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Difference of nutritional components between
Phyllostachys edulis seeds and main grain crops

Phyllostachys edulis tohumları ile temel tahıllardaki besin öğelerinin farkı

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Abstract: Objective: Major nutritional components of moso bamboo (Phyllostachys edulis) seeds were compared with main grain crops to study their nutritional and utilization value.

Methods: Older P. edulis seeds were harvested in autumn 2012 and stored at 4°C for 2 years, while fresh seeds were collected in autumn 2014. Starch, protein and fat contents of both old and fresh seeds were determined by ultraviolet spectrophotometer, Kjeldahl method, and acid hydrolysis method, respectively. The amino acid and fatty acid components of the old and fresh seeds were also analyzed with an auto-amino acid analyzer and a gas chromatograph, respectively. In addition, activities of superoxide dismutase, peroxidase and catalase in both old and fresh seeds were measured.

Results: Starch was the main content of P. edulis seeds. Activities of superoxide dismutase, peroxidase and catalase in fresh P. edulis seeds were significantly higher (P<0.05) than those that had been stored at 4°C for two years. Similar decline was also observed in the nutritional content of seeds upon two years of storage.

Conclusion: The seeds are starchy, containing high levels of protein, moderate fat levels and a wide range of amino acids. Notably, P. edulis seeds contain high levels of essential amino acids and polyunsaturated fatty acids and have great value for human nutrition and health. Its protein and essential amino acids contents were higher than that of main grain crops, while the fat content was low. Storage effect of two years on seeds and fresh grain was significant.

Keywords: P. edulis seeds, Starch, Protein, Fat, Antioxidant enzymes

Özet: Amaç: Moso bambu (Phyllostachys edulis) tohumlarının besin ve faydalanma değerleri belirlenerek, başlıca besin değerlerinin temel tahıllardakilerle karşılaştırılması amaçlanmıştır.


Bulgular: P. edulis tohumlarındaki ana bileşin nişasta olduğu saptandı. Taze P. edulis tohumlarındaki süperoksid
dismutaz, peroksidaz ve katalaz aktiviteleri, iki yıl süre-since 4°C'de saklanmış olan tohumlardakine göre belirgin olarak (P<0.05) fazlaydı. Tohumlardaki besin öğelerinin içeriklerinde de iki yıllık saklama süresi sonunda benzer bir azalma görüldü.


**Anahtar Kelimeler:** *P. edulis* tohumları, Nişasta, Protein, Yağ, Antioksidan enzimleri

### 1 Introduction

Bamboo (*Bambusoideae*) is by far the largest member of the grass family Poaceae, and is vital to the economy of many countries in the tropics and subtropics. Bamboo has several unique flowering characteristics; many species have 30–60 years, even 120 years in the juvenile phase, and then engage in a suicidal bout of sexual reproduction [1]. More remarkably, the onset of flowering is synchronous among ramets, genets and stands in a range of spatial scales, while only a few species flower annually or periodically [2,3]. Although the flowering cycle of the moso bamboo (*Phyllostachys edulis*) is elongated, the seed yield after flowering is extremely large. In Chinese folk records, *P. edulis* seeds were regarded as a crucial food source to allay hunger. Eating *P. edulis* seeds as food can nourish people and make them feel light and handy [4]. Plump *P. edulis* seeds with red color smell especially fragrant [5].

Bamboo resources are very rich in China. The bamboo forest area is about 7,200,000 ha, accounting for 6% of China’s forest area [6]. China is not only the country of origin for *P. edulis*, but also it is the largest *P. edulis* production, consumption and export country in the world [7].

However, *P. edulis* seeds are difficult to harvest and store, which restricts seedling culture, development and utilization. They are prone to mildew and decreased viability after harvest [8]. The germination percentage declined by 14% after 180 days of storage at 4°C [9]. Thus, it is vital to choose appropriate storage conditions to protect *P. edulis* germplasm resources. Most current research is focused on bamboo shoot nutrition and folia bambosae medicinal value [10], but studies on nutritional components of *P. edulis* seeds have not been reported. It is of important academic significance and practical value to study the nutritional components and antioxidant enzyme activity of *P. edulis* seeds. This investigation aimed to analyze the nutritional components of *P. edulis* seeds in order to make full use of germplasm resources and develop utilization of the seeds. The antioxidant enzyme activity of *P. edulis* seeds was studied to determine causes for the change of seed viability in the storage period and provide a scientific basis for preservation of *P. edulis* seeds.

