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Comparison and assessment of nutritional composition in shoots of six bamboo species in Southeast China

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ABSTRACT

The introduction of bamboo species is one of the strategies used to enrich edible fresh bamboo shoots resources across diverse regions. However, there is a lack of investigation on the adaptability of bamboo species and the nutritional profiles of their shoots post-introduction. In this study, the nutritional components of bamboo shoots from six bamboo species that have been successfully introduced were compared and evaluated. These six bamboo species possess shoots rich in soluble sugar, soluble protein, and crude fibre. Furthermore, the shoots exhibit significant concentrations of potassium and iron, along with an abundance of amino acids. Notably, the amino acid content is highest in the apical region of the bamboo shoot, followed by the middle section, with the base having the lowest levels. When evaluated through several assessment systems, the shoots exhibited varying scores and rankings. A comprehensive evaluation approach was then utilized to assign final scores and rankings to all six species. Recommendations are provided for the selection of high-quality nutrient-dense bamboo shoots grown in the same field following successful introduction.

1. Introduction

Bamboo belongs to the family Poaceae and subfamily Bambusoideae. As one of the most important non-timber forest resources, bamboo provides raw materials for papermaking, house construction and handicraft industries. Additionally, it provides food for humans (Zhao et al., 2018; Yang et al., 2023). One of the foods produced from bamboo is known as bamboo shoots. Specifically, these are the juvenile shoots developing as aerial buds that emerge from the nodes of bamboo rhizomes (Wang et al., 2020). Bamboo shoots are not only delicious but also abound in fibre, protein, vitamins and mineral nutrients (Chongtham et al., 2011). Bamboo shoots are widely consumed in Asian countries, particularly in China. It is estimated that approximately 2 million tonnes of fresh bamboo shoots are consumed annually, with China alone contributing approximately 1.3 million tonnes to this total (Nirmala et al., 2014). Bamboo shoots are considered to be an integral part of Chinese culinary culture (Pan et al., 2024).

The demand for bamboo shoots is steadily rising, leading to a corresponding increase in the need for both quantity and diversity of fresh bamboo shoots (Pan et al., 2024). However, the production of bamboo shoots faces geographical and temporal limitations, which restrict both the quantity and variety available. For example, the shoots of the giant bamboo (*Dendrocalamus sinicus* L.C.Chia & J.L.Sun, are exclusive to the southern region of Yunnan province and can only be harvested during the summertime. As a result, the shoots of *Dendrocalamus sinicus* are only available in local markets from July to August. To address the demand for fresh bamboo shoots across various regions and at different times of year, two potential solutions can be considered. Firstly, we can rely on sophisticated logistics systems to transport fresh bamboo shoots from their production regions to other areas. However, this approach requires the use of advanced freshness preservation techniques to ensure the quality of the bamboo shoots during transit. Alternatively, we can introduce a range of bamboo species, prolonging the period of shoot production, and cultivate them locally. When compared to the logistics-based approach, cultivating bamboo locally offers numerous advantages. For instance, it ensures a more consistent supply of fresh bamboo shoots for local consumption. Additionally, the price of the bamboo shoots is likely to be lower due to reduced transportation costs, making them more accessible to a wider range of consumers. Consequently, introducing and cultivating a range of bamboo species locally

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appears to be a more viable and beneficial solution to the problem of limited seasonal availability.

There have been numerous examples of bamboo introductions in recent decades (Wu et al., 2020; Wu et al., 2023). China even launched a project called “Transferring Bamboo from South to North” (Liu et al., 2014). This project involved the introduction of about 200 bamboo species from the south to the north of the country (Li et al., 2021). However, only a few studies have focused on investigating the adaptability and growth performance of introduced bamboo species (Getachew et al., 2021). Some introduced bamboo species may exhibit poorly adaptability to local climate conditions (Eyasu et al., 2024; Getachew et al., 2021), and this could potentially impact the nutritional value of their leaves and shoots (Bhardwaj et al., 2019). There is thus a need for a comprehensive assessment of the nutritional quantity and quality of bamboo shoots following their introduction.

In this study, six bamboo species were successfully introduced to Wenzhou, a city situated in the southeast of Zhejiang Province. These species were *Bambusa oldhamii* Munro, *Bambusa stenoaurita* (W.T.Lin) T. H.Wen, *Dendrocalamus minor* (McClure) L.C.Chia & H.L.Fung (syn. *Dendrocalamus sapidus* Q.H.Dai & D.Y.Huang), *Bambusa odashimae* Hatus. ex Ohrnb. (syn. *Dendrocalamopsis edulis* (Odash.) Keng f., *Bambusa variostriata* (W.T.Lin) L.C.Chia & H.L.Fung (syn. *Dendrocalamopsis vario-striata* (W.T.Lin) Keng f., and Chengma 8 (a hybrid species of *Bambusa pervariabilis* McClure × *Dendrocalamus latiflorus* Munro) (Ou, 2019). Notably, *Dendrocalamus minor* and *Bambusa variostriata* come from Guangxi Province, which features a subtropical monsoon climate, whereas *Bambusa stenoaurita*, *Bambusa odashimae*, and Chengma 8 are from Guangdong Province, characterized by a tropical monsoon climate. *Bambusa oldhamii* originates from Fujian Province, which has a subtropical monsoon climate. All six bamboo species are considered to be good sources of bamboo shoots. However, the nutritional values of the shoots of these species have not been thoroughly analyzed following their introduction to the more northerly location of Wenzhou. Therefore, the objectives of this study were to 1) to investigate the nutritional properties of the six bamboo species following their successful introduction; 2) to evaluate and compare the nutritional values of the species; and 3) to provide recommendations for ranking their nutritional values.

2. Materials and methods

2.1. Collection of bamboo shoots and site description

The shoots of six species (*Bambusa oldhamii*, *Bambusa stenoaurita*, *Dendrocalamus minor*, *Bambusa odashimae*, *Bambusa variostriata* and Chengma 8) were sampled from Jingshan Garden, located at 28°00’46” N, 120°64’19” E in the southeast of Zhejiang Province. The sampling site is characterized by a central subtropical monsoon climate with an average temperature ranging from 17.3 to 19.4°C and an average annual precipitation of 1113–2494 mm. The soil type is classified as Udic Ferrisols. The shoots used in this study were harvested after attaining a height of 15–30 cm. The shoots were washed and separated from the sheath before being dried in an oven at 80°C. For the determination of mineral elements and amino acids, the shoots were separated into three parts: top, middle and base.

2.2. Crude fibre and ash analysis

The determination of the crude fibre and ash content in bamboo shoot samples followed the standard AOAC procedures outlined in 2005. To determine the crude fibre content, the weight loss after the removal of acid detergent fibre was used, as described by Van Soest and McQueen (1973). For the ash weight determination, the samples were carbonized for 0.5 hours at 300°C in a muffle furnace and then incinerated for 4 hours at 570°C. The ash was then collected and weighed.

