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Research article

Physical and Antioxidant Properties of Bamboo Shoot: Impact of Boiling on Purine Content and Antioxidant Activity

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Abstract

Bamboo shoots are highly valued as a nutritious food source. However, their physical and nutritional properties vary depending on the species. Additionally, it is essential to process bamboo shoots before consumption to reduce their cyanide content, ensuring they are safe for consumption. Therefore, this research aimed to study the physical properties, antioxidant activity, and purine content in four bamboo shoot species: *Thyrsostachys siamensis, Gigantochloa albociliata, Bambusa burmanica,* and *Bambusa multiplex*. The effects of boiling at 100°C for 25 min on these properties were also investigated. The results showed that all fresh bamboo shoots had high moisture content (91.16%-92.73%) ($p>0.05$). Significant color differences were observed ($p\leq0.05$), with *B. multiplex* having the highest L*, whereas *B. burmanica* and *B. multiplex* had lower b* values than the others. In terms of texture, the shoots of *G. albociliata* had the lowest hardness ($p\leq0.05$), while the others showed no significant differences ($p>0.05$). The antioxidant results showed that *T. siamensis* exhibited the highest antioxidant activity by the DPPH method, whereas *B. multiplex* had the highest phenolic content (143.20 mg GAE/100g wb) and antioxidant activity by the ABTS method (14.77 mg TE/g wb). Regarding purine content, all bamboo shoots contained more adenine and guanine than hypoxanthine and xanthine. The shoots of *B. burmanica* and *B. multiplex* had total purine contents of 61.12 mg/100g wb and 66.26 mg/100g wb, respectively, classifying them as low-purine foods. The shoots of *T. siamensis* and *G. albociliata* had higher purine contents (107.19 mg/100g wb and 101.55 mg/100g wb, respectively), classifying them as moderate-purine foods. This research demonstrated that the physical properties, antioxidant activity, and purine content of bamboo shoots varied depending on the species. Although boiling reduced antioxidant levels, it also provided the benefit of significantly lowering purine content in all bamboo shoot species. For individuals concerned about purine intake, *B. burmanica* and *B. multiplex* were recommended, as they fell into the food category of "very low purine content" after boiling. Furthermore, *B. multiplex* not only had low purine levels but also demonstrated high phenolic content and strong antioxidant activity, as determined by the ABTS method.

Keywords: bamboo shoot; total phenolic; antioxidant activity; purine, boiling

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1. Introduction

There are more than 1,400 species of bamboo, but fewer than 100 species are considered edible (Chongtham et al., 2011). Bamboo shoots are widely consumed in various Asian countries and are rich in proteins, fibers, vitamins, and minerals, with low fat content. They contain various bioactive compounds such as phenolics, phytosterols, and flavones (Satya et al., 2010; Pandey & Ojha, 2014; Wang et al., 2020), known for their biological activities, including antimicrobial, antioxidant, anticancer, antibacterial, and anti-inflammatory effects (Galeotti et al., 2008; Oboh & Ademosun, 2012; Kong et al., 2020). Park and Jhon (2010) reported that extracts from bamboo shoots of *Phyllostachys pubescens* and *P. nigra* exhibited antioxidative and angiotensin-converting enzyme (ACE) inhibitory activities, associated with blood pressure regulation. Santosh et al. (2021) examined the addition of bamboo shoots (*Dendrocalamus hamiltonii*) to crispy salted snacks. They found that incorporating bamboo shoots into the crispy salted snack significantly enhanced its antioxidant activity, dietary fiber, phenolic, and phytosterol content compared to the control sample. The study concluded that bamboo shoots have significant potential as a fortifying ingredient, greatly enhancing the health benefits and palatability of fortified products. Sansenya et al. (2023) reported that bamboo shoots (*Dendrocalamus asper* Back.) are rich in bioactive compounds, including phenolic and flavonoid compounds. Notably, they identified the phytotoxic substance 2,4-DTBP, which has potential as a candidate for diabetes treatment.

