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Research Article

Nutritional value and antioxidant activity of *Artemisia princeps*, an edible plant frequently used in folk food in the Xiangxi region

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Abstract: As a raw material in the Xiangxi traditional food "Haocaibaba" (a very popular cake-like food from China), the application of *Artemisia princeps* has a long history in Xiangxi. In this study, the nutritional value and antioxidant activity of *A. princeps*, the raw material of "Haocaibaba", were analyzed by means of routine physical and chemical analyses, and an *in vitro* antioxidant test. The content of protein, fat, and dietary fiber in *A. princeps* was higher than that of *Oryza sativa*, *Solanum tuberosum*, *Brassica pekinensis*, *Spinacia oleracea*, or *Coriandrum sativum*. *A. princeps* was rich in aspartic acid and glutamic acid and contained at least 18 amino acids. *A. princeps* contained a variety of minerals, of which the content of potassium was the highest, followed by 25 elements, such as calcium, magnesium, iron, aluminum, manganese, and sodium. Four vitamins were detected, including vitamins A, C, E, and B_2. *A. princeps* had the ability to clear 1, 1-diphenyl-2-picrylhydrazyl radicals (DPPH) and 2, 2′-amino-di (3-ethylbenzthiazoline sulphonic acid-6) ammonium salt cationic radicals ($ABTS^{+}$•), to delay the carotene fading, and to inhibit lipid peroxidation. These results confirm that it is a very reasonable choice for the Xiangxi people to make "Haocaibaba" using *A. princeps*.

Keywords: Haocaibaba; *Artemisia princeps*; nutritional value; antioxidant

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1 Introduction

Wild edible plants are of great significance in maintaining the productivity and stability of traditional agricultural ecosystems[1]. Wild edible plants from rural and suburban areas have attracted considerable attention[2]. In developing countries, wild edible plants are still an indispensable component of many people's diets, especially during periods of seasonal food shortages[3]. Some wild food plants are also called "functional foods" because they contain physiologically active ingredients that can provide health benefits beyond basic nutrition[4].

Artemisia princeps Pamp is a perennial herbaceous plant in Asteraceae that is widely distributed in China, Japan, and Korea. Traditionally, *A. princeps* has the effects of relieving cold and dampness, and having anti-inflammatory, anti-cancer, anti-itch, anti-allergy, and other pharmacological activities[5-7]. *A. princeps* has also been reported in Japan, Korea, and other Asian countries to treat inflammation and as a component of rice cake and soup[8-11]. In addition to traditional applications, the plant characteristics, nutritional value, and processing technology of *A. princeps* have been studied in different countries[12, 13], but the nutritional value and active functions of *A. princeps* are still unclear.

Xiangxi (located in the Northwest of Hunan Province, China) is located in the Wuling Mountainous area of Central China, with rich biodiversity. *A. princeps* is rich in plant resources and is also widely distributed in all parts of Xiangxi. In Xiangxi, owing to eating habits and regional characteristics, *A. princeps* has been continuously made into "Haocaibaba" for consumption and has formed a special diet culture. People from all ethnic groups living here have adopted "Haocaibaba" as a food source in their daily lives and as a gift to each other. In this study, the raw material plant *A. princeps* was used to determine nutritional components and antioxidant activities to provide a scientific basis for the folk consumption and industrial application of *A. princeps*.

2 Materials and methods

2.1 Collection, identification and treatment of *A. princeps*

The *A. princeps* was collected from the garden of Jishou

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University, Jishou City, Hunan Province, China, in April 2019, and was identified by senior engineer Daigui Zhang. First, the fresh *A. princeps* was washed and dried at a constant temperature of 50 °C, then crushed, screened for 30 mesh, and finally bagged for use.

