Nutritional and health care valuation of seed embryo

Sterculia nobilis Smith


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Abstract: [Objective] To provide scientific basis for extention of a South China origin woody grain potential plant, Sterculia nobilis Smith (SNS), its seed embryo, the edible part of the plant was investigated on the characteristics of nutrition and health care. [Method] A comprehensive research was performed to determine nutritional compositions and antioxidant activities of polyphenols in seed embryo of two kinds of SNS (GXPNO1 and GDXNO1). [Result] The results indicated that the nutrient compositions of SNS seed embryo mainly consisted of starch and protein, and exhibited rich fat, starch, vitamin, polyphenol, amino acid and trace elements (Ca, Fe, Zn), and vitamin C and vitamin E contents were considerably higher than other vitamins. Additionally, SNS seed embryo contained considerable polyphenols (especially flavonoids), which possessed stronger antioxidant potential by evaluating reducing power, metal chelating capacity and radical–scavenging activity of 1,1–diphenyl–2–picrylhydrazyl (DPPH), and hydroxyl radical– and superoxide anion–scavenging activity. [Conclusion] Sterculia nobilis Smith is strongly recommended woody food plant for its nutritional seed embryo with health care results including antioxidant activities.

Key words: Sterculia nobilis Smith; seed embryo; nutritional compositions; content; antioxidant activities


苹婆（Sterculia nobilis Smith）种胚营养及保健性评价

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摘要：[目的] 研究华南原产的一种木本粮用果树苹婆可食部分——种胚的营养和人体保健性。为推广应用苹婆提供科学依据。[方法] 以广西不同产地来源苹婆GXPNO1和GDXNO1为材料，对其种胚营养成分进行测定，并通过测定其多酚提取物的还原力和金属螯合力以及对DPPH自由基，羟自由基和超氧阴离子自由基清除能力，了解其抗氧化活性。[结果] 苹婆种胚营养成分以淀粉和蛋白质为主，含有丰富的脂肪，维生素，多酚，氨基酸和微量元素（Ca，Fe，Zn），维生素C和维生素E含量明显高于其他维生素。此外，苹婆种胚多酚物质（尤其是类黄酮）含量高，并表现出较强的DPPH自由基清除能力，还原力，金属螯合力以及羟自由基和超氧阴离子自由基清除能力。[结论] 苹婆种胚具有较高的营养价值和包括较强的抗氧化能力在内的保健作用，苹婆是一种具有较高开发价值的木本粮用果树。

关键词： 苹婆；营养成分；多酚提取物；抗氧化

Sterculia nobilis Smith (SNS), a woody plant indigenous to southern China, belongs to the family Sterculiaceae. It is often planted as a garden tree in Taiwan, southeastern Fujian, southern Guangdong, Guangxi and Yunnan in China. It also sporadically distributes in India, Vietnam, Indonesia, Malaysia, Sri Lanka and Japan, etc. Although SNS has strong adaptation and high commercial value, a large scale cultivation is absent presently. Sterculia is a genus colloquially termed the tropical chestnuts. Some of Sterculia species, such as Sterculia foetida and Sterculia nobilis, are rich in polyphenols in their...
leaves or nuts (Ramachandran Nair et al., 1977; Xia et al., 2009), and therefore serve as the good natural medicines. SNS nut and follicle are often used as the traditional Chinese medicines for treating gastrointestinal disorder and bloody flux.

The ripe SNS nut has a vermeil shell enwrapping 1–5 brown seeds. The shell will automatically split when SNS nut matures. After removing the vermeil shell and the brown seed capsule from the seed, a pale yellow or creamy white seed embryo appears. The seed embryo is often used for dish in local diet. Additionally, the SNS lumber and bark can be utilized as the raw materials for furniture and paper. Owing to above benefits, SNS deserves attention and exploitation. The previous researches on this plant focused largely on its landscape gardening function. Up to now, little information is available on evaluation of nutritional quality and antioxidant activity of SNS nut, and the more investigation is required prior to further development of this nut. Actually, SNS nut contains a great quantity of protein, fiber, vitamins, amino acids and trace elements. It is rich in polyphenols with antioxidant activities, which play the important roles to human health.