### 2 Materials and Methods

#### 2.1 Plant material

Older *P. edulis* seeds were harvested in Guilin City in Guangxi Province in autumn 2012, while fresh seeds were collected in autumn 2014. The older seeds had been stored for two years at 4°C and packed in sealed plastic bags after ventilating and drying. The thousand-grain weight of old seeds was 21.56±0.62 g, while that of fresh seeds was 23.45±0.56 g. The nutritional components and antioxidant enzyme activity of old and fresh seeds were investigated to study the influence of storage. Each group had three replicates.

#### 2.2 Examination of seed nutritional components

The nutritional components in old and fresh *P. edulis* seeds were respectively determined and analyzed. Seeds were placed in a Soxhlet extractor and extracted for 7 h using 90% alcohol. Alcohol was volatilized using water bath extraction for 1.5 h. They were then washed three times with distilled water at 80°C. After cooling, the capacity of the 500 mL volume was determined.

Starch content was determined by anthrone–H₂SO₄ colorimetry [11,12]. Protein content was calculated from the nitrogen content which was determined by Kjeldahl method [13,14].

Fat content was analyzed by the acid hydrolysis method [15,16]. Seeds were placed in concentrated
hydrochloric acid and hydrolyzed in a water bath. Then alcohol was added and the mixture was blended. This was extracted by diethyl ether and then recycling solvent, then dried and weighed.

The amino acid component was determined using an auto-amino acid analyzer [17,18]. The fatty acid component was analyzed by gas chromatography [13,19]. Samples were placed in a mixture of light petroleum and benzene. Then 0.4 mol/L KOH-alcohol was added and the mixture was blended. Distilled water was added after 5–10 min and the supernatant extracted and nitrogen was added. The obtained concentrate was used for gas chromatography.

The above methods were in accordance with the National Standard of the People’s Republic of China.

### 2.3 Examination of antioxidant enzyme activity

Seeds (0.5 g) from each group were homogenized in a pestle and mortar with 5 mL of 0.05 M sodium phosphate buffer (pH 7.8). The homogenates were centrifuged at 10,000×g for 20 min at 4°C in a cooling centrifuge (Thermo Scientific Sorvall Stratos, Massachusetts, USA). The supernatants were stored at 4°C and used for analysis of superoxide dismutase (EC 1.15.1.1; SOD), peroxidase (EC 1.11.1.7; POD) and catalase (EC 1.11.1.6; CAT) activities. The above steps were carried out at 4°C. The SOD, POD and CAT activities were estimated according to the method of Zhang et al. [20].

### 3 Results

#### 3.1 Comparison of main nutrition components between old and fresh *Phyllostachys edulis* seeds

Carbohydrate was the main component of *P. edulis* seeds (Table 1). The thousand-grain weight of old seeds was 21.56±0.62 g, while that of fresh seeds was 23.45±0.56 g; and the corresponding starch contents were 61.97% and 59.00%, respectively. In addition, the fat content of fresh *P. edulis* seeds was 1.73% higher than that of old seeds. However, the protein content of old and fresh seeds reached 17.00 and 18.73%, respectively. The starch content was significantly higher in old than in fresh seeds. However, the fat and protein contents in *P. edulis* seeds showed different trends to the starch content.

#### 3.2 Comparison of amino acid composition between old and fresh *Phyllostachys edulis* seeds

Old *P. edulis* seeds had a wide range of amino acids – 33.75% of which were essential amino acids compared to 33.58% in fresh seeds – glutamic acid content was the highest, reaching 19.72 and 20.09% of the total, respectively. The total of essential amino acids in fresh *P. edulis* seeds was 5.90% (Table 2). The total of essential amino acids was notably lower in old than in fresh *P. edulis* seeds. The content of phenylalanine, leucine and valine was relatively high, while that of methionine and tryptophan was correspondingly low.