2.2 Determination of nutrients

Nutrient composition determination was conducted according to national standards: protein: GB 5009.5–2016 (Method 1); fat: GB 5009.6–2016 (Method 1); energy, carbohydrate: GB 28050–2011; crude fiber, dietary fiber (total dietary fiber (TDF), soluble dietary fiber (SDF) and insoluble dietary fiber (IDF)): GB/T 5009.10–2003, GB 5009.88–2014; moisture, ash: GB 5009.3–2016 (Method 2), GB 5009.4–2016 (Method 1); vitamin B_1, B_2, B_3: GB 5009.84–2016 (Method 1), GB 5009.85–2016 (Method 1), GB 5009.89–2016 (Method 2); vitamins A, D, E: GB 5009.82–2016 (vitamin A and E used Method 1, vitamin D used Method 3); vitamin C: GB 5009.86–2016 (Method 1); amino acids: GB 5009.124–2016, tryptophan refer to GB/T 15400–2018, cystine refer to GB/T 15399–2018; mineral elements: GB 5009.268–2016 (Method 1); crude polysaccharide: phenol-sulfuric acid colorimetric method in SN/T 4260–2015; total polyphenols: GB/T 8313–2018; and total flavonoids: curve equation $y = 0.016{,}6x - 0.023{,}1$, $r^2 = 0.998{,}7$[14]. The content was calculated on a dry basis.

2.3 Nutritional composition evaluation

The nutritional value of amino acids was evaluated according to the method of Yao *et al.*[15,16]. The amino acid composition of *A. princeps* was determined using the amino acid scoring standard model recommended by Food and Agriculture Organization/World Health Organization (FAO/WHO). Specific indicators included the ratio of amino acids (RAA) (equation (1)), ratio coefficient of amino acids (RC), and score of RC (SRC).

$$\mathrm{RAA}(\%) = \frac{C_x}{C_s} \times 100 \quad (1)$$

where C_x is the amino acid content in the sample (mg/(g N)); C_s is the amino acid content in the reference protein (mg/(g N)); and mg/(g N) is the quality of amino acids per gram of nitrogen (the content of amino acids in *A. princeps* × 62.5 × 100/the content of protein of *A. princeps*).

RC was calculated as the amino acid ratio per mean RAA. If the sample amino acid composition is the same as the amino acid composition, the RC of each amino acid should be equal to 1. An RC > 1 indicates that such amino acids are excessive in the amino acid composition pattern of the food; otherwise, it indicates that such amino acids are relatively insufficient. The amino acid with the smallest RC is the first limiting amino acid, and so on. SRC was calculated by equation (2).

$$\mathrm{SRC} = 100 - \mathrm{CV} \times 100 \quad (2)$$

where CV is the coefficient of variation of RC, and CV is the standard deviation/mean.

The significance of SRC is that when the amino acid composition of the sample is consistent with the amino acid composition of FAO/WHO, then CV = 0 and SRC = 100. The smaller the SRC, the worse the nutritional value of the protein source; the closer the SRC is to 100, the higher the nutritional value.

2.4 Scavenging effect on DPPH

A slight modification was made to the method of Wang *et al.*[17] to determine the scavenging effect on 1, 1-diphenyl-2-picrylhydrazyl radicals (DPPH). DPPH was dissolved in 95% ethanol, and a 0.058 mg/mL solution was prepared. 4 mL of the sample extract at different mass concentrations were mixed with 4 mL DPPH solution, which reacted at room temperature for 60 min in the dark, and contrasted with 95% ethanol. The other conditions remained unchanged. Four milliliters of 95% ethanol were used as the blank group, instead of DPPH solution. vitamin C and butylated hydroxytoluene (BHT) were used as positive controls. The absorbance value was measured at 517 nm on a UV-Vis spectrophotometer to calculate the scavenging rate of the extract. Free radical scavenging rate was calculated by equation (3).

$$\text{Free radical scavenging rate}(\%) = \left(1 - \frac{A_e - A_i}{A_s}\right) \times 100\% \quad (3)$$

where A_s is the absorbance value of the control tube; A_e is the absorbance value of the sample; and A_i is the absorbance value of the blank tube.

2.5 Scavenging effect on $ABTS^+$•

The method of Wang *et al.*[17], with a slight modification, was used to determine the scavenging effect on 2, 2′ -amino-di (3-ethylbenzthiazoline sulphonic acid-6) ammonium salt cationic radicals ($ABTS^+$•). ABTS aqueous solution (7 mmol/L) was mixed with the same volume of 2.45 mmol/L potassium persulfate solution and placed at room temperature in the dark for 12 h. The mixture was diluted with distilled water, and the absorbance was measured at 731 nm. In the range of 0.7 ± 0.2, it was used as the ABTS mixed dilution for subsequent experiments.