In biological system, the oxidative stress has been associated with the pathogenesis of many human diseases such as cancer, heart disease, hypertension and kidney disease (Karp and Koch, 2006; Mariani et al., 2005). The application of natural antioxidants from food sources can improve current treatments for these diseases. Polyphenols in some nuts, such as walnut (Anderson et al., 2001), Chinese water chestnut (You et al., 2007), cacao beans (Padilla et al., 2008), cashew nut (Kamath and Rajini, 2007), hazelnuts and pistachios (Arcan and Yemenicioğlu, 2009), exhibit the strong antioxidant activity and possess the ability to scavenge both active oxygen species and electrophiles (Robards et al., 1999). Just like other nuts, SNS nut is also a good resource of natural antioxidant because of its significant amount of polyphenols, and thus it is worthwhile to investigate this nut detailledly and thourghly. The objective of the present study was to evaluate nutritional quality and antioxidant activity of polyphenol extracts from SNS nut. The study is helpful to elucidate health benefit of SNS nut so as to further exploit and introduce it into more areas.

1 Materials and methods

1.1 Plant materials

Two kinds of SNS seed embryo (100 mature samples every kind of nut), GXN01 and GXDX01, were respectively harvested from orchards in Pingnan and Daxin towns of Guangxi in August, 2010. The nuts without any defects and diseases were selected, the shells were removed, while the seed embryos were collected, weighed and then stored at −20°C until further extraction and analysis.

The used chemicals and reagents included commercial standards 1,1-diphenyl−2-picrylhydrazyl (DPPH) and 2,2,4,6−tetrahydridyl−s−triazine (TPTZ), gallic acid, rutin, which were purchased from Sigma−Aldrich (St. Louis, MO, USA). Commercial antioxidant ascorbic acid was purchased from Aladdin Reagent Inc. (Shanghai, China). Other chemicals and reagents were of analytical grade.

1.2 Analysis of nutritional compositions

SNS seed embryos (20 g) were homogenized in distilled water. The homogenate was filtered through double layers of muslin. The filtrate was centrifuged at 3500 × g for 15 min and then the supernatant was collected as sample to analyze the contents of total soluble solids, total protein, total fat, ash, starch, vitamin and amino acid. Total soluble solids content was determined at 20°C with a hand−refractometer (CANY Co., Shanghai, China). Total protein content was estimated by Kjeldahl method and total fat content was assayed by Soxhlet method described by AOAC (1990). The ash content was determined by the ignition method using the crucible and muffle furnace. The starch was assayed by enzyme hydrolysis method. Trace elements were evaluated by atomic absorption spectrometry (Thermo, N.Y., USA). Vitamin contents were assayed by the methods described by Kenneth and AOAC (1990). Amino acid contents were determined using an automatic acid analyzer (Hitachi, Tokyo, Japan). All data was expressed on a fresh weight (FW) basis.

1.3 Extraction of polyphenols

Polyphenols were extracted according to the modified method of Zhang et al. (2000). At 20°C, 50 g of SNS seed embryos was chopped into pieces and then extracted for 30 min using 100 mL of methanol/acetone/water (3.5:3.5:3.0, v/v/v) containing 1%
formic acid. The extraction was performed twice in a shaking incubator (ZHFWY-200B, Zicheng Analytical Co., Shanghai, China). All extracts were combined and filtered through two layers of cheesecloth. The collected filtrate was centrifuged for 15 min at 7000 x g. The supernatant was collected and evaporated under vacuum at 40°C to remove methanol and acetone. Lipophilic pigments were then eliminated from the aqueous phase by two successive extractions in a separatory funnel with two-fold volume of petroleum ether. The aqueous phase was collected, evaporated and dried under vacuum at 35°C. The residue was re-dissolved in 10 mL of ethanol and used as polyphenol sample.

Total phenolic content was determined using the Folin–Ciocalteau method described by Singleton and Rossi (1965) with some modifications. At the room temperature, 1 mL of 10-fold diluted extracts by methanol/acetone/water (3.5:3.5:3.0 v/v/v) containing 1% formic acid was thoroughly mixed with 1 mL of Folin–Ciocalteau reagent and set for 3 min. Then, 3 mL of sodium carbonate (75 g/L) was added into the mixture and allowed to stand for 2 h. Sample aliquots were filtered through the 0.45 μm filter prior to the determination of total phenolics using a UV–Visible Spectrophotometer (UV–1700, Shimadzu, Kyoto, Japan) monitoring at 760 nm. Total phenolic content was standardized against gallic acid and expressed as microgram per milliliter of gallic acid equivalents (GAE).

