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Selenization Improves Physicochemical Properties, Antioxidant and Anti-glycation Activities of Bamboo Shoot Polysaccharides

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Abstract

This study aimed to investigate the physicochemical properties, antioxidant and anti-glycation activities of selenized bamboo shoot polysaccharides (Se-BSP). The molecular weight of Se-BSP was determined by using gel permeation chromatography, while its monosaccharide composition was identified via ion chromatography. Antioxidant activity was evaluated using an in vitro assay kit, and anti-glycation activity was assessed via the in vitro bovine serum albumin-glucose non-enzymatic glycosylation reaction system. The results showed that Se-BSP, with a selenium content of 1.134 ± 0.136 mg/g, has a molecular weight of approximately 24,600 g/mol and is composed of galactose, xylose, arabinose, glucose, glucuronic acid, and galacturonic acid in a molar ratio of 0.382:0.255:0.274:0.037:0.013:0.018. In comparison to the non-selenized bamboo shoot polysaccharides, Se-BSP demonstrated significant improvements in physicochemical properties, including water-holding, oil-holding, water-binding, and swelling capacities, as well as antioxidant activity and inhibitory effects on protein non-enzymatic glycosylation. These findings highlight the potential of Se-BSP as a functional food ingredient with health-beneficial properties.

Keywords

Selenized Bamboo Shoot Polysaccharides; Physicochemical Properties; Antioxidant Capacity; Protein Non-Enzymatic Glycosylation

1. Introduction

Bamboo shoots, the tender sprouts of bamboo plants, are valued for their dual role as natural food ingredients due to their low-fat composition, high fiber content, and abundance of essential nutrients [1]. Contemporary pharmacological research

demonstrates their therapeutic potential in mitigating metabolic disorders including obesity, hypertension, hyperlipidemia, and diabetes [2]. Bamboo shoot polysaccharides have garnered considerable research interest in nutritional science and biomedicine owing to their antioxidant capacities, immunomodulatory effects, and probiotic-enhancing bioactivities [3-4].

Selenized polysaccharides represent a groundbreaking advancement in the field of functional biomolecules, merging the inherent benefits of polysaccharides with the unique properties of selenium [5]. The incorporation of selenium into polysaccharide structures not only increases their bioavailability but also boosts their antioxidant and immunoregulatory potential, making them more effective in mitigating oxidative stress and inflammation associated with chronic diseases [6,7].

Bamboo shoot polysaccharides exhibit significant potential for development and application due to their various physiological activities. However, prior research on bamboo shoot polysaccharides has primarily focused on extraction methods, solubility enhancement, and functional properties [3-4], with no studies reported on selenized bamboo shoot polysaccharides and their activities. This study aimed to investigate the physicochemical properties, antioxidant, and anti-glycation activities of selenized bamboo shoot polysaccharides (Se-BSP).

2. Materials and methods

2.1. Materials and reagents

Spring bamboo shoots (*Phyllostachys edulis*) were purchased from local markets. Sodium selenite and aminoguanidine (AG) were purchased from Shanghai Aladdin Biochemical Technology Co., Ltd (Shanghai, China). Ascorbic acid and dialysis bags were obtained from Beijing Solarbio Science & Technology Co., Ltd (Beijing, China). Total antioxidant capacity assay kit and DPPH radical scavenging capacity assay kit were purchased from Nanjing Jiancheng Bioengineering Institute (Nanjing, China). Bovine serum albumin (BSA), glucose, nitroblue tetrazolium (NBT), and Girard-T reagent were obtained from Sinopharm Chemical Reagent Co., Ltd (Beijing, China). All other reagents were of analytical grade.

2.2. Preparation of Se-BSP

2.2.1. Extraction of bamboo shoot polysaccharides

The extraction of bamboo shoot polysaccharides was conducted following the method described by Wu et al. [8].

2.2.2. Preparation of Se-BSP

Se-BSP was synthesized using the nitric acid-sodium selenite method described by Huang et al [9]. A control sample of non-selenized bamboo shoot polysaccharides (named as BSP) was prepared following the same procedure without the addition of

sodium selenite.

2.3. Structural characterization of Se-BSP

2.3.1. Total sugar and selenium content determination

Total sugar content was determined using the phenol-sulfuric acid method. Selenium content was determined using the atomic fluorescence spectrometry method described in GB5009.93-2017 (Determination of Selenium in Foods).

2.3.2. Fourier transform infrared spectroscopy (FTIR) analysis

The FTIR analysis was conducted according to the method of Huang et al [9].