2.3. Soluble sugar, soluble protein and fat analysis

The soluble sugar content was determined using the method described by Yang et al. (2021). Briefly, the dried bamboo shoots were pulverized to a powder, and subsequently, 1 g samples were extracted using 10 ml deionized water. This extraction process was replicated three times to ensure thorough extraction. The supernatants were collected by centrifugation at 2360 xg for 15 minutes. 2 ml of supernatants was mixed with 0.8 ml of 5% aqueous solution of redistilled phenol in a test tube. 5 ml of concentrated sulfuric acid was added to the test tube with the mixture, then the test tube was placed in a boiling water bath for 20 minutes. The test tube was cooled in an ice bath for 2 minutes and was then placed at room temperature for 15 minutes. The light absorption at 485 nm was measured on a spectrophotometer (UV 2600; Shimadzu, Japan) and the carbohydrate concentration was determined according to a standard curve (Yang et al., 2021).

The soluble protein content was determined using the method described by Bradford (1976). 1 g of the above sample was mixed with 5 ml of 50 mM Phosphate Buffer Saline (PBS, pH 7.8) and centrifuged at a speed of 10,000 xg for 15 minutes (MDX 310; Tomy, Japan) at 4°C. After centrifugation, 0.1 ml supernatant was added to 5 ml Coomassie brilliant blue G-250 in a new centrifuge tube and mixed thoroughly. The absorbance at 595 nm was measured using a spectrophotometer. Using a standard curve for bovine serum protein, the soluble protein content was expressed as mg of bovine serum protein equivalent per g of sample.

The fat content was determined using an exhaustive extraction method that involved the use of petroleum ether along with a Soxhlet apparatus. 1 g of the above sample was packed in a thimble and the fat was extracted with petroleum ether (boiling point: 60–90°C) for 1.5 hours. Upon completion of the fat extraction, the fat was dried at 105°C for 5 h to remove residual water and petroleum ether. The fat content of the samples was calculated on the basis of dry weight of the bamboo shoots.

2.4. Elemental determination

For elemental determination, the powder bamboo shoot samples were digested with HNO_3 at a temperatures of 140°C. Elemental concentration in the digested solution, were determined using the ICP–MS system (X series 2; Thermo Scientific, MA, USA).

2.5. Total amino acid analysis

To extract amino acids, 100 mg of powdered bamboo shoot material was hydrolyzed with 5 ml of 6 N HCl in a sealed hydrolysis tube. The tube was heated at 110°C for 24 hours in an oven. After hydrolysis, the solution was diluted with Milli-Q water to 10 ml. Then, a 1 ml aliquot was dried in a glass tube using a termovap sample concentrator. The dried material was re-dissolved in 1 ml of 0.02 M HCl and filtered through a 0.22 μm membrane. The filtered sample was used for amino acid analysis. Specifically, the amino acid composition was analyzed using a S433D High-Performance Amino Acid Analyzer (Sykam, Germany).

2.6. Analytical methods and calculations

To compare and assess the nutritional qualities of the shoots of the six species, this study focused on analyzing the mineral elements and amino acid content in different parts of the bamboo shoots. In alignment with the Dietary Guidelines for Chinese Residents, which recommend 300 g of vegetables daily for adults, the study calculated the mineral element and amino acid content present in 300 g of the bamboo shoots. To conduct a comprehensive evaluation of mineral elements, the chemical scores (CS) and mineral elements index (MEI), which were adapted from (Pan et al., 2024), were determined using the following formulas:

$$CS = \sum \frac{A_x}{A_e} \times \frac{E_x}{E_e} \times 100 \tag{1}$$

$$TotalCS = CS_{top} + CS_{middle} + CS_{base} \tag{2}$$

where: Ax means content of an element in a sample，Ex means content of an element in the standard, Ae means content of all elements in a sample，Ee means content of all elements in the standard.

$$MEI = \sqrt[n]{\frac{A_P}{A_s} \times \cdots\cdots \times 100} \tag{3}$$

$$TotalMEI = MEI_{top} + MEI_{middle} + MEI_{base} \tag{4}$$

Where: Ap means content of an element in a sample，As means content of an element in the standard.

For a comprehensive evaluation of the amino acids, the Essential Amino Acid Score (EAAS) and the Essential Amino Acid Index (EAAI) were utilized, calculated using equations provided by Zhou et al. (2019).

$$EAAS = \sum \frac{a_p}{a_s} \tag{5}$$

$$TotalEAAS = EAAS_{top} + EAAS_{middle} + EAAS_{base} \tag{6}$$

Where: ap means content of an amino acid in a sample，as means content of an amino acid in standard.

$$EAAI = \sqrt[n]{\frac{Lys_p}{Lys_s} \times \frac{Thr_p}{Thr_s} \cdots\cdots \frac{His_p}{His_s} \times 100} \tag{7}$$

$$TotalEAAI = EAAI_{top} + EAAI_{middle} + EAAI_{base} \tag{8}$$

Where: p means content of an amino acid in a sample，s means content of an amino acid in standard.

The amino acid nutrient index (ANI) and elements nutrient index (ENI) adapted from Desai et al. (2018) were determined by the following formula:

$$ANI = \frac{EAAI \times PP}{100} \tag{9}$$

$$TotalANI = ANI_{top} + ANI_{middle} + ANI_{base} \tag{10}$$

Where: PP means percentage of essential amino acid in a sample.

$$ENI = \frac{MEI \times EP}{100} \tag{11}$$

$$TotalENI = ENI_{top} + ENI_{middle} + ENI_{base} \tag{12}$$

Where: EP means percentage of element in a sample.

To evaluate the nutrition of bamboo shoots by integrating amino acids and minerals, the total score was calculated using the following formula：

$$Final\ Scores(FS) = EAAS \times ANI + CS \times ENI \tag{13}$$

2.7. Statistical analysis

Data were analyzed using one-way ANOVA, followed by Tukey's multiple comparison tests. Data were analyzed by Origin 2021 (Originlab, USA) and they were expressed as the means ± SD of three biological replicates. $P<0.05$ was considered to be statistically significant.

3. Results

3.1. Crude fibre and Ash content

Fibre, which is invisible in food products, is an important food composition benefit for our health (Chongtham et al., 2011). The crude fibre content in bamboo shoots varies between 7.28% and 12.76%. The highest fibre content of 12.76% is found in *B. stenoaurita*, followed by 11.46% in *D. minor*, and the lowest fibre content of 7.28% in *B. variostriata* (Fig. 1 A).

The ash content in the bamboo shoot samples ranges from 9% to 12.57%. The highest ash content of 12.57% is observed in Chengma 8, followed by *B. odashimae*, *D. minor*, *B. variostriata*, *B. oldhamii*, and *B. stenoaurita*. However, there is no significant difference in ash content among the species, except for *Chengma 8* (Fig. 1B).

3.2. Soluble sugar, soluble protein and fat content

The soluble sugar content was high in the bamboo shoot samples, ranging from 187.5 to 276 mg/g. *B. variostriata* had the highest soluble sugar content, while *B. oldhamii* had the lowest. The soluble sugar contents of *B. odashinae* and Chengma 8 were comparable, ranging between 240 and 250 mg/g. The soluble sugar content of *B. stenoaurita* and *D. minor* were also comparable, ranging between 200 and 210 mg/g. These results indicate that most of the shoots included in this study contained high levels of soluble sugar (Fig. 2 A).

The soluble protein content in the samples ranged from 15.8 to 44.9 mg/g. *B. odashimae* had the highest soluble protein content, followed by *D. minor* with 43.2 mg/g, but the difference was not significant. The soluble protein content was much lower in *B. oldhamii* and *B. variostriata*, at 19.6 mg/g and 15.8 mg/g, respectively, compared to the other four species (Fig. 2B).