While bamboo shoots offer health benefits, they also contain toxins such as cyanides and purines. Fresh bamboo shoots contain cyanogenic glycosides called taxiphyllins, which can be eliminated through processing methods such as cutting, soaking, or boiling (Singhal et al., 2016; Kong et al., 2020), making processed bamboo shoots safe for consumption (Møller & Seigler, 1998; Haque & Bradbury, 2002). Singhal et al. (2022) found that the cyanogen content in fresh bamboo shoots was 93.23 ppm on a dry weight basis. A significant reduction in cyanogen content was observed in the dried samples compared to the fresh ones. The rapid and substantial decrease in cyanide in the dried shoots is attributed to heat, which causes the volatilization of hydrogen cyanide released during degradation. Pokhariya et al. (2018) indicated that processes such as boiling, steaming, soaking, and drying can reduce the hydrocyanic acid content (a decomposition product of cyanogenic glycoside) in bamboo shoots (*Dendrocalamus strictus*), with boiling identified as the most effective method for decreasing hydrocyanic acid levels. A significant reduction in hydrocyanic acid content was observed when bamboo shoots were boiled for different durations (5, 15, 25 min), with reductions ranging from 63.56% to 94.72%, depending on the boiling time. Therefore, before consuming bamboo shoots, it is necessary to process them to reduce cyanide content, ensuring they are safe for consumption. Boiling is an effective method for reducing cyanide levels. However, boiling may also affect other components in bamboo shoots, such as purine content and antioxidant compounds.

Purines are compounds found in various foods. In the human body, purines are metabolized into uric acid, and elevated levels of uric acid in the blood are associated with hyperuricemia and the development of gout. Previous studies have established a correlation between the consumption of high-purine foods and increased uric acid levels in the blood, as well as a heightened risk of developing gout. Additionally, purines have been identified as risk factors for cardiovascular diseases, hypertension, and kidney disorders. The recommended daily intake of purines is advised not to exceed 400 mg to prevent hyperuricemia and the onset of gout (Kaneko et al., 2014). There are four purine bases found in food: adenine, guanine, hypoxanthine, and xanthine. Hypoxanthine has been linked to an increased risk of gout (Kaneko et al., 2014). Aichayawanich et al. (2018) investigated the effects of boiling on uric acid content in bamboo shoots and found that boiling effectively reduced uric acid levels. Similarly, Phungamngoen and Suwan (2021) reported that boiling bamboo shoots at 80°C and 95°C led to a reduction in uric acid levels. However, studies on the effects of boiling on purine content in bamboo shoots remain limited. Therefore, further research is needed to evaluate the purine content in bamboo shoots following boiling.

Bamboo shoots are not only valued as a nutritious food source but also recognized for their bioactive compounds, such as phenolic compounds, which exhibit antioxidant properties. These attributes make bamboo shoots an appealing ingredient for developing functional foods and dietary supplements aimed at promoting health. Nevertheless, factors such as moisture content, physical properties, antioxidant activity, and purine levels differ across species, influencing their suitability for specific dietary and industrial applications. Additionally, understanding the purine content in bamboo shoots is crucial for dietary planning, particularly for individuals with conditions like gout or hyperuricemia. By examining the effects of boiling on bamboo shoots, this study provides valuable information on boiling methods that enhance their safety while ensuring that the boiled bamboo shoots retain bioactive compounds, supporting broader applications in the food industry.

Therefore, the objective of this study was to investigate the physical properties, antioxidant activity, and purine content in various species of bamboo shoots. Additionally, the impact of boiling on the levels of phenolic compounds, antioxidant properties, and purine content in bamboo shoots was examined.

2. Materials and Methods

2.1 Sample preparation

Four species of bamboo shoots were collected during August-October 2021 from Puparn Royal Development Study Centre: *Thyrsostachys siamensis*, *Gigantochloa albociliata*, *Bambusa burmanica*, and *Bambusa multiplex*. The bamboo shoots were delivered to the laboratory within 24 h after being collected. The samples were peeled, washed, and cut into pieces 0.5 cm thick and 5 cm long. The samples were divided into two groups: fresh bamboo shoots and boiled bamboo shoots. The boiling process involved immersing the bamboo shoots in boiling water (100°C) at a sample-to-water ratio of 1:4 (w/v) for 25 min to reduce cyanide content (Pandey & Ojha, 2014; Pokhariya et al., 2018), followed by cooling for 2 min in cold water. The physical properties of the fresh and boiled bamboo shoots were measured on the same day. For the chemical properties, the fresh and boiled bamboo shoots were packed in plastic bags and stored at -18°C until analysis.