Total flavonoid content was determined according to the modified method of Lin and Tang (2007). At the room temperature, 1 mL of polyphenol – ethanol solutions was thoroughly mixed with 0.3 mL of 5% sodium nitrite and set for 6 min. Then, 0.3 mL of 10% aluminum nitrate was added into the mixture. After 6 min, 4 mL of 4% sodium hydroxide was blended into the mixture. Sample aliquots were allowed to stand for 2 h before the determination of total flavonoid content using the spectrophotometer monitoring at 510 nm. Total flavonoid content was standardized against rutin and expressed as microgram per milliliter of rutin equivalents.

1. 4 Antioxidant activity assays

1. 4. 1 DPPH radical-scavenging activity The DPPH–scavenging activity was estimated by the modified method of Sun et al. (2007). Aliquots (0.5 mL) of 0 (control), 25, 50, 100, 250, 500 and 1000 μg/mL of polyphenol extracts dissolved in ethanol were added into 2.5 mL of 0.2 mM DPPH solution in ethanol. The absorbance at 517 nm of samples was measured after 30 min of incubation at 26°C in the dark. DPPH–scavenging activity (\( \% \)) = 1 - \[ (A - B) / A_0 \] \times 100, where \( A \) = absorbance of sample, \( B \) = absorbance of 0.5 mL of polyphenol extracts+2.5 mL of ethanol, and \( A_0 \) = absorbance of control. The calculation of 50% inhibition concentration (IC50) to scavenge 50% of radical was obtained according to the method of Seneviratne et al. (2006). Ascorbic acid was used as positive control.

1. 4. 2 Ferric reducing/antioxidant power (FRAP) FRAP assay was conducted by the modified method of Benzie and Strain (1996). The working FRAP reagent was produced by mixing 300 mM acetate buffer (pH 3.6), 10 mM TPTZ solution and 20 mM FeCl3·6H2O in a 10/1/1 ratio prior to use and then heated to 37°C in a water bath. A total of 3 mL of FRAP reagent was added to a test tube and a blank reading was then taken at 593 nm using the spectrophotometer. A total of 100 μL of 0–1000 μg/mL polyphenol extracts dissolved in ethanol and 300 μL of distilled water were added to the cuvette. After the addition of the FRAP reagent, a second reading at 593 nm was performed after 40 min of incubation at 37°C in a water bath. The changes in absorbance after 40 min from the initial blank reading were compared with the standard curve. Standards of known Fe (II) concentrations were used at 0–1000 μM and then a standard curve was prepared by plotting the FRAP value of each standard versus its concentration. The result was expressed as the concentration of antioxidant exhibiting a ferric reducing ability per gram of sample (μM/g).

1. 4. 3 Metal chelating capacity The metal chelating capacity (MCC) was determined by the modified method of Dinis et al. (1994). Aliquots (1 mL) of 0 (control), 25, 50, 100, 250, 500 and 1000 μg/mL polyphenol extracts dissolved in ethanol were added in 2.8–mL distilled water and then mixed with 50 μL of 2 mM FeCl3·4H2O and 150 μL of 5 mM ferrozine. The mixture was shaken at 120 × g. After 20 min, the Fe (II) was monitored by measuring the formation of ferrous ion–ferozine complex at 562 nm. The metal chelating capacity was calculated as follows: chelating capacity (\( \% \)) = (1 – absorbance of sample/absorbance of control) × 100.
1. 4. 4 Hydroxyl radical–scavenging activity The hydroxyl radical–scavenging activity was measured according to the modified method of Lee et al. (2002). A 0.4–mL aliquot of 0 (control), 50, 100, 250, 500 and 1000 μg/mL polyphenol–ethanol solutions was mixed with 1 mL of reaction buffer (containing 100.0 μM FeCl3, 104.0 μM EDTA, 2.5 mM H2O2, 2.5 mM deoxyribose, 100.0 μM ascorbic acid). The reaction solutions were incubated for 1 h at 37°C and then 1 mL of 0.5% thiobarbituric acid (dissolved in 0.025 M NaOH) and 1 mL of 2.8% trichloroacetic acid were added into the mixtures. The mixtures were incubated for 30 min at 80°C and cooled in ice bath. The absorbances of samples were measured at 532 nm. Hydroxyl radical–scavenging activity (%) = (1–absorbance of sample/absorbance of control) × 100.