Bamboo shoots are known for their low fat content, and there was no significant difference in fat content between the species, which ranged from 2.1% to 2.4% (Fig. 2 C).

3.3. Macro elements content

Mineral nutrients play a crucial role in our bodies and are referred to as essential nutrients. These nutrients can be classified as macro-minerals, which are required in amounts greater than 100 mg per day, and micro-minerals, which are required in amounts less than 100 mg per day (Salami and Afolayan, 2021). Given that the mineral content in bamboo shoots can vary depending on the shoot part (Chongtham et al., 2021), we aimed to determine the mineral content in different parts of the shoots (Tables 1, 2). The results indicate that the content and distribution of elements varied among different parts of the plant, depending on the bamboo species.

Potassium (K) is the principal cation found in intracellular fluid and plays a crucial role in acid-base balance and osmotic pressure regulation (Gharibzahedi and Jafari, 2017). The K content in the bamboo shoot samples ranged from 19.06 to 24.67 mg/g, and there were significant differences in K content among different parts of bamboo shoots from various species (Table1). In general, the K content was higher in the middle part of the bamboo shoots compared to the top and base parts. Chengma 8 had the highest K content (24.67 mg/g) in the middle part of the bamboo shoots, while *B. odashimae* had the lowest K content (19.87 mg/g).

The sodium (Na) content in the bamboo shoot samples ranged from 3.00 to 7.76 mg/g, and there were significant differences in Na content among different parts of the bamboo shoots. The Na content was highest in the middle part of Chengma 8, followed by the base part of *B. oldhamii*, and lowest in the base part of *B. odashimae* (Table1). There were also significant differences in Na content among different bamboo species. Chengma 8 had the highest Na content, while *B. odashimae* had a lower Na content.

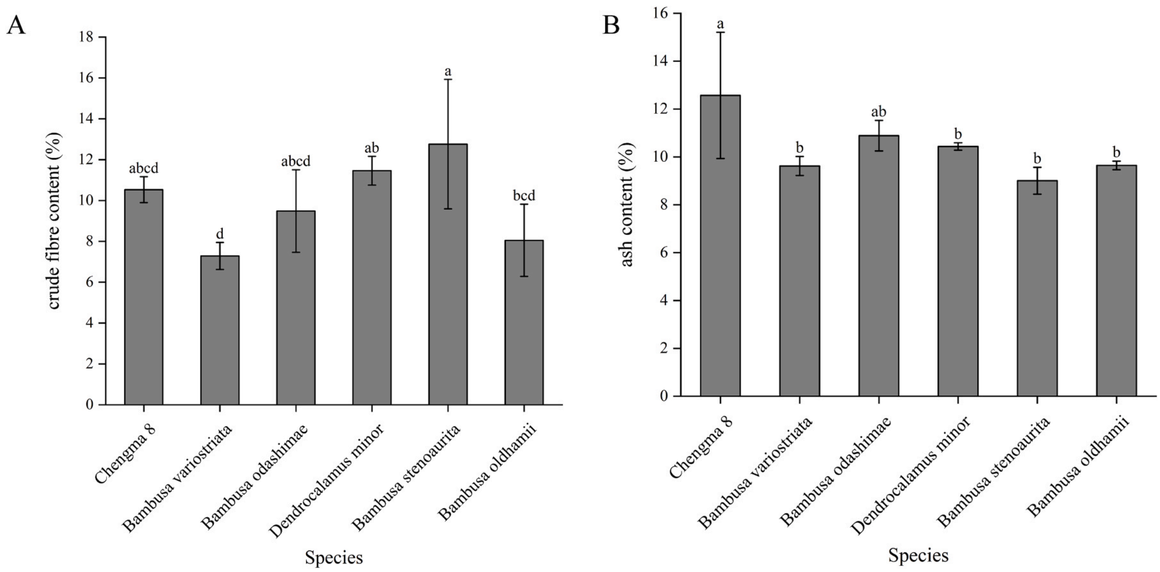

Fig. 1. . Crude fibre and ash content in bamboo shoots. A, crude fibre content of the shoots of six bamboo species; B, ash content of the bamboo shoots (Data are means ± SD (n=3), $P < 0.05$).

Calcium (Ca) is essential for normal skeleton development and maintenance (Gharibzahedi and Jafari, 2017). The Ca content was relatively low in the different parts of the shoot samples, ranging from 0.06 to 0.15 mg/g (Table1). The Ca content in different parts of the bamboo shoots was similar within the same species, but significant differences were observed between different species. *B. variostriata* had the highest Ca content, followed by *B. oldhamii*, while *D. minor* had the lowest Ca content.

Magnesium (Mg) is a component of bones and teeth and plays a role in muscle relaxation, and water and salt balance (Quintaes and Diez-Garcia, 2015). The Mg content was relatively low in all shoot samples, ranging from 0.37 to 0.49 mg/g. The Mg content trends were as follows: the top part of the bamboo shoots had the highest Mg content, followed by the middle part, and the base part had the lowest Mg content, with the exception of the base part from *D. minor* (Table1). The total Mg content of the bamboo shoots was highest in *B. stenoaurita* and lowest in *B. variostriata*.

The phosphorus (P) content in the shoot samples ranged from 0.83 to 1.55 mg/g. The highest P content was found in the top of the bamboo shoot in *B. oldhamii*, while the lowest content was observed in the base part of the bamboo shoot in *B. stenoaurita* (Table1).

3.4. Trace element content

Iron (Fe) content in shoot samples ranged from 103.1 to 244.6 μg/g. The Fe content varied in different parts of the bamboo shoots, with the highest Fe content in the middle part of *B. variostriata*, followed by the middle part of *B. oldhamii*, while the base part of *D. minor* had the lowest Fe content (Table2).

The zinc (Zn) content in the samples ranged from 3.10 to 8.08 μg/g. Significant differences were found in different parts of the bamboo shoots as well as among different bamboo species. For example, the tip part of *B. oldhamii* contained 8.08 μg Zn per g, which was much higher than its middle and base parts. In addition, *B. oldhamii* had much higher Zn content than the other bamboo species. Generally, Zn content was highest in the top part of the bamboo shoots and lowest in the base part (Table2).

In contrast, copper (Cu) potential accumulated high content in the middle and base parts of the bamboo shoots. The Cu content in the samples ranged from 2.86 to 13.0 μg/g. The Cu content of the base part of Chengma 8, *B. odashimae* and *B. stenoaurita* was higher than 10 μg/g, which was much higher than that in other parts of the bamboo shoots. The Cu content was lowest in the top part of the bamboo shoots in *B. variostriata* (Table2).

3.5. Amino acid composition

Bamboo shoots are rich in amino acids. Out of the 17 amino acids reported in bamboo shoots, 8 are essential for the human body (Nongdam and Tikendra, 2014). By analyzing the content of 17 amino acids in different species of bamboo shoots, we found that different parts of the bamboo shoots had different amino acid contents. The shoot top part had the highest amino acid content, followed by the middle part of the shoots, and the base part had the lowest content (Table3). Amino acids Asp and Glu were highly accumulated, while Cys was the lowest in all parts of the bamboo shoots.

Among the bamboo species, Chengma 8 had the highest total amino acid content, with 11 amino acids (Asp, Thr, Ser, Glu, Gly, Cys, Met, Ile, Leu, Phe, and Lys) being significantly higher than those of other species (Table3). In contrast, *B. variostriata* had the lowest total amino acid content.