The prepared sample extracts (0.6 mL), as well as vitamin C and BHT solutions of different mass concentrations, were added to 5.4 mL ABTS solution and shaken. After reacting for 6 min at room temperature, the absorbance of the solution in each test tube was measured at a wavelength of 731 nm. The absorbance value and scavenging rate were calculated. The other conditions were unchanged, and 95% ethanol was used as the control; 5.4 mL of water was used as the blank group instead of ABTS solution. Free radical scavenging rate was calculated by equation (4).

$$\text{Free radical scavenging rate}(\%) = \left(1 - \frac{A_e - A_i}{A_s}\right) \times 100 \quad (4)$$

where A_s is the absorbance value of the control tube; A_e is the absorbance value of the sample; and A_i is the absorbance value of the blank tube.

2.6 Determination of total reducing power

Following Feng *et al.*[18], 1 mL of sample extracts of different mass concentrations was placed into centrifuge tubes, and 2.5 mL of 0.2 mol/L phosphate buffer (pH 6.6) and 2.5 mL of 1% potassium ferricyanide solution were added. After being mixed at 50 °C for 30 min, and 2.5 mL of 10% trichloroacetic acid was added and centrifuged at 4,200 r/min for 10 min. In a centrifuge tube, 2.5 mL distilled water and 0.5 mL 0.1% ferric chloride solution were added to 2.5 mL of supernatant. After reacting for 10 min, the zero was adjusted with distilled water as a blank group, and the absorbance value was measured at 693 nm. Other conditions remained unchanged. Ethanol (95%) was used as a

control, and vitamin C and BHT were used as positive controls.

2.7 Determination of ferric-reducing antioxidant power (FRAP)

According to Xu *et al.*[19] with some modifications, 0.8 mL of sample extracts with different mass concentrations were added to 5.6 mL of distilled water and 3.6 mL of TPTZ working solution that was freshly prepared and preheated to 37 °C. The samples were mixed well and placed in a 37 °C water bath for 30 min. Absorbance was measured at 599 nm. The greater the measured absorbance value, the greater the iron reduction ability of the sample. Vitamin C and BHT were used as positive controls.

2.8 β-Carotene fading test

Following Li *et al.*[20] with some modifications, 6 mg β-carotene was dissolved in 1 mL chloroform and 40 μL linoleic acid and 400 μL Tween 80 were added and mixed well. The samples were rotary evaporated at 40–50 °C to remove the chloroform, and 10 mL of distilled water was immediately added. The solution was transferred to a 250 mL volumetric flask, and 0.01 mol/L H_2O_2 was used to adjust the volume to 250 mL. In a test tube, 10 mL of the above-configured solution and 1 mL sample solution, positive control (vitamin C and BHT) (20 mg/L), blank solvent (normal control group) were mixed well and placed in a 50 °C water bath. Absorbance was measured at 470 nm every 30 min until the carotene-related color percentage (equation (5)) was less than 25%.

$$\text{β-Carotene color percentage}(\%) = \left(1 - \frac{A_{\text{test at 0 min}} - A_{\text{test at } t \text{ min}}}{A_{\text{control at 0 min}} - A_{\text{control at 180 min}}}\right) \times 100 \quad (5)$$

where $A_{control}$ is the absorbance of the blank group with distilled water; A_{test} is the absorbance of the sample group with the extract; and t is the reaction time.

2.9 Ferric thiocyanate (FTC) experimental determination

To determine the FTC content, Zhang *et al.*[21] was followed with modifications. 2 mL of ethanol solution (2,000 mg/L) of the sample was added to 2 mL of 2.5% linoleic acid absolute ethanol solution and 4 mL of 50 mmol/L phosphate buffer (pH 7.0), sealed with 2 mL distilled water, and placed in a 40 °C incubator protected from light. In the normal control group, considering that the experiment was sealed with water, it was replaced with 2 mL of ethanol solution that did not contain the sample to be tested, and vitamin C and BHT were used as positive controls. Starting from time 0, the reaction solution was measured every 24 h.