2.2 Physical properties analysis

2.2.1 Color measurement

Color was measured using the CIE L*a*b* system with a HunterLab colorimeter (ColorFlex EZ, HunterLab, USA). The L* value indicates lightness, a* indicates greeness-redness, and b* indicates blueness-yellowness. The hue angle was calculated as follows (Sirijariyawat et al., 2018):

$$\text{Hue angle} = \text{arctangent}(b^*/a^*) \quad (1)$$

2.2.2 Texture measurement

Texture was measured using a texture analyzer (TA.XT2, Stable Micro System Ltd, UK) with a 2 mm probe (SMS P/2). The samples were compressed to 50% strain at a speed of 0.5 mm/s to measure the maximum force required, reported as hardness (N) (Zheng et al., 2020).

2.3 Chemical properties analysis

2.3.1 Moisture content

Moisture content was determined by drying the samples in a hot air oven at 105°C. The moisture content was reported as grams per 100 grams of sample (g/100g wb) (AOAC, 2019).

2.3.2 Total phenolic content

Total phenolics were measured using the Folin-Ciocalteau method. Bamboo shoot samples (1.5 g) were extracted with 80% methanol (12.5 mL) for 60 min, filtered, and then 10 µL of the extract was mixed with 50 µL of 10% Folin-Ciocalteau reagent. After 2 min, 150 µL of 7.5% sodium carbonate solution was added. The mixture was kept in the dark at room temperature for 30 min, and absorbance was measured at 765 nm using a microplate reader (Synergy HT, Biotek Instruments, USA). Results were reported as milligrams of gallic acid per 100 grams of sample (mg GAE/100g wb) (Bravo et al., 2013).

2.3.3 Antioxidant activity by DPPH method

The antioxidant activity was measured using the DPPH method. A 100 µL methanol extract of the sample was mixed with 150 µL of DPPH solution and kept in the dark at room temperature for 30 min. Absorbance was measured at 515 nm using Trolox as a standard, and results were reported as milligrams of Trolox per 100 grams of sample (mg TE/100g wb) (Bravo et al., 2013).

2.3.4 Antioxidant activity by ABTS method

Antioxidant activity was also measured using the ABTS method. A 0.36 mM potassium persulfate solution was mixed with 0.9 mM ABTS solution in phosphate-buffered saline (PBS) (pH 7.4) in a 1:1 ratio. The $ABTS^{\bullet+}$ was kept in the dark for 16 h. The solution was diluted with PBS to achieve an absorbance of 0.7. Then, 10 µL of the extract was mixed with 200 µL of the $ABTS^{\bullet+}$ solution and kept in the dark at room temperature for 30 min. Absorbance was measured at 734 nm using a microplate reader, with Trolox as a standard. Results were reported as milligrams of Trolox per gram of sample (mg TE/g wb) (Bravo et al., 2013).

2.3.5 Purine content analysis

Purine content was analyzed following the method of Li et al. (2019). Bamboo shoot samples (0.5 g) were mixed with 4 mL of acid mix (90% trifluoroacetic acid (TFA) and 80% formic acid (FA) in a 1:1 ratio) and heated at 90°C for 10 min. The solution was evaporated and dissolved in 4 mL of mobile phase (water, methanol, acetic acid, and 20% tetrabutylammonium hydroxide in a ratio of 879:100:15:6). The solution was centrifuged at 8,000 g and 4°C for 10 min, filtered through a 0.22 µm filter, and analyzed using a HPLC (Agilent Technologies LC1200 Series, Agilent Technologies, USA) with a DAD detector. The Zorbax SD-C18 column (4.6*150 mm, 5-micron, Agilent, USA) was used at 28°C with a flow rate of 0.7 mL/min, and absorbance was measured at 254 nm. The standards used were adenine, guanine, hypoxanthine, and xanthine at concentrations of 0, 5, 50, and 100 mg/L. Results were reported as milligrams per 100 grams of sample (mg/100g wb). Total purine content was calculated as follows (Kaneko et al., 2014):

$$\text{Total purine} = \text{Adenine} + \text{Guanine} + \text{Hypoxanthine} + \text{Xanthine} \quad (2)$$

2.4 Statistical analysis

A completely randomized design (CRD) was used for the experiments, with three replicates. A one-way analysis of variance (ANOVA) was performed using SPSS software for data analysis. Differences between means were compared using Duncan's Multiple Range Test (DMRT) at a significance level of 0.05.