3.6. Evaluation and ranking of shoots from 6 species of bamboo using a chemical score, an essential amino acid score and a final score

A chemical score and an essential amino acid score were employed to assess the richness and stability of mineral elements and amino acids in different bamboo shoots. Distinct scores for each species were identified in both evaluation systems.

In the chemical score evaluation, *B. variostriata* shoots received the highest score, with 269.2, indicating a richer mineral content than in the other species. Conversely, Chengma 8 received the lowest score, suggesting a lower mineral content richness (Table 4). However, in the essential amino acid score evaluation, Chengma 8 excelled with the highest score of 8.67, signifying a richer essential amino acid content than the shoots of other species. *B. variostriata* obtained the lowest score (Table 5).

To provide a comprehensive assessment of nutrients in bamboo shoots, we also calculated their nutritional index based on daily nutritional requirements and introduced a final score scoring system (Table 6). *B. oldhamii* achieved the highest score among all six species, with a total of 16.45. This was followed by Chengma 8 (16.42),

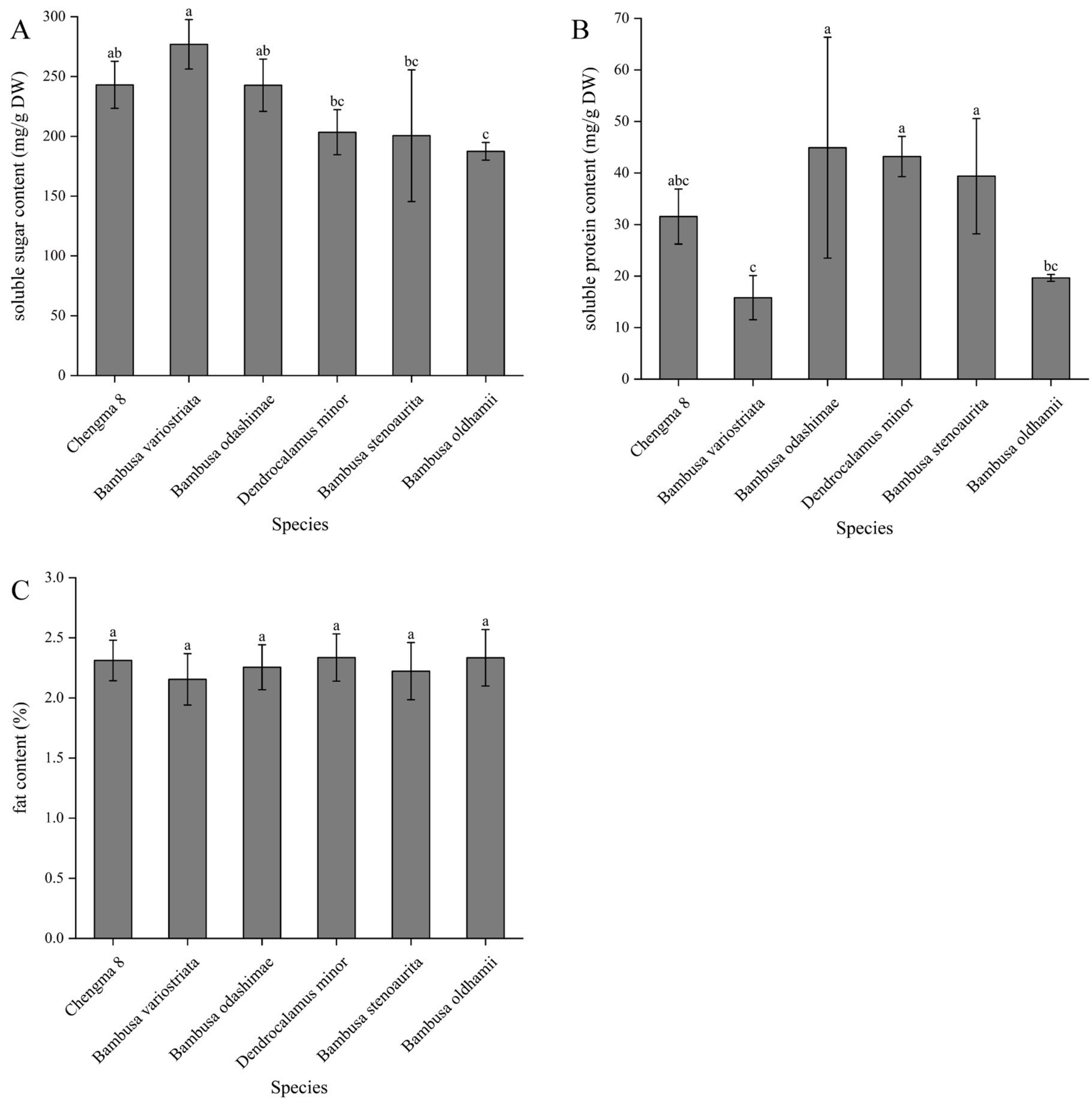

Fig. 2. Soluble sugar, soluble protein and fat content in bamboo shoots. A, soluble sugar content of the shoots of six species of bamboo shoot in six species. B, solution protein content of the shoots of the six species. C, fat content of the shoots of six species (Data are means ± SD (n=3), $P < 0.05$).

B. stenoaurita (14.89), *B. odashimae* (13.83), and *D. minor* (13.75). *B. variostriata* recorded the lowest score of 13.50.

4. Discussion

Bamboo shoots are known for their high crude fibre content and their relatively low fat content. There were differences in the fibre content among various bamboo species (Fig. 1). Notably, *B. variostriata* contained the lowest fibre content, at 7.28%, which is still much higher than many common vegetables such as cucumber, radish and cabbage, which contain only 0.4%, 0.6%, and 1.0% fibre, respectively (Chongtham et al., 2011). On the other hand, the fat content of the shoots was low. The highest fat content was found in *D. minor*, amounting to 2.4%, while the lowest was in *B. variostriata*, at 2.1% (Fig. 2 C). The similarity in fat content across the different species suggests that the environmental conditions of the introduction site likely exerted minimal impact on fat accumulation in bamboo shoots after introduction. Soluble protein and sugar was detected in all bamboo shoots (Fig. 2), indicating their potential as sources of protein and carbohydrates. *B. variostriata* was found to possess a lower content of crude fibre, soluble protein and fat compared to other bamboo species. This suggests that the adaptability of this bamboo species may be less optimized for the introduction site. However, a comparative analysis of the nutritional quality of this bamboo shoot from both the introduction site and the origin site is necessary for a more comprehensive evaluation.

Bamboo shoots are also rich in mineral elements such as K, Na, Mg, Ca, Fe, Zn. Among all the macronutrients, K content was the highest, aligning with previous research findings (Ye et al., 2016; Chongtham et al., 2021). K is a heart-healthy mineral crucial for proper heart function. In the body, K is classified as an electrolyte and plays a role in acid-base balance, regulation of osmotic pressure, and other important functions (Satya et al., 2012). Bamboo shoots are known for their high K content, with values ranging from 19.06 to 24.67 mg/g in this study (Table 1). This is significantly higher than the K content found in many common vegetables such as asparagus (10.94 mg/g), pea (3.3 mg/g), bean (2.3 mg/g) and lettuce (2.2 mg/g) (Chongtham et al., 2021). Therefore, bamboo shoots are exceptional vegetables for promoting K intake and overall heart health.