Using 0.1 mL of the reaction solution, 9.7 mL of 75% ethanol aqueous solution, 0.1 mL of 30% ammonium thiocyanate solution, and 0.1 mL of ferrous chloride solution (3.5% hydrochloric acid is configured to have a concentration of 0.02 moL/L) were mixed quickly and evenly. After reacting for 3 min, the absorbance value was measured at 484 nm. The absorbance value was measured every 24 h until the value of the control group reached the maximum.

2.10 Experimental determination of thiobarbituric acid (TBA)

One milliliter of the reaction solution used in the FTC experiment was added to 2 mL of 20% trichloroacetic acid aqueous solution and 2 mL of 0.67% TBA solution and mixed well. The samples were placed in a boiling water bath to react for 10 min. The samples were centrifuged at 3,000 r/min for 20 min. The supernatant was collected, and its absorbance was measured at 533 nm. The antioxidant activity of the sample was calculated based on the absorbance value measured on the last day of the FTC experiment; that is, the value measured on the second day when the absorbance value of the normal control group reached its maximum value. Inhibit the percentage of lipid peroxidation was calculated by equation (6).

$$\text{Inhibit the percentage of lipid peroxidation}(\%) = \frac{A_s - A_i}{A_s} \times 100 \quad (6)$$

where A_s is the standard absorbance value, and A_i is the sample absorbance value.

2.11 Statistical analysis

The data were analyzed using Microsoft Office Excel 2003 and OriginPro 9.1 drawing software. All of the statistical analyses (paired t test or non-paired t test (two tails)) were based on at least 3 parallel repeated experiments, and the results were expressed in terms of $\bar{x} \pm s$.

3 Results

3.1 Contents of basic nutrients

Different components of fresh *A. princeps* were analyzed in this study. In 100 g fresh plant material, there was 1,094.00 kJ energy matter, 19.54 g protein, 1.69 g fat, 27.00 g carbohydrate, 10.17 g moisture, 11.22 g ash, and 38.31 g dietary fiber (Table 1). The dried sample of *A. princeps* contained three vitamins, A, E, and B_2, with contents of 0.03, 2.30, and 0.42 mg/100g, respectively (Table 1). In addition, general nutrient content in other plants were referred to Chinese food ingredient list[22].

3.2 Composition and evaluation of amino acids

3.2.1 *Composition of amino acids*

The protein content of *A. princeps* was 19.54 g/100 g, and the total amount of amino acids (TAA) was 16.63 g/100 g. It contained at least 18 amino acids (Table 2), among which Asp content was the highest (some may be produced by Asn hydrolysis), followed by Glu, and cystine content was the lowest.

3.2.2 *Essential amino acids*

Essential amino acids refer to amino acids that cannot be synthesized by the human body (or other vertebrates) or the synthesis speed of which is far from the needs of the body and must be supplied by food proteins. These include Lys, Trp, Phe, Met, Thr, Ile, Leu, and Val. There are two other essential amino acids for children: His and Arg. *A. princeps* contains all eight essential amino acids and the two for children, with the total amount of essential amino acids being 5.86 g/100 g and that for children being 0.66 and 1.02 g/100 g. In addition, the ratios of total essential amino acids/total amino acids (TEAA/TAA) and total essential amino acids/total non-essential amino acids (TEAA/TNAA) were 35.22% and 54.36%, respectively, which were close to the FAO/WHO standard values (36.35% and 57.11%, respectively), and were quite different from the

Table 1 General nutrient content in *A. princeps* and other plants (dry weight, $n = 3$)