3. Results and Discussion

3.1 Physical properties and moisture content of fresh bamboo shoots

The four species of bamboo shoots (*Thyrsostachys siamensi*s, *Gigantochloa albociliata*, *Bambusa burmanica*, and *Bambusa multiplex)* were analyzed for various properties, including color, texture, and moisture content. The study results are presented in Tables 1.

Table 1. Physical properties and moisture content of fresh bamboo shoots from different species

Sample	L*	a*	b*	Hue angle	Hardness (N)	Moisture^{ns} (g/100 g)
T. siamensis	75.30±1.46^{b}	0.35±0.31^{a}	21.39±1.16^{a}	89.05±0.84^{b}	8.05±0.14^{a}	91.16±0.33
G. albociliata	74.68±1.55^{b}	-0.04±0.28^{ab}	19.45±0.93^{ab}	90.13±0.84^{ab}	6.53±0.56^{b}	92.33±0.96
B. burmanica	77.62±3.03^{b}	0.34±0.42^{a}	13.99±2.04^{c}	88.63±1.53^{b}	8.65±0.67^{a}	92.73±0.14
B. multiplex	88.95±1.05^{a}	-0.55±0.20^{b}	16.94±1.97^{bc}	91.91±0.83^{a}	8.08±0.50^{a}	91.91±0.61

Note: Data are expressed as mean±standard deviation. Different letters in the vertical direction indicate statistical differences ($p \leq 0.05$). ns indicates no significant differences ($p > 0.05$)

Table 1 shows that the color of each bamboo shoot species differed. The highest L* value was observed in the shoots of *B. multiplex* ($p \leq 0.05$), indicating the highest brightness. The L* values for the shoots of *T. siamensis*, *G. albociliata*, and *B.burmanica* were not significantly different (p>0.05). For the a* value, which indicated redness/greenness, slightly negative values were observed in the shoots of *G. albociliata* and *B. multiplex* (-0.44 and -0.55, respectively), indicating a slight green color. Slightly positive a* values were observed in the shoots of *T. siamensis* and *B. burmanica* (0.35 and 0.34, respectively) with no significant differences (p>0.05), indicating a slight red color. For the b* value, which indicated yellowness, the highest yellowness was observed in *T. siamensis*, and *G. albociliata* (p>0.05). The lowest b* value was observed in *B. burmanica* (13.99), which was significantly lower than *T. siamensis* and *G. albociliata* (p≤0.05). The hue angle, indicating the shade of the color, showed that a hue angle of 90.13 was observed in *G. albociliata*, indicating a yellow color, while a hue angle of 91.91 was observed in *B. multiplex*, indicating a yellow-green color. Whereas yellow-red color was observed in the shoots of *T. siamensis* and *B. burmanica*.

In comparison to previous studies, Mahayotpanya and Phoungchandang (2016) found that fresh bamboo shoots (*Dendrocalamus asper* Backer) had similar color values: L* 78.06-82.23, a* -0.98 to 0.44, and b* 16.84-21.50. Zheng et al. (2013) reported that fresh bamboo shoots (*D. latiflorus*) had values of L* 82.41, a* -1.46, and b* 10.38.

As for the texture measurement of bamboo shoots, a texture analyzer was used to measure the maximum force required to press the samples, which was reported as hardness (N). The results showed that the maximum force for the four bamboo shoot species ranged from 6.53 to 8.65 N. The lowest maximum force was observed in the shoots of *G. albociliata* (p≤0.05), while no significant differences were observed in *T. siamensis*, *B. burmanica*, and *B. multiplex* (p>0.05), with values ranging from 8.05 to 8.65 N. This indicated that the shoots of *G. albociliata* was less hard than the shoots of the other species, while those of *B. burmanica*, *B. multiplex*, and *T. siamensis* had similar hardnesses.

Regarding the moisture content of fresh bamboo shoots, the four species were found to have high moisture content, ranging from 91.16% to 92.73% wb, with no significant difference (p>0.05). Therefore, fresh bamboo shoots have a short shelf life and require processing to extend their usability. The moisture contents reported in this study aligned with previous studies. Mahayotpanya and Phoungchandang (2016) found that bamboo shoots (*Dendrocalamus asper*) had moisture contents between 92.95% and 93.25%. Wang et al. (2020) reviewed bamboo shoot components and reported moisture content between 78% and 94%, depending on the species of bamboo shoot.