1. 4. 5 Superoxide anion–scavenging activity The superoxide anion–scavenging activity was measured according to the modified method of Siddhurajua et al. (2002). A 0.4–mL aliquot of 0 (control), 50, 100, 250, 500 and 1000 μg/mL polyphenol–ethanol solutions was mixed with 3 mL of reaction solution (containing 1.3 μM riboflavin, 13.0 mM methionine, 63.0 μM NBT, 100.0 μM EDTA, 0.05 M pH 7.8 sodium phosphate buffer) and then incubated for 15 min under the 4000 lumix illumination at 25°C. The absorbances of samples were measured at 560 nm. Superoxide anion–scavenging activity (%) = (1–absorbance of sample/absorbance of control) × 100.

1. 5 Data analysis

All experiments were performed in triplicate (n = 3), and an ANOVA test (using SPSS 13.0 statistical software, SPSS Inc., Chicago, USA) was used to compare the mean values of each treatment. Significant differences between the means of parameters were determined by using the LSD test (P < 0.05). The results represented mean ± standard error (SE) of three replicated determinations.

2 Results and discussion

2. 1 Nutritional compositions

In the present study, total soluble solids, starch, total protein and total fat contents were no significant difference in both SNS seed embryos (Tab. 1). Under the same conditions, the contents of above nutritional compositions in both SNS seed embryos were obviously higher than those in some nut kernels with similar taste from China, such as Chinese chestnut (cv. Hubei; Total soluble solid, starch and total protein contents were 18.036±1.769% Brix, 45.908±4.18 g/100 g FW and 8.608 ± 1.16 g/100 g FW) (Chen et al., 2000) and Carya humanensis Cheng (Total soluble solid, total protein and total fat contents were 3.51% Brix, 8.18 g/100 g FW and 56.57 g/100 g FW) (Fan et al., 2007). Trace elemental levels in SNS seed embryos were also listed in Tab. 1 on a FW basis. Generally speaking, the contents of calcium (Ca), iron (Fe) and zinc (Zn) were very high in both SNS seed embryos. The contents of Ca and Fe in GXP01 were obviously higher than those in GXDX01, while the manganese (Mn) content in GXP01 was significantly lower than that in GXDX01. Additionally, the total amino acid contents was determined accounting for an average of 2.31 g/100 g FW for GXP01 and 2.41 g/100 g FW for GXDX01 (Tab. 2). There was no obvious difference in individual amino acid content in both SNS seed embryos. From Tab. 2, vitamin C and vitamin E contents were considerably high in comparison with other vitamins in both SNS seed embryos. These two vitamins in GXDX01 were remarkably superior to those in GXP01.

Tab. 1 Contents of nutritional compositions in nut kernels of Sterculia nobilis

<table>
<thead>
<tr>
<th>Nutritional compositions</th>
<th>GXDX01</th>
<th>GXP01</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total soluble solids (Brix)</td>
<td>36.82±0.02</td>
<td>25.75±0.03</td>
</tr>
<tr>
<td>Ash (g/100 g FW)</td>
<td>3.8±0</td>
<td>4.8±0</td>
</tr>
<tr>
<td>Starch (g/100 g FW)</td>
<td>62.85±0.05</td>
<td>58.0±0.3</td>
</tr>
<tr>
<td>Total protein (g/100 g FW)</td>
<td>18.36±0.02</td>
<td>22.29±0.03</td>
</tr>
<tr>
<td>Total fat (g/100 g FW)</td>
<td>2.0±0</td>
<td>2.35±0.05</td>
</tr>
<tr>
<td>Total phenolic (μg/g GAE)</td>
<td>332.69±3.97</td>
<td>471.69±4.12</td>
</tr>
<tr>
<td>Total flavonoids (mg/g Rutin)</td>
<td>1.97±0.01</td>
<td>2.03±0.48</td>
</tr>
<tr>
<td>Ca (mg/g FW)</td>
<td>12.34±0.07</td>
<td>13.94±0.06</td>
</tr>
<tr>
<td>Fe (mg/g FW)</td>
<td>72.32±0.02</td>
<td>201.39±1.84</td>
</tr>
<tr>
<td>Zn (mg/g FW)</td>
<td>33.73±0.50</td>
<td>34.97±0.03</td>
</tr>
<tr>
<td>Mn (mg/g FW)</td>
<td>14.97±0.05</td>
<td>6.93±0.01</td>
</tr>
<tr>
<td>Mg (mg/g FW)</td>
<td>0.154±0.0005</td>
<td>0.0985±0.0025</td>
</tr>
<tr>
<td>Ca (μg/g FW)</td>
<td>420±14.14</td>
<td>575±21.21</td>
</tr>
</tbody>
</table>