Index	*A. princeps*	*Zea mays*	*Oryza sativa*	*Solanum tuberosum*	*Brassica pekinensis*	*Spinacia oleracea*	*Coriandrum sativum*
Energy (kJ/100 g)	1,094.00 ± 0.00	1,457	1,464	1,437	1,275	1,290	1,296
Protein (g/100 g)	19.54 ± 0.10	10.02	8.35	6.43	6.89	7.05	8.16
Fat (g/100 g)	1.69 ± 0.02	4.38	1.14	0.56	0.89	0.66	1.43
Carbohydrate (g/100 g)	27.00 ± 0.00	73	78.3	80.7	72.9	75.7	71.2
Moisture (g/100 g)	9.23 ± 0.02	13.2	12.6	11.4	10	9.2	9.3
Ash (g/100 g)	10.81 ± 0.13	1.5	0.92	1.92	11.22	8.92	11.91
Dietary fiber (g/100 g)	38.31 ± 0.49	7.37	0.92	3.72	10.46	13.99	9.04
Vitamin A (mg/kg)	0.03 ± 0.00	0.02	0.00	0.00	0.00	0.66	0.52
Vitamin C (mg/kg)	0.00	0.00	0.00	22.57	207.78	90.31	82.69
Vitamin D (mg/kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vitamin E (mg/kg)	2.30 ± 0.03	4.48	1.48	0.00	0.00	8.51	24.42
Vitamin B_1 (mg/kg)	0.00	0.24	0.13	0.16	0.27	0.22	0.19
Vitamin B_2 (mg/kg)	0.42 ± 0.00	0.15	0.05	0.00	0.00	0.2	0.31
Vitamin B_3 (mg/kg)	0.00	2.88	2.63	0.00	5.33	4.3	6.62
Ca (mg/kg)	10,552.39 ± 115.46	16.13	29.75	44.02	1,008.89	452.64	797.13
K (mg/kg)	38,311.76 ± 1292.17	3.46	156.75	301.35	2,521.11	10.9	1,136.71
Na (mg/kg)	121.55 ± 5.75	3.8	1.72	25.51	547.22	266.52	1,342.34
Mg (mg/kg)	2,290.05 ± 78.35	110.6	56.06	57.56	243.33	201.54	296.58
Fe (mg/kg)	350.04 ± 15.28	2.76	1.6	2.71	15.33	28.52	24.59
Zn (mg/kg)	54.10 ± 0.35	1.96	1.76	0.46	5.2	4.31	1.89
Se (mg/kg)	0.20 ± 0.02	4.06×10^{-3}	3.10×10^{-3}	2.45×10^{-3}	7.03×10^{-3}	0.01	0.02
Cu (mg/kg)	17.41 ± 0.19	0.29	0.29	1.48	0.97	2.29	1.82
Mn (mg/kg)	116.89 ± 1.95	0.55	1.76	0.41	2.94	1.77	2.71

Table 2 Amino acid content (g/100 g) of *A. princeps* and *Glycine max* (dry weight, $n = 3$)

Amino acids	*A. princeps*	*G. max*	Amino acids	*A. princeps*	*G. max*
Asp*	2.17 ± 0.01	4.63	His***	0.66 ± 0.02	0.96
Thr**	0.77 ± 0.01	1.4	Lys**	0.90 ± 0.02	2.33
Ser*	0.73 ± 0.01	1.81	Arg***	1.02 ± 0.02	2.88
Glu*	1.85 ± 0.04	6.3	Pro*	1.78 ± 0.09	3.31
Gly*	0.88 ± 0.02	1.53	Trp**	0.23 ± 0.00	0.46
Ala*	0.92 ± 0.03	1.67	Cys	0.19 ± 0.00	0.34
Val**	0.88 ± 0.02	1.71	TAA	16.63 ± 0.37	37.25
Met**	0.19 ± 0.01	0.33	TEAA	5.86 ± 0.13	12.58
Ile**	0.70 ± 0.02	1.67	TFAA	8.34 ± 0.19	19.25
Leu**	1.33 ± 0.03	2.76	TEAA/TAA (%)	35.22	33.77
Tyr	0.57 ± 0.01	1.24	TFAA/TAA (%)	50.12	51.68
Phe**	0.85 ± 0.02	1.92	TEAA/TNEAA (%)	54.36	50.99