3.2 Total phenolic content and antioxidant activity of fresh and boiled bamboo shoots

Phenolic compounds have been related to various health benefits, mainly attributed to their antioxidant properties. Table 2 presents the total phenolic content, antioxidant activity measured by the DPPH method, and antioxidant activity measured by the ABTS method for the four species of bamboo shoots, both fresh and boiled. The results indicated that each species of bamboo shoot exhibited different levels of total phenolic content and antioxidant activity (p≤0.05). The shoots of *B. multiplex* had the highest phenolic content (p≤0.05), measured at 143.20 mg GAE/100g wb. This was followed by the shoots of *G. albociliata*, *T. siamensis*, and lastly, the shoots of *B. burmanica*, which had the least phenolic content (p≤0.05), measured at 123.51, 79.58, and 23.33 mg GAE/100g wb, respectively.

Table 2. Total phenolic content (mgGAE/100g wb), antioxidant activity by DPPH method (mgTE/100 g wb) and ABTS method (mgTE/g wb) of fresh and boiled bamboo shoot

Samples		Phenolic (mg gallic/100g wb)	DPPH (mg TE/100g wb)	ABTS (mg TE/g wb)
Fresh	*T. siamensis*	79.58±7.69 [d]	19.23±0.88 [a]	6.81±0.99 [c]
	G. albociliata	123.51±7.69 [b]	16.75±1.46 [b]	10.85±0.46 [b]
	B. burmanica	23.33±3.62 [f]	4.86±1.13 [e]	0.96±0.02 [f]
	B. multiplex	143.20±8.60 [a]	16.04±0.66 [b]	14.77±0.86 [a]
Boil	*T. siamensis*	63.86±5.71 [e]	8.17±0.28 [d]	2.48±0.32 [e]
	G. albociliata	92.72±9.16 [c]	9.28±0.92 [d]	4.82±0.64 [d]
	B. burmanica	22.78±2.22 [f]	4.91±0.51 [e]	0.36±0.05 [f]
	B. multiplex	112.53±6.88 [b]	10.98±0.86 [c]	5.92±0.41 [c]

Note: Data are expressed as mean ± standard deviation. Different letters in the vertical direction indicate statistical differences ($p \leq 0.05$).

The highest antioxidant activity measured by the DPPH method was found in the shoot of *T. siamensis* ($p \leq 0.05$). The shoots of *G. albociliata* and *B. multiplex* had similar antioxidant activities measured by the DPPH method, with no significant difference ($p > 0.05$), while *B. burmanica* had the lowest antioxidant activity measured by the DPPH method. For the antioxidant activity measured by the ABTS method, the shoots of *B. multiplex* had the highest value at 14.77 mg TE/g wb, followed by the shoots of *G. albociliata* and *T. siamensis*, with the shoots of *B. burmanica* having the lowest antioxidant activity measured by the ABTS method ($p \leq 0.05$).

This study showed that the shoots of *B. burmanica* had the lowest total phenolic content and the lowest antioxidant activity measured by both DPPH and ABTS methods ($p \leq 0.05$). The shoots of *B. burmanica* had about 3-4 times lower antioxidant activity measured by the DPPH method and about 7-15 times lower antioxidant activity measured by the ABTS method compared to other bamboo shoot species. In contrast, the shoot of *B. multiplex* had the highest total phenolic content and antioxidant activity measured by the ABTS method, and relatively high antioxidant activity measured by the DPPH method. These phenolic content and antioxidant activities were associated with a reduced risk of developing various chronic diseases.

Previous studies have reported the phenolic content and antioxidant activity of various species of bamboo shoots. Singhal et al. (2022) reported that the bamboo shoots of the *B. vulgaris* species contained 307.55 mg GAE/100g dw. Nirmala et al. (2018) collected data on phenolic content in various bamboo species and reported that the shoots of *B. pallida* had low phenolic content at 79.85 mg GAE/100g, whereas the shoot of *D. strictus* had high phenolic content at 630.0 mg GAE/100g. Wang et al. (2020) collected data on bamboo shoots and reported that bamboo shoots were rich in vitamin C and vitamin E, which are involved in antioxidant activities. They are a source of phytosterols, which benefit the body by reducing cholesterol levels, inhibiting stomach ulcers formation, cancer, inflammation, and boosting the immune system. Bamboo shoots are a source of phenolics, important for antioxidant activities, with phenolic content varying depending on the species of bamboo shoot. Wang et al. (2020) reported that the shoots of *B. pallida* had the lowest phenolic content at 79.85 mg GAE/100 g, and the shoots of *Phyllostachys* *violascens* had the highest phenolic content at 2,541.02 mg GAE/100 g. The main phenolic compounds found in bamboo shoots were phenolic acids and flavonoids.