#### 3.3 Comparison of fatty acid composition between old and fresh *Phyllostachys edulis* seeds

The fatty acids of *P. edulis* seeds were mainly oleic, linoleic, linolenic, palmitic and stearic acids (Table 3). Unsaturated fatty acid (UFA) content was 1.31 and 1.58% in old and fresh seeds, respectively. The contents of UFA and
Table 2: The comparison of amino acid contents between *P. edulis* seeds and other crops* (%).

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>Old seeds of <em>P. edulis</em></th>
<th>Fresh seeds of <em>P. edulis</em></th>
<th><em>O. sativa</em></th>
<th><em>Z. mays</em></th>
<th><em>T. aestivum</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Thr</td>
<td>0.58±0.01b</td>
<td>0.64±0.03a</td>
<td>0.29</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>Val</td>
<td>0.81±0.01a</td>
<td>0.87±0.03a</td>
<td>0.40</td>
<td>0.44</td>
<td>0.45</td>
</tr>
<tr>
<td>Met</td>
<td>0.41±0.01a</td>
<td>0.46±0.03a</td>
<td>0.14</td>
<td>0.16</td>
<td>0.15</td>
</tr>
<tr>
<td>Leu</td>
<td>1.22±0.20a</td>
<td>1.36±0.05a</td>
<td>0.66</td>
<td>1.13</td>
<td>0.76</td>
</tr>
<tr>
<td>Lys</td>
<td>0.63±0.01b</td>
<td>0.70±0.02a</td>
<td>0.28</td>
<td>0.25</td>
<td>0.26</td>
</tr>
<tr>
<td>Trp</td>
<td>0.19±0.01a</td>
<td>0.19±0.00a</td>
<td>0.16</td>
<td>0.08</td>
<td>0.11</td>
</tr>
<tr>
<td>Ile</td>
<td>0.54±0.00a</td>
<td>0.58±0.01a</td>
<td>0.25</td>
<td>0.40</td>
<td>0.38</td>
</tr>
<tr>
<td>Phe</td>
<td>1.01±0.01a</td>
<td>1.10±0.06a</td>
<td>0.34</td>
<td>0.40</td>
<td>0.49</td>
</tr>
<tr>
<td>Total of essential amino acid</td>
<td>5.39±0.03a</td>
<td>5.90±0.22a</td>
<td>2.52</td>
<td>3.21</td>
<td>2.94</td>
</tr>
<tr>
<td>Arg</td>
<td>1.58±0.03a</td>
<td>1.71±0.07a</td>
<td>–</td>
<td>–</td>
<td>0.55</td>
</tr>
<tr>
<td>His</td>
<td>0.37±0.01a</td>
<td>0.40±0.01a</td>
<td>–</td>
<td>–</td>
<td>0.28</td>
</tr>
<tr>
<td>Ala</td>
<td>0.95±0.01a</td>
<td>1.06±0.03a</td>
<td>–</td>
<td>–</td>
<td>0.47</td>
</tr>
<tr>
<td>Ser</td>
<td>0.78±0.01b</td>
<td>0.87±0.03a</td>
<td>–</td>
<td>–</td>
<td>0.55</td>
</tr>
<tr>
<td>Gly</td>
<td>0.79±0.01a</td>
<td>0.87±0.03a</td>
<td>–</td>
<td>–</td>
<td>0.52</td>
</tr>
<tr>
<td>Pro</td>
<td>0.61±0.01a</td>
<td>0.70±0.03a</td>
<td>–</td>
<td>–</td>
<td>1.14</td>
</tr>
<tr>
<td>Glu</td>
<td>3.15±0.02a</td>
<td>3.53±0.13b</td>
<td>–</td>
<td>–</td>
<td>4.48</td>
</tr>
<tr>
<td>Tyr</td>
<td>0.56±0.02a</td>
<td>0.54±0.03a</td>
<td>–</td>
<td>–</td>
<td>0.25</td>
</tr>
<tr>
<td>Asp</td>
<td>1.49±0.01a</td>
<td>1.67±0.06a</td>
<td>–</td>
<td>–</td>
<td>0.67</td>
</tr>
<tr>
<td>Cys</td>
<td>0.30±0.01a</td>
<td>0.32±0.02a</td>
<td>–</td>
<td>–</td>
<td>0.21</td>
</tr>
<tr>
<td>Total</td>
<td>15.97±0.13a</td>
<td>17.57±0.66a</td>
<td>–</td>
<td>–</td>
<td>12.06</td>
</tr>
</tbody>
</table>

Values with different letters differ significantly from each other by ANOVA and Tukey’s test (P<0.05). *The data of *O. sativa*, *Z. mays* and *T. aestivum* were quoted from reference [41], ‘-’ means it was not provided.