2.3.3. Molecular weight determination

The weight-average molecular weight (Mw) Se-BSP was determined using a Waters GPC 1515 gel permeation chromatography system (Milford, MA, USA) according to the method of Huang et al [9].

2.3.4. Monosaccharide composition analysis

The monosaccharide composition of Se-BSP was characterized using an ICS-1100 ion chromatography system (Thermo Fisher Scientific, Waltham, MA, USA) according to the method of Huang et al [9].

2.4. Determination of physicochemical properties

2.4.1. Water-holding capacity (WHC)

Each sample (0.500 g, X0) was placed in centrifuge tubes. The combined mass (X1) of sample and centrifuge tube was noted after adding 10 mL water, mixing, and equilibrating for 12 h. Following centrifugation, the supernatant was decanted and residual mass (X2) recorded. The WHC was calculated using Equation (1).

$$WHC=(X2-X1)/X0 \quad (1)$$

2.4.2. Oil-holding capacity (OHC)

Samples (0.500 g, m) were weighed into tubes, initial mass (X1) recorded, mixed with 10 mL rapeseed oil, equilibrated, and centrifuged. The supernatant was removed, and final mass (X2) measured. The OHC was calculated using Equation (2).

$$OHC=(X2-X1)/m \quad (2)$$

2.4.3. Water-binding capacity (WBC)

Test portions (0.500 g) were hydrated with 20 mL water, vortexed, equilibrated (24 h), and vacuum-filtered. Samples were weighed (W1) and dried to constant mass (W2) at 105°C. The WBC was calculated using Equation (3).

$$WBC=(W1-W2)/W2 \quad (3)$$

2.4.4. Swelling capacity (SC)

Precisely weighed Samples (0.250 g, m) hydrated with 5 mL water had volume (V1) recorded before vortex-mixing and degassing. After 24 h equilibration, final gel volume (V2) was measured. The SC in mL/g was calculated using Equation (4).

$$SC=(V2-V1)/m \quad (4)$$

2.5. Measurement of *in vitro* antioxidant activity

The DPPH (1,1-Diphenyl-2-picrylhydrazyl) radical scavenging activity of the samples was determined using a DPPH assay kit. Total antioxidant capacity was determined via the ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)) method according to the manufacturer's protocol.

2.6. Experiment design of protein non-enzymatic glycosylation

2.6.1. Construction of non-enzymatic glycosylation reaction system

The BSA-glucose non-enzymatic glycosylation reaction system was established following previous method [10] with minor modifications. Under sterile conditions, 4 mL of BSA (40 mg/mL) and 3 mL of D-glucose (2 M) were sequentially transferred to a sterile culture vessel. The mixture was supplemented with penicillin-streptomycin (100 IU/mL) in phosphate-buffered saline (PBS, 200 mM, pH 7.4) and brought to a final volume of 10 mL using PBS. The complete glycosylation system control group (Fa) was incubated at 37°C for 10 days. Two parallel control groups were established: Fb (no sample/glucose) and Fc (sample without BSA). Two test groups (F1 and F2) received 0.6 mg/mL BSP and selenium-modified BSP (Se-BSP), respectively. The positive control received 0.6 mg/mL of AG. Advanced glycation end products (AGEs) formation was quantified at specified time points (days 0, 2, 4, 6, 8, 10) using methods detailed in Sections 2.6.2–2.6.4.

2.6.2. NBT reduction assay

The NBT reduction assay was conducted according to previous method [10].

2.6.3. Detection of dicarbonyl compounds

The dicarbonyl compounds was detected according to previous method [10].

2.6.4. Fluorescence intensity measurement of end products

A 0.75 mL aliquot from the glycosylation reaction mixture was quantitatively transferred for fluorescence intensity measurements performed at excitation/emission wavelengths of 370 nm and 440 nm, respectively. The inhibitory effects of BSP, Se-BSP, and AG on non-enzymatic protein glycation were calculated according to Equation (5).

$$\text{Inhibition Rate}/\%=(1-(F-Fa-Fc)/(Fa-Fb))\times 100\% \quad (5)$$

2.7. Data analysis

Data from triplicate experiments are presented as mean ± standard deviation. Statistical analyses were conducted using SPSS software (version 20.0, IBM Corp.), with Independent-samples t-test and Duncan's multiple range test in one-way ANOVA. Statistical significance was defined as $p < 0.05$.

3. Results and discussion

3.1 Structural characterization of Se-BSP

3.1.1. Total sugar content and selenium content

The total sugar content of Se-BSP was determined to be 92.3 ± 1.2% and the selenium content of Se-BSP was measured to be 1.134 ± 0.136 mg/g.