When comparing boiled bamboo shoot samples with fresh ones, the study showed that boiling reduced the total phenolic content, DPPH antioxidant activity, and ABTS antioxidant activity of the bamboo shoots ($p \leq 0.05$), except for *B. burmanica*, which already had low total phenolic content, DPPH antioxidant activity, and ABTS antioxidant activity. Regardless of the species of bamboo shoot, boiling resulted in an average reduction of total phenolic content, DPPH antioxidant activity, and ABTS antioxidant activity by 22.0%, 44.6%, and 59.7%, respectively, compared to fresh bamboo shoots. The reduction of phenolic compounds and antioxidant activity could be attributed to oxidation processes, thermal degradation, and leaching out of some bioactive compounds into the boiling water.

The effect of boiling on the reduction of total phenolic content and antioxidant activity was consistent with previous research. Pandey & Ojha (2014) reported the total phenolic content of four species of bamboo shoots (*B. bambos, B. tulda, D. strictus,* and *D. asper*) ranging from 0.36-0.63 g/100g, depending on the species of bamboo shoot. Boiling reduced the total phenolic content as boiling time increased, with 10 min of boiling reducing the total phenolic content to 0.08-0.31 g/100g. Mahayotpanya and Phoungchandang (2016) reported that boiling the shoots of *D. asper* Backer before hot-air drying at 40-60°C resulted in dried bamboo shoots having lower total phenolic content and antioxidant activity than those dried without boiling. Boiled and hot-air dried bamboo shoots at 60°C had a total phenolic content of 432.54 mg GAE/100g dw, DPPH antioxidant activity of 76.74 mg TE/100g dw, and ABTS antioxidant activity of 129.22 mg TE/100g dw. Wang et al. (2020) reviewed data on bamboo shoots and reported that boiling reduced the phenolic content of bamboo shoots by 20-73%, depending on boiling conditions and bamboo shoot species. Pattarathitiwat et al. (2021) found that fresh bamboo shoots (*D. asper* Back.) had a total phenolic content of 12.12 mg GAE/g dw, DPPH antioxidant activity of 19.43%, and ABTS antioxidant activity of 29.78%. Boiling for 30 min reduced the total phenolic content and antioxidant activity to 9.27 mg GAE/g dw, 16.00%, and 12.43%, respectively. Singhal et al. (2023) reported that boiling bamboo shoots (*B. vulgaris*) in hot water at 100°C for 2-10 min reduced the phenolic content from 1.21 mg GAE/g to approximately 0.6 mg GAE/g. Santosh et al. (2021) observed that boiling bamboo shoot (*D. hamiltonii*) for 20 min led to a reduction in antioxidant activity and bioactive compounds, including total phenols, phytosterols, vitamin C, and vitamin E. They suggested that this decrease in antioxidant activity could be due to the degradation and leaching of antioxidant compounds into the boiling water.

3.3 Purine content

Purines are compounds found in many foods and are associated with blood uric acid levels. Consuming large amounts of purine-rich foods can significantly affect uric acid levels, which poses risks for conditions such as gout, cardiovascular diseases, and kidney diseases. Purines are present in both higher plants and microorganisms, with their concentrations varying depending on the species (Kaneko et al., 2014; Hafez et al., 2017). When analyzing the purine content of the four species of bamboo shoots, the four purine bases (adenine, guanine, hypoxanthine, and xanthine) were examined, and the total purine content was calculated. The study results are shown in Figures 1 and 2, respectively.

