 rpm for 5 min for LC-MS analysis and antioxidative assays. Fresh fruit was prepared the same way, except for the drying process. DPPH• solution was prepared by dissolving accurately weighed DPPH (24.6 mg) into a 100 mL brown volumetric flask right with methanol before the experiments and the whole procedure was protected from light. FRAP stock solution contained with methanol before the experiments and the whole procedure was performed meaningful data mining. Then the formula

\[
\text{FRAP} = \frac{\text{Sample absorbance} - \text{Blank absorbance}}{\text{Control absorbance} - \text{Blank absorbance}} \times 1000 
\]

was used to extract molecular features and compounds were identified based on the exact masses, MS² spectra, and the database, such as Scifinder (scifinder.cas.org/), HMDB (https://hmdb.ca/), Pubchem (https://pubchem.ncbi.nlm.nih.gov/) and METLIN (https://metlin.scripps.edu/index.php) and previous reports.

Relative LC-MS peak areas were the relative share of each identified compound from the total chromatogram peak area in a sample. The fold change higher than 1.5 was considered statistically significant, and a positive value means a relatively higher content in dried fruits, while a negative value means fresh fruits showed higher content. And all the tests were performed in triplicate. The significance of discriminating each compound with the same type was determined by the t-test device. The difference with \( p < .05 \) was considered statistically significant.

Microplate Assay of DPPH• Scavenging Activity

DPPH• scavenging activity was performed using a reported method, with slight modification. Briefly, fresh and dried fruit extracts were adjusted to the same dried weight. Then, 300 µL DPPH• solution was added to a 150 µL extract solution or L-ascorbic acid standard solution (5.3, 10.6, 21.2, 42.4, and 84.8 mg/mL), then stirred. Samples were incubated in the dark at room temperature for 30 min and then detected by measuring the absorbance

\[
\text{Scavenging Activity} = \frac{A_{\text{blank}} - A_{\text{sample}}}{A_{\text{blank}}} \times 100\%
\]

Ferric Reducing/Antioxidant Power Assay

The FRAP assay was carried out as previously described. Then 50 µL of properly diluted sample was added to 250 µL of freshly prepared FRAP reagent in a 96-well plate and mixed thoroughly. The mixture was incubated at 37 °C for 10 min, and then measured at 593 nm. The FRAP value was calculated as millimoles of Fe²⁺ equivalents per 100 g of sample (mmol Fe²⁺ equiv/100 g) based on a calibration curve plotted using FeSO₄·7H₂O as the standard curve.

LC-MS Data Analysis

LC-MS data was extracted by Peakview (AB SCIEX) to perform meaningful data mining. Then the formula finder

\[
\text{scavenging activity} = \frac{1 - (A_{\text{sample}} + DPPH - A_{\text{sample}})}{(A_{\text{DPPH}} - A_{\text{blank}})} \times 100\%
\]

was calculated as follow:
Declaration of Conflicting Interests
The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding
The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the China Evergrande Group, SKLIRD Open Project (grant numbers 2020GIRHHMS04 and SKLIRD-OP-202108).

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

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

ORCID iD
Guanyu Yan https://orcid.org/0000-0001-7928-8104

Supplemental Material
Supplemental material for this article is available online.