3.1.2. FTIR spectra analysis

The FTIR spectra of BSP and Se-BSP are shown in Figure 1. The absorption peak at 3412 cm^{-1} corresponds to the stretching vibration of -OH. Peaks at 2930 cm^{-1} and 2342 cm^{-1} are attributed to the stretching vibrations of C-H. The absorption peak at 1645 cm^{-1} is ascribed to the stretching vibration of C=O. The peak at 1384 cm^{-1} is characteristic of C-H adjacent to Se=O [9]. The absorption peak at 799 cm^{-1} is indicative of Se=O [9], while the peaks at 668 cm^{-1} and 611 cm^{-1} are attributed to Se-OH and Se-O-C-, respectively [11]. These results suggest that selenium is incorporated into the polysaccharide in the form of selenite esters, binding to the hydroxyl groups of the bamboo shoot polysaccharides.

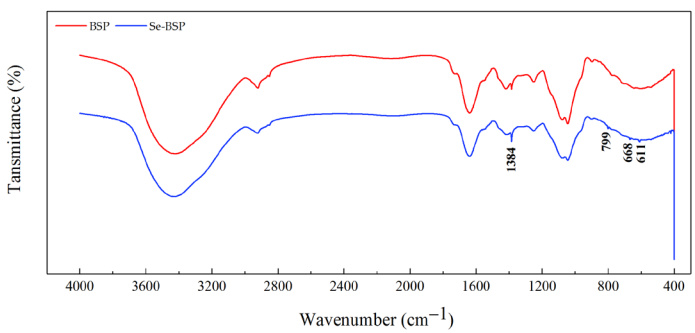

Figure 1. FTIR spectra of BSP and Se-BSP.

3.1.3. Molecular weight

Figure 2 shows that both samples displayed singular elution peaks. The Mw of Se-BSP was determined to be 24,600 g/mol.

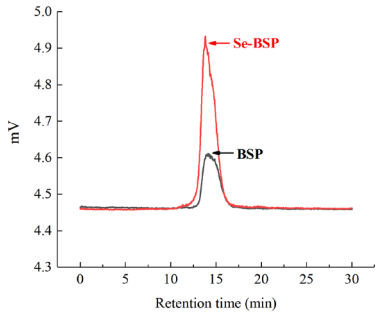

Figure 2. Gel permeation chromatograms of BSP and Se-BSP.

3.1.4. Monosaccharide composition

The analysis result shows that the relative molar ratios of the monosaccharides in Se-BSP were as follows: galactose : xylose : arabinose : glucose : glucuronic acid : galacturonic acid = 0.382 : 0.255 : 0.274 : 0.037 : 0.013 : 0.018.

3.2. Physicochemical properties

As summarized in Table 1, compared to BSP, Se-BSP exhibited significant increases in WHC, OHC, WBC, and SC ($p < 0.05$ or $p < 0.01$). These findings demonstrate that selenization enhanced the physicochemical properties of bamboo shoot polysaccharides. This improvement may be explained by the more porous surface morphology of selenized polysaccharides, which increases specific surface area. The structural modification enables water molecules to more readily permeate the polysaccharide matrix and interact with additional hydrogen bond donors/acceptors, thereby increasing adsorption capacity for both aqueous and lipid phases [12].

Table 1. Physicochemical properties of BSP and Se-BSP.

Sample	Physicochemical properties			
	WHC (g/g)	OHC (g/g)	WBC (g/g)	SC (mL/g)
BSP	8.16 ± 0.20	1.76 ± 0.09	11.20 ± 0.56	4.9 ± 0.3
Se-BSP	8.97 ± 0.30*	7.64 ± 0.53**	14.83 ± 0.86*	13.2 ± 1.0**

Note: An asterisk (*) above the values in the same column indicates a significant difference ($p < 0.05$), and a double asterisk (**) indicates a highly significant difference ($p < 0.01$).

3.3. Antioxidant capacity

As presented in Table 2, compared to BSP, Se-BSP demonstrated significantly enhanced DPPH radical scavenging capacity ($p < 0.05$) and total antioxidant activity ($p < 0.01$). This suggests that selenization significantly improved the antioxidant capac-

ity of bamboo shoot polysaccharides, which was consistent with the results reported by Li et al [13]. Selenization may enhance the hydrogen-donating ability of polysaccharides through the presence of selenate esters, thereby improving their antioxidant properties [13].

Table 2. Antioxidant capacity of BSP and Se-BSP.