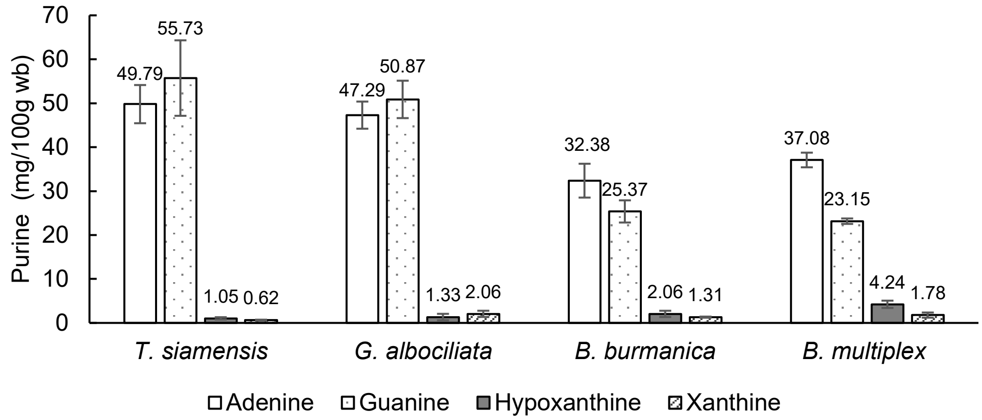

Figure 1. Adenine, guanine, hypoxanthine, and xanthine content (mg/100g wb) of fresh bamboo shoot
Note: Data are expressed as mean±standard deviation.

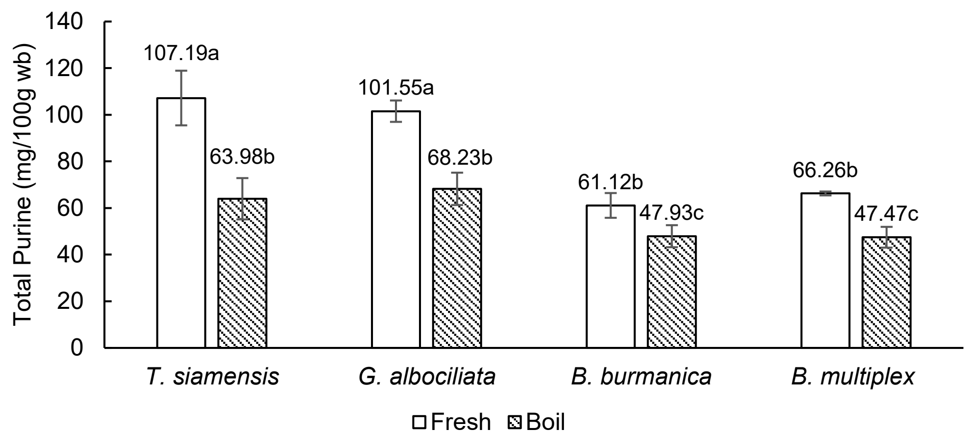

Figure 2. Total purine content (mg/100g wb) of fresh and boiled bamboo shoot
Note: Data are expressed as mean±standard deviation, Different alphabets on a bar indicate statistical differences (p≤0.05).

Figure 1 shows that the four species of bamboo shoots studied contained higher proportions of adenine and guanine compared to hypoxanthine and xanthine. Adenine and hypoxanthine were reported to be associated with increased uric acid levels in the blood, with hypoxanthine being the purine base most related to the risk of gout (Kaneko et al., 2014). Hypoxanthine, which is present in small amounts in bamboo shoots, has been identified as having the greatest impact on uric acid levels. When considering the total purine content, it was found that the shoots of *G. albociliata* and *T. siamensis* had similar total purine levels, at 101.55 and 107.19 mg/100g wb, respectively. These values were higher than those found in the shoots of *B. burmanica* and *B. multiplex*, which had total purine contents of 61.12 and 66.26 mg/100g wb, respectively. According to Kaneko et al. (2014), *B. burmanica* and *B. multiplex* belong to the group of foods with low purine content

(50-100 mg/100g wb), while *G. albociliata* and *T. siamensis* fall into the group with moderate purine content (100-200 mg/100g wb).

The proportions of purines and total purine content found in the four species of bamboo shoots in this study are consistent with previous research, indicating higher levels of adenine and guanine than hypoxanthine and xanthine (Kaneko et al., 2014). Brulé et al. (1992) reported that hypoxanthine has a greater impact on blood uric acid levels than other purines, and that guanine does not affect changes in uric acid levels in blood and urine. Kaneko et al. (2014) found that different parts of the bamboo shoot contain varying levels of purine and uric acid, with the upper part having higher levels of adenine, guanine, hypoxanthine, xanthine, total purines, and uric acid than the lower part. This demonstrates that, aside from the species of bamboo shoot, the position of the shoot affects purine and uric acid content, with the upper part having higher amounts than the lower part.