Table 3: The fatty acid contents of *P. edulis* seeds (%).

<table>
<thead>
<tr>
<th>Fatty acid</th>
<th>Old seeds of <em>P. edulis</em></th>
<th>Fresh seeds of <em>P. edulis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Oleic acid</td>
<td>0.46±0.01a</td>
<td>0.51±0.02a</td>
</tr>
<tr>
<td>Linoleic acid</td>
<td>0.82±0.02a</td>
<td>1.02±0.02a</td>
</tr>
<tr>
<td>Linolenic acid</td>
<td>0.03±0.00a</td>
<td>0.05±0.00a</td>
</tr>
<tr>
<td>Unsaturated fatty acid</td>
<td>1.31±0.02a</td>
<td>1.58±0.03a</td>
</tr>
<tr>
<td>Palmitic acid</td>
<td>0.49±0.00a</td>
<td>0.54±0.01a</td>
</tr>
<tr>
<td>Stearic acid</td>
<td>0.06±0.00a</td>
<td>0.06±0.00a</td>
</tr>
<tr>
<td>Total fatty acid</td>
<td>1.86±0.02a</td>
<td>2.18±0.04a</td>
</tr>
</tbody>
</table>

Values with different letters differ significantly from each other by ANOVA and Tukey’s test (P<0.05).

total fatty acids were lower in old than in fresh seeds, indicating significant reductions after two years of storage at 4°C. The content of linoleic acid, an essential amino acid for humans, was 0.82% and 1.82% in old and fresh seeds, respectively, while the corresponding content of linolenic acid was 0.03% and 0.05%. The ratio of UFA to saturated fatty acid (SFA) in fresh *P. edulis* seeds was up to 2.63.

### 3.4 Comparison of antioxidant enzyme activity between old and fresh *P. edulis* seeds

The antioxidant enzyme activity of *P. edulis* seeds showed a clear decline after two years of storage at 4°C (Table 4). The SOD activity was significantly higher in fresh seeds (314.48 U·g⁻¹ FW) than in old seeds (259.26 U·g⁻¹ FW). There was a similar situation for POD activity, with fresh seeds having three times the POD activity of old seeds. Additionally, the CAT activity of old seeds was also clearly reduced after long-term storage.

### 4 Discussion

Starch stored in seeds and tubers is globally important as a source of food and has a wide range of industrial applications. Much of this agriculturally produced starch is synthesized in developing seeds, where its biological function is to provide energy for seedling establishment. Starch is a crucial plant nutrient and can also provide energy for the human body [21]. However, it can be converted to fat in the body and excess starch is harmful to human health. The starch content of *P. edulis* seeds was significantly lower than that of *O. sativa*, *Z. mays* and *T. aestivum*. Proteins are the foundation substances of life and are closely connected with all sorts of vital activities, participating in all cells and important parts of the body. There are many kinds of protein with diverse functions in the human body, consisting of 20 different amino acids in various proportions, and are metabolized and reno-
The results showed that antioxidant enzyme activities in old seeds of *P. edulis* were significantly decreased with prolonged storage, likely because excessive ROS produced in the oxidation of fatty acids of *P. edulis* seeds prolonged the average life of rats by 12% [25]. UFA, especially PUFA content is an important index for evaluating plant nutritional value. The contents of the essential fatty acids oleic and linoleic acids accounted for 23.39% and 46.79%, respectively, of total fatty acids in the fresh seeds of *P. edulis*, and were clearly higher than levels in old seeds. The contents of linoleic and linolenic acids were both significantly higher than that of *Brassica campestris* and *Arachis hypogaea* [26]. Oleic and linoleic acids are not only applying to clinical medicine, but are also widely used in industry. In addition, they can play a crucial role in conquering the blood grease and preventing and treating coronary disease [27]. Yang *et al.* [28] found that the ratio of edible oil structure should be SFA:monounsaturated fatty acid (MUFA):PUFA of 1:1:1; that of fresh *P. edulis* seeds was 1:0.85:1.78 (Table 3), indicating that the fatty acids of *P. edulis* seeds had high value for nutrition development and utilization. The seeds have great potential in developing blended oil that is beneficial to human health. UFAs are one of the main ingredients of cell membranes and can increase cell membrane fluidity and improve the cold resistance of seeds. However, cell senescence and seed deterioration caused by membrane lipid peroxidation occur if seeds are not properly stored. More attention should be given to storage of *P. edulis* seeds [29].