The trace elements Fe and Zn are of particular importance due to their essential roles in human metabolic processes. These elements serve

Table 1
Macro elements content (mg/g) of the shoots of six bamboo species.

Element	*Chengma 8*			*Bambusa variostriata*			*Bambusa odashimae*			*Dendrocalamus minor*			*Bambusa stenoaurita*			*Bambusa oldhamii*		
	Top	Middle	Base	Top	Middle	Base	Top	Middle	Base	Top	Middle	Base	Top	Middle	Base	Top	Middle	Base
K	22.76 ±1.16a	24.67 ±2.64a	22.00 ±1.47a	19.5 ±1.02b	19.97 ±2.14b	19.06 ±1.16a	19.40 ±1.59b	19.87 ±1.36b	23.22 ±1.21a	22.91 ±1.35a	22.66 ±2.35ab	22.52 ±3.8a	22.00 ±1.12ab	22.74 ±2.12ab	23.08 ±2.4a	23.48 ±1.99a	24.27 ±1.02a	22.55 ±1.77a
Na	5.58 ±1.25a	7.76 ±0.21a	5.86 ±0.94a	4.48 ±0.83a	3.57 ±0.72c	4.58 ±0.69ab	4.08 ±0.57a	3.37 ±0.78c	3.00 ±1.07b	5.65 ±1.41a	3.14 ±0.74c	5.77 ±1a	5.52 ±0.97a	5.32 ±0.99b	4.48 ±0.92ab	5.44 ±0.4a	4.19 ±0.29bc	6.52 ±1.59a
Ca	0.07 ±0.02bc	0.10 ±0.04bc	0.12 ±0.01ab	0.15 ±0.05a	0.15 ±0.02a	0.13 ±0.01a	0.09 ±0.01bc	0.07 ±0.03c	0.09 ±0c	0.06 ±0c	0.06 ±0.01c	0.08 ±0.01c	0.10 ±0.01bc	0.09 ±0.03bc	0.11 ±0.02ab	0.11 ±0ab	0.13 ±0.02ab	0.10 ±0.01bc
Mg	0.46 ±0.02a	0.44 ±0.01a	0.37 ±0.04a	0.42 ±0.01b	0.41 ±0.01a	0.39 ±0.03a	0.45 ±0.02ab	0.44 ±0.03a	0.41 ±0.06a	0.46 ±0.02a	0.42 ±0.04a	0.47 ±0.04a	0.49 ±0.02a	0.46 ±0.02a	0.43 ±0.07a	0.47 ±0.01a	0.44 ±0.01a	0.38 ±0.06a
P	1.51 ±0.13a	1.20 ±0.29a	1.00 ±0.33a	0.99 ±0.1bc	1.04 ±0.18a	0.86 ±0.2a	0.88 ±0.04c	0.99 ±0.32a	0.90 ±0.29a	1.09 ±0.12bc	0.85 ±0.07a	0.96 ±0.15a	1.17 ±0.21b	0.97 ±0.03a	0.83 ±0.13a	1.55 ±0.21a	1.16 ±0.01a	1.04 ±0.2a

Table 2
Trace elements content (mg/g) of the shoots of six bamboo species.

Element	*Chengma 8*			*Bambusa variostriata*			*Bambusa odashimae*			*Dendrocalamus minor*			*Bambusa stenoaurita*			*Bambusa oldhamii*		
	Top	Middle	Base	Top	Middle	Base	Top	Middle	Base	Top	Middle	Base	Top	Middle	Base	Top	Middle	Base
Fe	123.83 ±15.14a	136.52 ±21.13bc	138.59 ±10.62a	141.30 ±33.81a	244.58 ±38.75a	161.57 ±49.12a	149.66 ±26.48a	112.54 ±25.55c	111.74 ±11.38a	125.68 ±26.19a	123.78 ±10.35c	103.08 ±6.44a	175.36 ±64.48a	176.69 ±64.93bc	187.65 ±95.11a	169.97 ±39.22a	201.32 ±26.92ab	155.59 ±17.01a
Zn	4.69 ±1.05b	4.07 ±0.51bc	4.38 ±0.42a	4.31 ±0.41b	5.39 ±1.08ab	4.65 ±0.63a	5.29 ±2.66ab	3.20 ±0.25c	3.10 ±0.1a	5.34 ±0.49ab	4.26 ±0.67abc	4.46 ±0.27a	7.69 ±1.88a	5.54 ±0.78a	4.89 ±3.41a	8.08 ±1.02a	5.42 ±0.74ab	4.75 ±1.42a
Cu	3.81 ±1.2b	8.04 ±0.64ab	10.96 ±1.44ab	2.86 ±1.18b	9.33 ±2.44a	6.43 ±2.81b	4.84 ±0.65ab	4.11 ±1.49c	7.53 ±0.74b	5.32 ±0.81ab	6.33 ±2.26bc	7.10 ±2.33b	8.63 ±3.15a	9.38 ±0.45a	13.02 ±5.38a	7.92 ±3.44a	8.75 ±0.8ab	7.29 ±0.36b

Table 3
Amino acid content (mg/g) of the shoots of six bamboo species.