Sample	Antioxidant capacity	
	DPPH radical scavenging rate (%)	Total antioxidant capacity (Trolox equivalent, nM)
BSP	62.96 ± 4.29	0.83 ± 0.02
Se-BSP	77.50 ± 4.74*	1.01 ± 0.02**

Note: An asterisk (*) above the values in the same column indicates a significant difference ($p < 0.05$), and a double asterisk (**) indicates a highly significant difference ($p < 0.01$).

3.4. Anti-glycation activity

3.4.1. Effect of Se-BSP on early stage of non-enzymatic glycation

Figure 3A shows that the reaction proceeded, the inhibitory effects of all three compounds on Amadori product formation progressively increased. Notably, Se-BSP demonstrated significantly stronger inhibitory effects compared to BSP at days 8 and 10 ($p < 0.05$), suggesting that selenization substantially improved BSP's capacity to scavenge early-stage glycation intermediates.

3.4.2. Effect of Se-BSP on intermediate stage of non-enzymatic glycation

Figure 3B shows that the inhibition rates of BSP, Se-BSP, and AG on dicarbonyl compound formation gradually increased over time. On days 8 and 10, Se-BSP exhibited significantly better inhibition than BSP ($p < 0.05$), suggesting that selenization significantly enhanced BSP's ability to suppress the mid-stage glycation products.

3.4.3. Effect of Se-BSP on advanced stage of non-enzymatic glycation

Figure 3C shows that the inhibition rates of BSP, Se-BSP, and AG on AGEs formation increased progressively over time. On day 10, the inhibition rates of BSP and Se-BSP were 34.59 ± 3.16% and 48.23 ± 4.34%, respectively. On days 6, 8, and 10, Se-BSP exhibited significantly higher inhibition rates than BSP ($p < 0.05$), indicating that selenization significantly enhanced the ability of BSP to inhibit AGEs formation. These findings are consistent with the results reported by Zhao et al [14], who demonstrated that selenized Ribes nigrum L polysaccharides exhibited superior inhibition of AGEs compared to unmodified polysaccharides. Furthermore, Wang et al. [15] observed similar enhancement patterns in selenized sweet corn cob polysaccharides relative to native polysaccharides. The mechanism might involve competi-

tive binding of selenized polysaccharides with BSA's free amino groups, thereby protecting them from glycation and amplifying AGEs formation suppression [16].

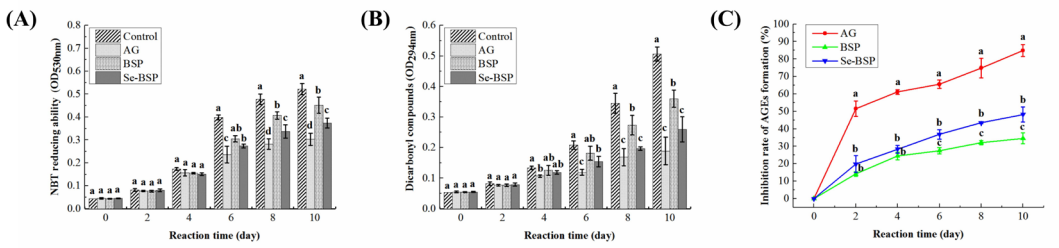

Figure 3. The intervention effects of BSP and Se-BSP on protein non-enzymatic glycosylation. (A) NBT reduction capacity; (B) Dicarbonyl compounds; (C) Inhibition rate of AGEs formation. Note: Different letters above the values for the same reaction day indicate significant differences ($p < 0.05$).

4. Conclusions

The present study found that selenium incorporation significantly enhanced the functional properties of bamboo shoot polysaccharides, including superior water- and oil-retention capacities, improved swelling behavior, and elevated antioxidant and anti-glycation activities. The modification demonstrates selenium's capacity to modulate polysaccharide's bioactivity through structural alterations. Subsequent in vivo studies will be essential to assess therapeutic potential of Se-BSP.

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References

[1] Fan, X., Chang, H., Lin, Y., Zhao, X., Zhang, A., Li, S., ... Chen, X. (2020). Effects of ultra-sound-assisted enzyme hydrolysis on the microstructure and physicochemical properties of okara fibers. Ultrasonics Sonochemistry, 69, 105247. http://dx.doi.org/10.1016/j.ultsonch.2020.105247.

[2] Gan, J., Xie, L., Peng, G., Xie, J., Chen, Y., & Yu, Q. (2021). Systematic review on modification methods of dietary fiber. Food Hydrocolloids, 119, 106872. http://dx.doi.org/10.1016/j.foodhyd.2021.106872.