References
1. Xu JW, Vidyarthi SK, Bai WB, Pan ZL. Nutritional constituents, health benefits and processing of Rosa roxburghii: a review. J Funct Foods. 2019;60:ARTN 103456. doi:10.1016/j.jff.2019.103456.
2. Mou JF, Wang SM. Preliminary study on the storage of fresh Rosa roxburghii fruits. (article in Chinese). Food Science. 1981;4(4):46-51.
3. Hasan M Ul, Malik AU, Ali S, et al. Modern drying techniques in fruits and vegetables to overcome postharvest losses: a review. J Food Process Pres Suppl 1:S110. 2018;132:109943. doi:10.1016/j.jfpp.2018.109943.
4. Baskaran R, Pullencheri D, Somasundaram R. Characterization of free, esterified and bound phenolics in custard apple (Annona squamosa L.) fruit pulp by UPLC-ESI-MS/MS. J Agric Food Sci Technol. 2016;82:121-127. doi:10.1016/j.j.foodres.2016.02.001.
5. Sanchez-Rabaneda F, Jauregui O, Lamuela-Raventos RM, Viladomat F, Bastida J, Codina C. Qualitative analysis of phenolic compounds in apple pomace using liquid chromatography coupled to mass spectrometry in tandem mode. Rapid Commun Mass Spectrom: RCM. 2004;18(5):553-563. doi:10.1002/rcm.1370.
6. Brownmiller C, Howard LR, Prior RL. Processing and storage effects on procyanidin composition and concentration of processed blueberry products. J Agric Food Chem. 2009;57(5):1896-1902. doi:10.1021/jf803015x.
7. Kim ES, Liang YR, Jin J, et al. Impact of heating on chemical compositions of green tea liquor. Food Chem. 2007;103(4):1263-1267. doi:10.1016/j.foodchem.2006.10.031.
8. Kim MY, Lee BW, Lee HU, et al. Phenolic compounds and antioxidant activity in sweet potato after heat treatment. J Sci Food Technol. 2019;99(15):6833-6840. doi:10.1002/jfsa.9968.
9. Xiang L, Xing D, Lei F, et al. Effects of season, variety, and processing method on cllagic acid content in pomegranate leaves. Tsioghua Sci Technol. 2008;13(4):460-465. doi:10.1016/s1007-0214(08)70074-9.
10. Gertsch J, Schoop R, Kuenzel U, Suter A. Echinacea alkaloids modulate TNF-alpha gene expression via cannabinoid receptor CB2 and multiple signal transduction pathways. FEBS Lett. 2004;577(3):563-569. doi:10.1016/j.febslet.2004.10.064.
11. Goey AKL, Rosing H, Meijerman I, Sparidans RW, Schellens JHM, Beijnen JH. The bioanalysis of the major Echinacea purpurea constituents dodeca-2E,4E,8Z,10E/Z-tetraenoic acid isobutyrlamides in human plasma using LC–MS/MS. J Chromatogr B. 2012;902:151-156. doi:10.1016/j.jchromb.2012.06.022.
23. Jiao ZZ, Yue S, Sun HX, et al. Indoline amide glucosides from Portulaca oleracea: Isolation, structure, and DPPH radical scavenging activity. *J Nat Prod.* 2015;78(11):2588-2597. doi:10.1021/acs.jnatprod.5b00524.

24. Bradish CM, Perkins-Veazie P, Fernandez GE, Xie G, Jia W. Comparison of flavonoid composition of red raspberries (*Rubus idaeus* L.) grown in the southern United States. *J Agric Food Chem.* 2012;60(23):5779-5786. doi:10.1021/jf203474e.

25. Gadkari PV, Balaraman M. Catechins: sources, extraction and encapsulation: a review. *Food Bioprod Process.* 2015;93:122-138. doi:10.1016/j.fbp.2013.12.004.

26. He J, Sun M, Tian S. Procyanidin B2 prevents lupus nephritis development in mice by inhibiting NLRP3 inflammasome activation. *Innate Immun.* 2018;24(5):307-315. doi:10.1177/1753425918780985.

27. Lu YY, Foo Y. Antioxidant and radical scavenging activities of polyphenols from apple pomace. *Food Chem.* 2000;68:81-85. doi:10.1016/S0308-8146(99)00167-3

28. Piljac-Zegarac J, Belsak A, Piljac A. Antioxidant capacity and polyphenolic content of blueberry (*Vaccinium corymbosum* L.) leaf infusions. *J Med Food.* 2009;12(3):608-614. doi:10.1089/jmf.2008.0081.

29. Brand-Williams W, Cuvelier ME, Berset CL. Use of a free radical method to evaluate antioxidant activity. *LWT—Food Sci Technol.* 1995;28(1):25-30. doi:10.1016/S0023-6438(95)80008-5

30. Thasleema SA. Green tea as an antioxidant—a short review. *J Pharm Sci Res.* 2013;5(9):171-173.

31. Zhu MZ, Wu W, Jiao LL, Yang PF, Guo MQ. Analysis of flavonoids in Lotus (*Nelumbo nucifera*) leaves and their antioxidant activity using macroporous resin chromatography coupled with LC-MS/MS and antioxidant biochemical assays. *Molecules.* 2015;20(6):10553-10565. doi:10.3390/molecules200610553.