Amino Acid	*Chengma 8*			*Bambusa variostriata*			*Bambusa odashimae*			*Dendrocalamus minor*			*Bambusa stenoaurita*			*Bambusa oldhamii*		
	Top	**Middle**	**Base**	**Top**	**Middle**	**Base**	**Top**	**Middle**	**Base**	**Top**	**Middle**	**Base**	**Top**	**Middle**	**Base**	**Top**	**Middle**	**Base**
Asp	24.84 ±0.71a	16.38 ±0.51a	11.23 ±1.18a	23.27 ±3.57ab	11.30 ±3.86bc	8.06 ±2.91a	19.46 ±2.99ab	15.77 ±1.01ab	10.71 ±4.5a	16.71 ±6.37ab	8.97 ±1.24c	12.86 ±1.86a	20.4 ±5.02b	19.43 ±4.66a	8.52 ±5.53a	22.55 ±3.21ab	11.39 ±0.69bc	7.92 ±1.05a
Thr	6.35 ±0.37ab	3.86 ±0.3a	2.61 ±0.07a	5.26 ±0.51ab	2.58 ±0.58ab	1.44 ±0.36b	5.02 ±0.27ab	3.12 ±0.17ab	2.58 ±0.55a	5.17 ±2.29ab	2.38 ±0.64ab	2.21 ±0.28a	4.35 ±0.81b	3.57 ±1.42b	1.48 ±0.57b	6.78 ±0.66a	3.34 ±0.38ab	2.25 ±0.28a
Ser	5.47 ±0.38ab	3.21 ±0.57a	1.95 ±0.2a	3.82 ±0.49ab	1.53 ±0.26a	0.64 ±0.21b	3.29 ±0.44ab	1.84 ±0.27a	1.97 ±1.28a	4.67 ±4.09ab	1.33 ±0.4a	1.23 ±0.43ab	2.15 ±0.49b	2.85 ±2.67a	1.04 ±0.47ab	5.74 ±0.52a	2.68 ±0.36a	1.95 ±0.33a
Glu	25.47 ±0.79a	14.21 ±1.19ab	10.57 ±0.73ab	20.75 ±4.22a	9.52 ±3.04b	7.11 ±0.86bc	17.97 ±2.13a	12.41 ±0.55ab	11.91 ±3.27a	16.92 ±8.64a	9.03 ±3.75b	10.37 ±2.19ab	19.39 ±4.76a	15.62 ±5.57a	5.51 ±3.61c	24.6 ±3a	11.53 ±1.65ab	8.08 ±1.04abc
Gly	6.36 ±0.39a	3.05 ±0.05ab	1.79 ±0.71a	5.47 ±1.56a	2.12 ±1.26abc	1.23 ±0.44a	5.08 ±1.07a	2.87 ±0.5abc	2.02 ±0.79a	4.52 ±3.74a	1.22 ±0.29c	1.84 ±0.17a	3.54 ±0.87a	3.52 ±1.68a	0.89 ±0.95a	5.45 ±0.52a	1.56 ±0.26bc	0.86 ±0.1a
Ala	13.45 ±0.76ab	9.02 ±1.16a	6.21 ±0.52ab	12.26 ±0.89b	6.34 ±0.98b	4.18 ±0.72c	11.81 ±0.54b	8.51 ±0.48a	6.24 ±0.56ab	12.66 ±0.25b	8.19 ±2.06ab	6.56 ±0.38ab	13.16 ±2.37b	9.13 ±0.84a	5.50 ±1.09b	15.55 ±1.38ab	9.01 ±0.52a	7.15 ±0.77a
Cys	0.97 ±0.1b	0.34 ±0.02b	0.20 ±0.07b	1.60 ±0.38a	0.84 ±0.36a	0.75 ±0.15a	1.26 ±0.24ab	1.13 ±0.1a	0.85 ±0.15a	1.47 ±0.29a	1.02 ±0.21a	0.92 ±0.13a	1.54 ±0.28a	0.98 ±0.33a	0.69 ±0.4a	1.14 ±0.15ab	0.37 ±0.06b	0.21 ±0.01b
Val	8.00 ±0.5a	5.34 ±0.15a	4.24 ±0.39abc	7.18 ±0.59a	4.70 ±0.9a	3.42 ±0.68bc	7.72 ±2.16a	5.46 ±0.07a	4.69 ±0.55a	8.50 ±1.91a	4.65 ±1.08a	4.35 ±0.13ab	9.14 ±1.45a	5.81 ±0.41a	3.24 ±0.78c	8.45 ±0.45a	5.35 ±0.69a	3.80 ±0.32abc
Met	3.50 ±0.24a	2.10 ±0.29a	1.42 ±0.07a	2.61 ±0.45b	1.23 ±0.29b	0.78 ±0.2b	2.29 ±0.04b	1.61 ±0.03ab	1.38 ±0.48a	2.39 ±0.34b	1.64 ±0.64ab	1.27 ±0.22ab	2.71 ±0.35b	1.79 ±0.22ab	0.91 ±0.36ab	3.50 ±0.16a	1.84 ±0.21ab	1.19 ±0.14ab
Ile	5.76 ±0.4a	3.79 ±0.14a	2.99 ±0.29a	4.90 ±0.46a	3.15 ±0.63a	2.20 ±0.52bc	5.47 ±1.78a	3.52 ±0.05a	2.92 ±0.29a	5.94 ±1.6a	2.96 ±0.63a	2.79 ±0.07ab	6.22 ±1.07a	3.81 ±0.34a	2.03 ±0.4c	5.85 ±0.27a	3.71 ±0.51a	2.60 ±0.22abc
Leu	13.64 ±0.69a	8.75 ±0.52a	6.21 ±0.37a	11.43 ±1.49a	5.93 ±1.29c	3.75 ±0.79b	11.76 ±1.73a	7.67 ±0.31abc	6.22 ±1.35a	12.04 ±2.55a	6.69 ±1.81bc	5.73 ±0.39a	11.75 ±1.88a	8.13 ±0.93ab	4.06 ±1.15b	13.60 ±1.13a	7.35 ±0.67abc	5.09 ±0.51ab
Tyr	4.09 ±0.51ab	2.40 ±0.21b	1.75 ±0.14a	3.49 ±0.24ab	1.52 ±0.42b	0.99 ±0.25a	3.37 ±0.59ab	2.02 ±0.23b	1.70 ±0.18a	3.21 ±0.69b	1.74 ±0.71b	1.47 ±0.25a	4.50 ±1.07a	5.16 ±1.45a	1.95 ±1.28a	4.31 ±0.32ab	2.21 ±0.29b	1.48 ±0.17a
Phe	6.59 ±0.42a	3.76 ±0.57a	2.97 ±0.11a	5.56 ±0.76a	2.81 ±0.75a	1.73 ±0.38bc	5.72 ±1.12a	3.17 ±0.25a	2.32 ±0.11ab	5.18 ±1.73a	2.67 ±0.92a	2.38 ±0.33ab	5.02 ±0.72a	3.58 ±0.57a	1.59 ±0.64c	6.51 ±0.35a	3.62 ±0.47a	2.44 ±0.35a
His	8.02 ±0.5ab	4.93 ±0.34a	3.36 ±0.18ab	8.06 ±0.92ab	4.17 ±0.98a	2.26 ±0.42c	7.40 ±0.65ab	4.90 ±0.26a	3.26 ±0.14ab	6.85 ±1.58b	4.11 ±0.88a	3.85 ±0.4a	6.43 ±0.92b	5.38 ±0.87a	2.74 ±1.05bc	9.02 ±0.79a	4.59 ±0.29a	3.10 ±0.37abc
Lys	7.08 ±0.17ab	3.32 ±0.22a	1.90 ±0.22ab	5.77 ±1.47ab	1.63 ±0.72b	0.94 ±0.26b	4.72 ±1.34b	3.38 ±0.23a	2.26 ±0.34a	4.96 ±2.08ab	2.01 ±0.93b	2.17 ±0.4a	5.75 ±1.95ab	3.49 ±0.3a	1.08 ±1.12b	7.99 ±1.93a	2.24 ±0.35b	1.40 ±0.2ab
Arg	16.23 ±1.24a	5.91 ±0.64b	3.01 ±0.3a	14.91 ±3.77a	3.05 ±0.96d	1.46 ±0.49b	8.11 ±1.3b	4.64 ±0.26bc	2.79 ±0.09a	10.86 ±1.87ab	4.35 ±0.86c	3.43 ±0.17a	15.85 ±4.64a	7.49 ±0.35a	2.47 ±1.46ab	15.74 ±2.7a	5.31 ±0.72bc	2.63 ±0.46ab
Pro	6.56 ±0.43ab	4.39 ±0.22a	2.77 ±0.22a	6.51 ±0.65ab	3.22 ±0.4b	1.83 ±0.49b	6.33 ±0.33b	4.60 ±0.57a	2.84 ±0.17a	7.43 ±0.36ab	4.76 ±0.92a	3.36 ±0.05a	7.82 ±1.36a	4.63 ±0.31a	2.88 ±0.53a	7.06 ±0.65ab	4.13 ±0.1a	3.02 ±0.26a
EAA	64.00 ±3.42a	38.59 ±1.23ab	27.64 ±1.2a	55.86 ±6.84a	28.56 ±6.84c	18.25 ±3.86c	54.75 ±9.29a	35.99 ±1.21abc	28.16 ±3.36a	55.71 ±14.1a	29.88 ±8.43bc	27.14 ±2.32ab	57.39 ±9.57a	41.70 ±3.52a	19.76 ±7.53bc	67.15 ±6.13a	34.61 ±3.73abc	23.55 ±2.53abc
TAA	162.38 ±7.74a	94.76 ±5.13a	65.19 ±1.79a	142.86 ±20.36a	65.65 ±17.28b	42.75 ±9.25b	126.79 ±14.61a	86.63 ±0.61ab	66.65 ±8.41a	129.47 ±38.84a	67.73 ±16.97b	66.79 ±4.43a	139.7 ±28.48a	104.38 ±17.77a	46.56 ±20.75ab	163.84 ±17.49a	80.22 ±7.88ab	55.16 ±6.48ab
EAA/TAA	0.39	0.41	0.42	0.39	0.44	0.43	0.43	0.42	0.42	0.43	0.44	0.41	0.41	0.40	0.42	0.41	0.43	0.43

Table 4
Result of CS for the shoots of six bamboo.