2. 2 Determination of total phenolic and total flavonoid contents

Total phenolic and total flavonoid contents in SNS seed embryos were calculated as 332.69 ± 3.97 μg/g GAE and 1.97±0.01 mg/g Rutin for GXDX01, while 471.69±40.12 μg/g GAE and 2.03±0.48 mg/g Rutin for GXP01. The total phenolic contents in two SNS seed embryo were lower than that in Chinese chestnut (1620±10 μg/g GAE), but the total flavonoid contents in both were higher than that in Chinese chestnut (0.059±0.002 mg/g Rutin) (Qi et al., 2009).
Polyphenols, especially flavonoids, were closely related to antioxidant activities of SNS seed embryo. Many researches have reported that polyphenols such as flavonoids exhibit strong free radical scavenging activities and antioxidant capabilities in vivo and in vitro, suggesting that they play an important role in improving immunity, inhibiting mutagenesis or preventing cancer, inflammatory and cardiovascular diseases (Lin et al., 1999; Yilmaz and Toledo, 2004). Through the present study, SNS seed embryos contained considerable polyphenols, especially flavonoids, and therefore the nuts probably possessed strong antioxidant potential, which would exhibit biologic effects in terms of health promotion.

Tab.2 Contents of vitamin and amino acid in nut kernels of Sterculia nobilis

<table>
<thead>
<tr>
<th>Amino acids</th>
<th>GDX01 (g/100 g FW)</th>
<th>GXPN1 (g/100 g FW)</th>
<th>Vitamin</th>
<th>GDX01 (μg/100 g FW)</th>
<th>GXPN1 (μg/100 g FW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total amino acid</td>
<td>2.41</td>
<td>2.31</td>
<td>Vitamin A</td>
<td>61.6</td>
<td>75.2</td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>0.28</td>
<td>0.29</td>
<td>Vitamin B2</td>
<td>8360</td>
<td>6000</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.10</td>
<td>0.09</td>
<td>Vitamin C</td>
<td>3.50</td>
<td>2.96</td>
</tr>
<tr>
<td>Serine</td>
<td>0.09</td>
<td>0.08</td>
<td>Vitamin D</td>
<td>580</td>
<td>480</td>
</tr>
<tr>
<td>Glutamic acid</td>
<td>0.33</td>
<td>0.31</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proline</td>
<td>0.14</td>
<td>0.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arginine</td>
<td>0.35</td>
<td>0.34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glycine</td>
<td>0.12</td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alanine</td>
<td>0.14</td>
<td>0.11</td>
<td></td>
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<tr>
<td>Cysteine</td>
<td>0.02</td>
<td>0.02</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Valine</td>
<td>0.13</td>
<td>0.13</td>
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<td></td>
</tr>
<tr>
<td>Methionine</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Isoleucine</td>
<td>0.09</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leucine</td>
<td>0.15</td>
<td>0.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tyrosine</td>
<td>0.12</td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>0.08</td>
<td>0.08</td>
<td></td>
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<tr>
<td>Lysine</td>
<td>0.21</td>
<td>0.19</td>
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<tr>
<td>Histidine</td>
<td>0.05</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tryptophan</td>
<td>0.02</td>
<td>0.02</td>
<td></td>
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</tr>
</tbody>
</table>

* The contents of amino acids and vitamins were assayed by Center for Analysis and Test Research, Guangxi Zhuang Autonomous Region, and the results represented mean of three replicates determination.