Kaneko et al. (2014) analyzed the purine content in 270 types of food and found that only a small group of foods had high purine levels. Foods with high purine content were mostly in the categories of meats, animal organs, and yeast. They categorized foods into two groups based on the proportions of the four detected purine bases: Group 1 had high levels of adenine and guanine, while Group 2 had high levels of hypoxanthine. The total purine content and hypoxanthine levels are critical in assessing the risk of hyperuricemia and gout. Foods were divided into five groups based on total purine content: Group 1 with very low purine content (<50 mg/100g), Group 2 with low purine content (50-100 mg/100g), Group 3 with moderate purine content (100-200 mg/100g), Group 4 with high purine content (200-300 mg/100g), and Group 5 with very high purine content (>300 mg/100g). Kaneko et al. (2014) reported that bamboo shoots are classified within the low to very low purine groups. Phungamngoen and Suwan (2021) reported that the shoots of *T. siamensis* contained 161.43 mg/100g of uric acid, which increased upon slicing and exposure to air. Exposure for 30 min led to the highest increase, reaching 244.73 mg/100g, after which the uric acid levels stabilized.

As for the effect of boiling, the study found that boiling reduced the total purine content in bamboo shoots compared to fresh bamboo shoots ($p \leq 0.05$) (Figure 2). There is a well-established correlation between the consumption of high-purine foods and elevated uric acid levels in the blood, which can increase the risk of gout, cardiovascular diseases, hypertension, and kidney disorders. Therefore, reducing purine content in food is beneficial for health. The reduction in purine content may be due to the loss caused by high heat and the direct contact of the bamboo shoots with hot water, which leads to some purines being lost into the boiling water. Previous research has shown the effects of boiling on purine and uric acid content. Aichayawanich et al. (2018) studied the effects of boiling on uric acid content in bamboo shoots and found that fresh bamboo shoots contained 247.8 mg/100g of uric acid. Boiling reduced the uric acid content to 61.5-239.0 mg/100g, depending on the temperature (60-100°C) and boiling time (1-45 min). Higher temperatures and longer boiling times result in lower uric acid levels. Phungamngoen & Suwan (2021) reported that boiling the bamboo shoots at 80 and 95°C caused a rapid reduction in uric acid levels during the initial heating period (5-10 min), with levels dropping to approximately 100 mg/100g, after which the reduction slowed significantly (10-30 min). Additionally, the effects of boiling on purine content in other foods have also been reported. Li et al. (2019) studied purine content in different parts of fish and found that boiling caused a loss of purines into the boiling water, thus reducing the purine content in the fish. Xiao et al. (2022) studied the effects of processing on purine content in shiitake mushrooms and found that boiling for 25 min reduced the purine content in the mushroom pieces, with the amount of purines lost to the boiling water being greater than the amount retained in the mushroom pieces.

4. Conclusions

Bamboo shoots exhibited variations in physical and chemical properties among species. *Gigantochloa albociliata* had the lowest hardness (p≤0.05), *T. siamensis* showed the highest antioxidant activity as measured by the DPPH method (p≤0.05), and *B. multiplex* had the highest total phenolic content and antioxidant activity as measured by the ABTS method (p≤0.05). Purine analysis revealed low hypoxanthine levels across all species. *Bambusa burmanica* and *B. multiplex* were classified as low-purine foods, while *G. albociliata* and *T. siamensis* were categorized as moderate-purine foods. Boiling significantly reduced purine content (p≤0.05) but also decreased phenolic content and antioxidant activity. The study highlighted that boiled bamboo shoots are beneficial to health due to their phenolic content, antioxidant properties, and classification as foods with low purine content.

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6. Authors' Contributions

Jessada Techamahasaranont : Project administration, conceptualization, data collection, manuscript drafting and editing.
Pancheewan Ponpang-nga : Data analysis support, literature review, and manuscript preparation assistance.
Arpassorn Sirijariyawat : Conceptualization, methodology design, data collection, analysis, manuscript drafting and editing.

7. Conflicts of Interest

There is no conflict of interest.

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