[3] Huang, X. Y., Chen, X. Y., Xian, Y. H., & Jiang, F. M. (2024). The material sources, pharmaco-logical activities of bamboo polysaccharides and influencing factors: A review. Industrial Crops and Products, 210, 118037. http://dx.doi.org/10.1016/j.indcrop.2024.118037.

[4] Jana, U. K., Bhardwaj, P. K., Jeyaram, K., Shukla, J. K., Somkuwar, B. G., & Mukherjee, P. K. (2025). Bamboo shoots: Comprehensive perspectives on food composition, nutritional value, and therapeutic potential. Journal of Food Composition and Analysis, 140, 107198. http://dx.doi.org/10.1016/j.jfca.2025.107198.

[5] Jiang, G., Kong, H., Wang, Y., Wang, Y., Zhou, J., Wang, Z., & Niu, J. (2025). Antioxidant and

hepatic fibrosis-alleviating effects of selenium-modified Bletilla striata polysaccharide. International Journal of Biological Macromolecules, 301, 140234. http://dx.doi.org/10.1016/j.ijbiomac.2025.140234.

[6] Kuzan, A. (2021). Toxicity of advanced glycation end products (Review). Biomedical Re-ports, 14(5), 46. http://dx.doi.org/10.3892/br.2021.1422.

[7] Li, J., Shen, B. X., Nie, S. L., Duan, Z. H., & Chen, K. S. (2019). A combination of selenium and polysaccharides: Promising therapeutic potential. Carbohydrate Polymers, 206, 163-173. http://dx.doi.org/10.1016/j.carbpol.2018.10.088.

[8] Wu, W., Hu, J., Gao, H., Chen, H., Fang, X., Mu, H., ... Liu, R. (2020). The potential cholest-er-ol-lowering and prebiotic effects of bamboo shoot dietary fibers and their structural characteristics. Food Chemistry, 332, 127372. http://dx.doi.org/10.1016/j.foodchem.2020.127372.

[9] Huang, F., Sun, X., & Ouyang, J. (2020). Preparation and characterization of selenized Astragalus polysaccharide and its inhibitory effect on kidney stones. Materials Science and Engineering: C, 110, 110732. https://doi.org/10.1016/j.msec.2020.110732.

[10] Oso, B. J., Olaoye, I., & Oso, O. T. (2023). Experimental and hypothetical appraisal on in-hibi-tion of glucose-induced glycation of bovine serum albumin by quercetin. Journal of Genet-ic Engineering and Biotechnology, 21(1), 123. http://dx.doi.org/10.1186/s43141-023-00588-5.

[11] Wang, L., Li, X., & Wang, B. (2018). Synthesis, characterization and antioxidant activity of selenium modified polysaccharides from Hohenbuehelia serotina. International Journal of Biological Macromolecules, 120, 1362-1368. http://dx.doi.org/10.1016/j.ijbiomac.2018.09.139.

[12] Tian, Y., Wu, T., Sheng, Y., Li, L., & Wang, C. (2023). Effects of cavitation-jet technology combined with enzyme treatment on the structure properties and functional properties of OKARA insoluble dietary fiber. Food Chemistry, 423, 136286. http://dx.doi.org/10.1016/j.foodchem.2023.136286.

[13] Li, Q., Wang, W., Zhu, Y., Chen, Y., Zhang, W., Yu, P., ... Wu, X. (2017). Structural elucida-tion and antioxidant activity a novel Se-polysaccharide from Se-enriched Grifola fron-dosa. Carbohydrate Polymers, 161, 42-52. http://dx.doi.org/10.1016/j.carbpol.2016.12.041.

[14] Zhao, M., Bai, J., Bu, X., Yin, Y., Wang, L., Yang, Y., & Xu, Y. (2021). Characterization of selenized polysaccharides from Ribes nigrum L. and its inhibitory effects on α-amylase and α-glucosidase. Carbohydrate Polymers, 259, 117729. https://doi.org/10.1016/j.carbpol.2021.117729.

[15] Wang, X., Zhou, Z., Wang, Z., Xiu, W., Luo, Y., & Ma, Y. (2023). Inhibitory effect of selenium sweet corncob polysaccharide on non-enzymatic glycosylation. Science and Technology of Food Industry, 44(19), 17-23. https://doi.org/10.13386/j.issn1002-0306.2022100014.

[16] Zhou, N., Long, H., Wang, C., Yu, L., & Liu, X. (2020). Research progress on the biological ac-tivities of selenium polysaccharides. Food & Function, 11(6), 4834-4852. http://dx.doi.org/10.1039/C9FO02026H.