2.3 Antioxidant activity

2.3.1 DPPH radical-scavenging activity Free radical-scavenging activity is one of the known mechanisms by which antioxidants inhibit lipid peroxidation (Duan et al., 2007). The DPPH radical-scavenging activity has been extensively used for screening antioxidants from fruits, vegetables and nuts. From Fig.1, the polyphenol extracts from SNS kernels exhibited strong DPPH radical-scavenging activity. In the low concentration range from 0 to 250 μg/mL, no significant difference (P>0.05) in the scavenging activity was observed and polyphenol of GXPN01 and GDX01 showed similar DPPH radical-scavenging capabilities to the strong commercial antioxidant ascorbic acid. However, in the high concentration range from 500 to 1000 μg/mL, ascorbic acid presented more intense scavenging activity than polyphenol of GXPN01 and GDX01. In comparison with two SNS polyphenol extracts, the scavenging activity of GDX01 polyphenol was somewhat higher than that of GXPN01 at high concentration (e.g. at 1000 μg/mL, the DPPH radical-scavenging activity of GDX01 and GXPN01 polyphenol were around 75.06 and 67.29%, respectively). The calculation of IC₅₀ further confirmed that GDX01 polyphenol (IC₅₀=207.183 μg/mL) possessed higher DPPH radical-scavenging activity than GXPN01 (IC₅₀=246.206 μg/mL). In addition, in the present study, the DPPH radical-scavenging activity was linearly correlated with the concentrations of SNS polyphenol extracts and ascorbic acid in the low concentration range from 0 to 100 μg/mL. The corresponding correlation coefficients were 0.9794 for GXPN01 polyphenol (y=0.3717x+2.0749), 0.9638 for GDX01 polyphenol (y=0.415x+1.2182) and 0.9881 for ascorbic acid (y=0.4557x+1.3383).

![Figure 1: Scavenging activity (%) of polyphenol extracts from SNS nuts on DPPH radical](image)

2.3.2 FRAP assay Reducing power is widely used in evaluating the antioxidant activity of polyphenols. The reducing property is generally associated with the presence of reductones which exert antioxidant action by breaking the free radical chains via hydrogen atom donation (Duh, 1998). Reductones are also reported to prevent peroxide formation by reacting with certain precursors of peroxide (Rathee et al., 2007). As shown in Fig.2, the concentration-dependent scavenging effect of SNS polyphenol extracts and the positive control (ascorbic acid) was evident. The reducing pow-
er of ascorbic acid and GXDX01 polyphenol had no significant difference \( (P>0.05) \), while was significantly higher \( (P<0.05) \) than that of GXPN01 polyphenol from 100 \( \mu g/mL \). Furthermore, the FRAP value was positively correlated with the concentrations of SNS polyphenol extracts and ascorbic acid in the ranges from 0 to 1000 \( \mu g/mL \). The corresponding correlation coefficients were determined to be 0.9885 for GXPN01 polyphenol \( (y=1.3765x+55.796) \), 0.9441 for GXDX01 polyphenol \( (y=1.6541x+128.53) \) and 0.9396 for ascorbic acid \( (y=1.6621x+134.97) \).

![Fig.2 Reducing power (FRAP values) of polyphenol extracts from SNS nuts](image)

2. 3. 3 Metal chelating capacity The metal chelating capacity (MCC) depends on the ability of samples to chelate transition metals, which possess the ability to catalyze hydrogen peroxide decomposition and Fenton–type reactions. As shown in Fig.3, the MCC of GXPN01 polyphenol was slightly lower than that of EDTA (positive control), but significantly higher \( (P<0.05) \) than that of GXDX01 polyphenol from 100 \( \mu g/mL \). In addition, the MCC was linearly correlated with the concentrations of SNS polyphenol extracts and EDTA in the low concentration range from 0 to 100 \( \mu g/mL \). The corresponding correlation coefficients were 0.9132 for GXPN01 polyphenol \( (y=0.60564x+5.0783) \), 0.8709 for GXDX01 polyphenol \( (y=0.33023x+4.4841) \) and 0.9855 for EDTA \( (y=0.7462x-1.6314) \).