SOD, POD and CAT synergistically constitute the antioxidant enzyme system [30,31], which plays a protective role by stabilizing the amounts of reactive oxygen species (ROS) in plant cells [32]. SOD is a crucial part of the antioxidant defense system in plants. The major function of SOD is to catalyze the disproportionation of *O*₂⁻· and the decline of *O*₂⁻· concentration in plants may prevent *O*₂⁻· damage to plant cells. Increased *O*₂⁻· concentrations may also result in increased SOD activity [33]. POD is also an important enzyme that is widely expressed in plant tissues [34] and has many physiological functions, including detoxification [35]. POD can eliminate hydrogen peroxide (*H*₂*O*₂), a major substance degraded by SOD, and increased *H*₂*O*₂ concentration may result in increased POD activity [36]. CAT is the most general oxidoreductase that converts *H*₂*O*₂ to *H*₂O and *O*₂ to protect plant cells from damage [37].

### Table 4: The antioxidant enzyme activity of *P. edulis* seeds.

<table>
<thead>
<tr>
<th>Antioxidant enzyme activity</th>
<th>Old seeds of <em>P. edulis</em></th>
<th>Fresh seeds of <em>P. edulis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>SOD (U·g⁻¹·FW)</td>
<td>259.26±9.47b</td>
<td>314.48±2.88b</td>
</tr>
<tr>
<td>POD (OD₄₇₀·min⁻¹·g⁻¹·FW)</td>
<td>12.07±0.43c</td>
<td>49.52±1.75c</td>
</tr>
<tr>
<td>CAT (OD₃₄₀·min⁻¹·g⁻¹·FW)</td>
<td>8.57±0.40b</td>
<td>11.93±0.66c</td>
</tr>
</tbody>
</table>

Values with different letters differ significantly from each other by ANOVA and Tukey’s test (P<0.05).
metabolic processes actually decreased SOD activity [38]. The ability of scavenging free radicals and peroxides was weakened; and free radicals likely kept accumulating and attacking the membrane lipids, fatty acid chains and proteins, inducing peroxidation and inhibiting antioxidant enzyme activity [39]. Dai [40] indicated that the dehydrogenase and SOD activity of *Camellia oleifera* seeds was reduced in the aging process. Free radicals and peroxides play a vital role in integrity of the plasma membrane, so their scavenging system function is particularly important in seeds. Research showed that the antioxidant enzyme activity was positively correlated with seed vigor index. Therefore, we deemed that the *P. edulis* seed vigor index was significantly decreased after two years of storage. Treatment with the gibberellin GA3 may improve the antioxidant activity; however, the results showed that old *P. edulis* seeds were not suitable for planting. Appropriate storage of seeds needs to be associated with seed production and economic benefits. Two years of storage treatment significantly affected nutritional components and antioxidant enzyme activity of *P. edulis* seeds. The nutritional content was significantly higher in fresh than in old *P. edulis* seeds. The contents of protein, fat, amino acids and fatty acids declined by 1.73%, 0.33%, 1.6% and 0.32% after storage, respectively. The significant reduction of antioxidant enzyme activity indicated that the *P. edulis* seed vitality and germination percentage declined after two years of storage at 4°C. The results showed that old *P. edulis* seeds were not suitable for establishing seedlings. Appropriate storage of *P. edulis* seeds should be further studied to lay the foundation for the conservation of germplasm resources and realization of *P. edulis* genetic breeding.

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**Conflict of interest:** None declared.

### 5 References