Ranking	Species name	Top	Middle	Base	Total points
6	*Chengma 8*	89.32	88.08	87.40	264.80
1	*Bambusa variostriata*	90.18	89.66	89.31	269.15
2	*Bambusa odashimae*	89.68	89.76	88.82	268.26
4	*Dendrocalamus minor*	88.99	89.45	87.75	266.19
5	*Bambusa stenoaurita*	88.47	88.75	88.40	265.62
3	*Bambusa oldhamii*	88.46	89.53	88.81	266.80

Table 5
Result of EAAS for six species bamboo shoots.

Ranking	Species name	Top	Middle	Base	Total points
1	*Chengma 8*	4.25	2.58	1.85	8.67
6	*Bambusa variostriata*	3.70	1.92	1.22	6.84
3	*Bambusa odashimae*	3.64	2.39	1.89	7.92
5	*Dendrocalamus minor*	3.73	1.97	1.80	7.50
4	*Bambusa stenoaurita*	3.79	2.74	1.30	7.84
2	*Bambusa oldhamii*	4.48	2.32	1.58	8.37

Table 6
Result of FS for six species bamboo shoots.

Ranking	Species name	Total points
2	*Chengma 8*	16.42
6	*Bambusa variostriata*	13.50
4	*Bambusa odashimae*	13.82
5	*Dendrocalamus minor*	13.75
3	*Bambusa stenoaurita*	14.89
1	*Bambusa oldhamii*	16.45

as components of hemoglobin, catalytic factors, and more, crucial for maintaining our well-being (Hu et al., 2023). However, Fe and Zn deficiencies are a significant global issue, considered as a "hidden hunger" in many parts of the world today. Approximately two billion people worldwide suffer from iron and zinc deficiencies, with the majority being preschool-aged children and pregnant women living in developing countries (Hu et al., 2023; Kong et al., 2022). In this study, we found that the shoots of all six species had high levels of Fe and Zn accumulation. For instance, the highest Fe content was observed in *Bambusa variostriata* at 244.6 μg/g, which is significantly higher than most common cereal grains and vegetables. This suggests that the six bamboo shoots studied here can serve as valuable dietary sources of Fe, contributing to the mitigation of Fe malnutrition. Therefore, these bamboo shoots are not only a source of fibre but also valuable for Fe intake, making them exceptional health-promoting plants.

To gain a deeper understanding of the distribution of minerals and amino acids within individual bamboo shoots, we divided them into three distinct sections: top, middle, and base. In the typical processing of bamboo shoots, the upper and base sections are often discarded due to their bitter taste and lignification. Our results (Tables 1, 2) indicate that various mineral elements accumulate differently in different parts of the shoots across the six bamboo species. For instance, elements such as Mg and Zn tend to be highly concentrated in the tops of the shoots, while elements such as K and Cu are more abundant in the middle and base sections.

Different parts of the shoots had distinct amino acid profiles. A general trend emerged where the highest amino acid content being found in the shoot top section, followed by the middle section, with the lowest content in the base section (Table3). This suggests that the tips of bamboo shoots possess superior nutritional value. Furthermore, it appears that different parts of the bamboo shoot represent varying levels of maturity, with the tips being the youngest. It is possible that the amino acid content is higher in younger tissues compared to mature tissues. This pattern contrasts with previous research that has reported an increase in lignin, crystalline cellulose and xylan deposition with shoot maturation (Chang et al., 2013). Our findings align with other studies that have shown a decrease in amino acid content from shoot tip to shoot base (Nirmala et al., 2007). This shift in nutritional composition during bamboo shoot development can be attributed to an increase in photosynthesis-driven metabolic activity (Bhardwaj et al., 2023).

The distribution of mineral elements in bamboo shoots differs from that of amino acids. There is no general pattern in the accumulation of mineral elements, and the factors that influence their accumulation in different parts of the shoots are complex. For instance, the mobility of elements within plants, as well as external environmental conditions, can significantly impact the accumulation and distribution of mineral elements in bamboo shoots. In summary, there are notable variations in the nutritional composition of bamboo shoots across different varieties. To gain a more comprehensive understanding, further consideration should be given to factors such as harvest maturity, time of harvest, and cultivation environment, beyond the variety and part of the bamboo shoots. Additionally, the impact of different processing methods and storage techniques on the nutritional value of bamboo shoots is a topic that deserves further investigation.

5. Conclusions

The importance of bamboo shoots in global food and health is increasing, and screening and evaluating bamboo shoots with high nutritional value is important for their comprehensive utilization and industrial development. We found that the upper sections of bamboo shoots had the highest amino acid contents and that these could be used as a source of amino acids for daily consumption. Bamboo shoots also contain a large amount of soluble proteins, fibres, carbohydrates and various essential minerals but are low in fat, making them an ideal food choice for individuals seeking weight loss. The comprehensive assessments indicate that the shoots of *B. oldhamii* are particularly nourishing.

CRediT authorship contribution statement

Ji Feng Shao: Writing – review & editing, Writing – original draft, Supervision, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Wanyu Ni:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Haibao Ji:** Writing – original draft, Investigation, Funding acquisition, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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References

Bhardwaj, D.R., Sharma, P., Bishist, R., Navale, M.R., Kaushal, R., 2019. Nutritive value of introduced bamboo species in the northwestern Himalayas. India J. . Res. 30, 2051–2060 doi:org/10.1007/s11676-018-0750-2.

Bhardwaj, D.R., Rana, S., Kumar, D., Sharma, P., 2023. Nutritive value of tender shoots of different bamboo species in relation to harvesting height in mid-hills of north-western Himalayas. Appl. Food Res. 3 (1), 100244 https://doi.org/10.1016/j.afres.2022.100244.

Bradford, M.M., 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Anal. Biochem. 72 (1-2), 248–254.

Chang, W.J., Chang, M.J., Chang, S.T., Yeh, T.F., 2013. Chemical composition and immunohistological variations of a growing bamboo shoot. J. Wood Chem. Technol. 33 (2), 144–155. https://doi.org/10.1080/02773813.2013.769114.

Chongtham, N., Bisht, M.S., Haorongbam, S., 2011. Nutritional properties of bamboo shoots: potential and prospects for utilization as a health food. Compr. Rev. Food Sci. Food Saf. 10 (3), 153–168.