![Fig.3 Metal chelating capacity of polyphenol extracts from SNS nuts](image)

2. 3. 4 Hydroxyl radical–scavenging activity Hydroxyl radical is one of the most effective free radicals amongst all the oxygen free radicals, so it has been a very important research field in order to find some natural antioxidants or scavengers which having strong scavenging effects on oxygen free radicals especially on hydroxyl radical (Adom and Liu, 2002). To determine the hydroxyl radical scavenging capacity, the effect of polyphenol extracts on hydroxyl radical generated by \( Fe^{3+} \) ions was analyzed by evaluating the degree of deoxyribose degradation. From Fig.4, there was no significant difference \( (P>0.05) \) on hydroxyl radical–scavenging activity between GXPN01 polyphenol and GXDX01 polyphenol in the whole concentration range. By the calculation, the IC\(_{50}\) of GXDX01 polyphenol \( (IC_{50} = 237.234 \mu g/mL) \) was slightly lower than that of GXPN01 polyphenol \( (IC_{50} =257.335 \mu g/mL) \), suggesting that the hydroxyl radical–scavenging activity of GXDX01 polyphenol was slightly higher than that of GXPN01 polyphenol. Ascorbic acid showed the highest scavenging activity \( (IC_{50}=130.784 \mu g/mL) \) comparing with both SNS polyphenol extracts. Additionally, the hydroxyl radical–scavenging capacity was linearly correlated with the concentrations of SNS polyphenol extracts and ascorbic acid in the low concentration range from 0 to 100 \( \mu g/mL \). The corresponding correlation coefficients were 0.9005 for GXPN01 polyphenol \( (y=0.40097x+3.20071) \), 0.9544 for GXDX01 polyphenol \( (y=0.43119x+2.5635) \) and 0.8478 for ascorbic acid \( (y=0.48375x+4.06756) \).

![Fig.4 Hydroxyl radical scavenging capacity of polyphenol extracts from SNS nuts](image)
2.3.5 Superoxide anion–scavenging activity

Superoxide anion radical plays an important role in plant tissues, which involves in the formation of other cell–damaging free radicals. Superoxide anion radical is the intermediary metabolite (Blokhina et al., 2003). The relative scavenging activity of polyphenol extracts on superoxide radical is shown in Fig.5. Generally, no significant difference ($P>0.05$) on the scavenging activity was observed between GXPN01 polyphenol ($IC_{50} = 888.373 \mu g/mL$) and GXDX01 polyphenol ($IC_{50} = 935.246 \mu g/mL$) in the whole concentration range. Ascorbic acid ($IC_{50} = 600.451 \mu g/mL$) showed the highest superoxide anion–scavenging activity, comparing with both SNS polyphenol extracts. In addition, the superoxide anion–scavenging activity was linearly correlated with the concentrations of SNS polyphenol extracts and ascorbic acid in the low concentration range from 0 to 100 $\mu g/mL$. The corresponding correlation coefficients were 0.9767 for GXPN01 polyphenol ($y = 0.28541x - 0.06879$), 0.8887 for GXDX01 polyphenol ($y = 0.25599x + 1.15501$) and 0.9504 for ascorbic acid ($y = 0.32366x + 2.74328$).

![Fig.5 Superoxide anion–scavenging activity of polyphenol extracts from SNS nuts](image)

3 Conclusions

By the present study, the nutritional compositions in two kinds of SNS seed embryo (GXPN01 and GXDX01) were determined. The results indicated that both SNS seed embryos exhibited significantly higher contents of total soluble solids, starch, total proteins and total fat comparing with several nuts with similar taste from China. The trace elements Ca, Fe and Zn contents were very high and the individual amino acid content was no obvious difference in GXPN01 and GXDX01 kernels. Vitamin C and vitamin E contents were considerably high comparing with other vitamins in both kernels. Additionally, SNS seed embryos contained considerable polyphenols (especially flavonoids), which possessed strong antioxidant potential. The antioxidant activity analysis on polyphenol extracts from both SNS seed embryos showed that, in certain concentration range, GXDX01 polyphenol possessed higher DPPH radical–scavenging activity and reducing power than GXPN01 polyphenol, while GXPN01 polyphenol had higher metal chelating capacity than GXDX01 polyphenol. There was no significant difference on hydroxyl radical–scavenging activity and superoxide anion–scavenging activity between GXPN01 polyphenol and GXDX01 polyphenol in the whole concentration range from 0 to 1000 $\mu g/mL$. The further research is needed to investigate chemical structure and other bioactivity of SNS polyphenol. By through investigation, the health benefit of SNS nut can be elucidated so that it can be spread into more areas.

References


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