Chongtham, N., Bisht, M.S., Santosh, O., Bajwa, H.K., Indira, A., 2021. Mineral elements in bamboo shoots and potential role in food fortification. J. Food Compos. Anal. 95, 103662.

Desai, A.S., Beibeia, T., Brennan, M.A., Guo, X., Zeng, X.A., Brennan, C.S., 2018. Protein, amino acid, fatty acid composition, and in vitro digestibility of bread fortified with *Oncorhynchus tschawytscha* powder. Nutrients 10, 1923.

Eyasu, G., Gebrewahid, Y., Darcha, G., Kassa, H., 2024. Adaptation and growth performance of different bamboo species in Dryland areas of Northern Ethiopia. For. Sci. Technol. 1–6 doi:org/10.1080/21580103.2024.2316723.

Getachew, G., Wudu, D., Alamire, G., Kasahun, H., Ayalew, A., Redae, T., Wudu, M., 2021. Adaptability and growth performance of introduced bamboo species in north east Ethiopia. Abyss-.-. J. Sci. Technol. 6 (1), 1–5.

Gharibzahedi, S.M.T., Jafari, S.M., 2017. The importance of minerals in human nutrition: Bioavailability, food fortification, processing effects and nanoencapsulation. Trends Food Sci. Technol. 62, 119–132. https://doi.org/10.1016/j.tifs.2017.02.017.

Hu, Q., Wang, R., Hu, L., Chen, R., Yu, X., Shao, J.F., 2023. The potential of bamboo seeds for natural biofortification of dietary zinc and iron. npj Sci. Food 7 (1), 15. https://doi.org/10.1038/s41538-023-00192-4.

Kong, D., Khan, S.A., Wu, H., Liu, Y., Ling, H.Q., 2022. Biofortification of iron and zinc in rice and wheat. J. Integr. Plant Biol. https://doi.org/10.1111/jipb.13262.

Li, Y., Lan, L., Ding, Y., Xie, J., 2021. Open a new chapter of "South Bamboo Transplanted to the North" for better ecological protection and high-quality development of the yellow river basin. World Bamboo Ratt. 19 (5), 1–8 doi:10.12168/sjzttx.2021.05.001.(In Chinese).

Liu, W.Y., Hui, C.M., Shi, M., Deng, J., 2014. A review on major types of bamboo communities in China. Adv. Mater. Res. 1073-1076, 1071–1074.

Nirmala, C., Bisht, M.S., Laishram, M., 2014. Bioactive compounds in bamboo shoots: health benefits and prospects for developing functional foods. Int. J. Food Sci. Technol. 49 (6), 1425–1431.

Nirmala, C., David, E., Sharma, M.L., 2007. Changes in nutrient components during ageing of emerging juvenile bamboo shoots. Int. J. Food Sci. Nutr. 58 (8), 612–618. https://doi.org/10.1080/09637480701359529.

Nongdam, P., Tikendra, L., 2014. The nutritional facts of bamboo shoots and their usage as important traditional foods of northeast India. Int. Sch. Res. Not. 2014, 679073 https://doi.org/10.1155/2014/679073.

Ou, L., 2019. Modular characteristics and biomass accumulation and allocation of *Bambusa pervariabilis* Mc-Clure × *Dendrocalamus latiflorus* Munro No 8. J. Bamboo Res. 38 (4), 49–53 (In Chinese).

Pan, X., Ji, H., Gong, X.X., Yang, W.T., Jin, Z., Zheng, Y., Ding, S., Xia, H., Shen, Z., Shao, J.F., 2024. Screening and evaluation of bamboo shoots: Comparing the content of trace elements from 100 species. Food Chem.: X 21, 101071. https://doi.org/10.1016/j.fochx.2023.101071.

Quintaes, K.D., Diez-Garcia, R.W., 2015. The importance of minerals in the human diet. : Handb. Miner. Elem. Food 1–21. https://doi.org/10.1002/9781118654316.ch1.

Salami, S.O., Afolayan, A.J., 2021. Evaluation of nutritional and elemental compositions of green and red cultivars of roselle: *Hibiscus sabdariffa* L. Sci. Rep. 11 (1), 1030. https://doi.org/10.1038/s41598-020-80433-8.

Satya, S., Singhal, P., Bal, L.M., Sudhakar, P., 2012. Bamboo shoot: a potential source of food security. Mediterr. J. Nutr. Metab. 5 (1), 1–10.

Van Soest, P., McQueen, R., 1973. The chemistry and estimation of fibre. Proc. Nutr. Soc. 32 (3), 123–130.

Wang, Y., Chen, J., Wang, D., Ye, F., He, Y., Hu, Z., Zhao, G., 2020. A systematic review on the composition, storage, processing of bamboo shoots: Focusing the nutritional and functional benefits. J. Funct. Foods 71, 104015.

Wu, R.W., Nan, X.G., Yan, H., Yang, F., Shi, Y., Bao, Z.Y., 2020. A survey on the history of the introduction of bamboo from China to the United States (1898-2010) and the application of bamboo in urban greening. Urban Urban Green. 55. Artn 12679210.1016/J.Ufug.2020.126792.

Wu, Y.F., Li, J., Yu, L.X., Wang, S.G., Lv, Z., Long, H., Zhai, J.Y., Lin, S.Y., Meng, Y., Cao, Z.H., Sun, H., 2023. Overwintering performance of bamboo leaves, and establishment of mathematical model for the distribution and introduction prediction of bamboos. Front. Plant Sci. 14. Artn 125503310.3389/Fpls.2023.1255033.

Yang, F., Chang, Y.Z., Zheng, Y.T., Pan, X.Y., Ji, H.B., Shao, J.F., 2023. Physiological and transcriptomic characterization of cadmium toxicity in Moso bamboo (*Phyllostachys edulis*), a non-timber forest species. Tree Physiol. 43 (7), 1250–1264. https://doi.org/10.1093/treephys/tpad028.

Yang, W.T., Gong, X.X., Ji, H.B., Shao, J.F., 2021. Qualitative and quantitative characterization of nutrient content and morphology in seeds of bamboo, rice, and wheat. J. Cereal Sci. 101. Artn 10327310.1016/J.Jcs.2021.103273.

Ye, J., Su, Z., Lin, L., Zha, Y.B., Wang, M., Yang, C.L., 2016. Determination of inorganic elements content and distribution in bamboo shoots by microwave digestion and ICP-MS. J. Agric. Chem. Environ. 05, 152–157.

Zhao, H., Gao, Z., Wang, L., Wang, J., Wang, S., Fei, B., Chen, C., Shi, C., Liu, X., Zhang, H., Lou, Y., Chen, L., Sun, H., Zhou, X., Wang, S., Zhang, C., Xu, H., Li, L., Yang, Y., Wei, Y., Yang, W., Gao, Q., Yang, H., Zhao, S., Jiang, Z., 2018. Chromosome-level reference genome and alternative splicing atlas of moso bamboo (*Phyllostachys edulis*). Gigascience 7 (10). https://doi.org/10.1093/gigascience/giy115.

Zhou, M.Y., Huai, T.T., Mae, X.F., Sung, H., Xu, L., 2019. Protein content and amino acids profile in 10 cultivars of ginkgo (*Ginkgo biloba* L.) nut from China. R. Soc. Open Sci. 6 (3) doi:Artn 18157110.1098/Rsos.181571.