Note: Asp: Aspartic; Thr: Threonine; Ser: Serine; Glu: Glutamine; Gly: Glycine; Ala: Alanine; Val: Valine; Met: Methionine; Ile: Isoleucine; Leu: Leucine; Tyr: Tyrosine; Phe: Phenylalanine; His: Histidine; Lys: Lysine; Arg: Argnine; Pro: Proline; Trp: Tryptophane; Cys: Cysteine; **essential amino acids; ***essential amino acid for children; *flavor amino acid; TEAA: total essential amino acids; TNEAA: total non-essential amino acids.

composition pattern of egg protein amino acids (49.80% and 99.22%, respectively; Table 2). It is generally believed that the closer the protein amino acid composition ratio is to the FAO/WHO standard value and the closer the essential amino acid composition ratio is to the human essential amino acid ratio, the better the quality of a plant and the higher its nutritional value. From the perspective of the balance of amino acids, the composition pattern in *A. princeps* was similar to human protein. From the perspective of the composition ratio of essential amino acids, although the composition ratios of *A. princeps* and *G. max*[22,23] were slightly different; they both contained all eight essential amino acids and the two for children. The ratio of TEAA/TAA in *A. princeps* was higher than that in *G. max*; therefore, the ratio of *A. princeps* was closer to the ratio of essential amino acids in the human body compared with that of *G. max*. Thus, the protein in *A. princeps* is high quality or has a high biological price, and some of its qualities were better than those of *G. max*.

3.2.3 *Evaluation of amino acids*

Tables 3 and 4 show the evaluation results of the amino acid nutrition of *A. princeps* based on FAO/WHO. According to the

Table 3 Amino acid scores of *A. princeps* and *G. max*

Essential amino acids	*A. princeps*	*G. max*	Egg	FAO/WHO	Ratio of amino acids-*A. princeps*	Ratio coefficient of amino acids-*A. princeps*	Ratio of amino acids-*G. max*	Ratio coefficient of amino acids-*G. max*
Ile	223	268	331	250	67.37	98.43	80.97	111.73
Leu	426	443	534	440	79.78	116.55	82.96	114.48
Lys	289	374	441	340	65.53	95.74	84.81	117.03
Met + Cys	122	107	386	220	31.61	46.18	27.72	38.25
Phe + Tyr	455	507	565	380	80.53	117.65	89.73	123.83
Thr	247	225	292	250	84.59	123.58	77.05	106.33
Trp	74	74	106	60	69.81	101.99	69.81	96.34
Val	281	274	411	310	68.37	99.89	66.67	92.00

Table 4 Limiting amino acid composition of *A. princeps* and *G. max*

Material		Ile	Leu	Lys	Met + Cys	Phe + Tyr	Thr	Trp	Val	SRC
A. princeps	RAA-P	0.89	0.97	0.85	0.55	1.20	0.99	1.23	0.91	77.64
	RC-P	0.94	1.02	0.90	0.58	1.26	1.04	1.30	0.96	
G. max	RAA-M	1.07	1.01	1.10	0.49	1.33	0.90	1.23	0.88	74.36
	RC-M	1.07	1.01	1.10	0.49	1.33	0.90	1.23	0.88	

principle that the lowest grade of amino acid represents the grade of protein, the amino acid score of *A. princeps* was 0.58, which was higher than that of *G. max*[22, 23].

3.3 Analysis of the antioxidant of total flavonoids

3.3.1 *Scavenging effect on DPPH and ABTS$^+$•*

It can be inferred from Fig. 1A that the total flavonoids of *A. princeps* had a scavenging effect on DPPH. Within the concentration range of 1.25–1,280 mg/L, the scavenging rate of DPPH showed an upward trend, and when the concentration was 1,280 mg/L, the scavenging rate was at the maximum of 90.34%, after which the scavenging rate stabilized, and its half inhibitory mass concentration (IC_{50}) was 14.78 mg/L. The maximum scavenging rates of BHT and vitamin C were 87.81% and 95.94%, respectively, and their IC_{50} were 34.62 and 9.40 mg/L, respectively. Vitamin C showed the strongest free radical scavenging capacity. The maximum scavenging rate of the total flavonoids of *A. princeps* was slightly greater than that of BHT, and the IC_{50} of the total flavonoids of *A. princeps* to DPPH was less than that of BHT. The scavenging capacity of *A. princeps* on DPPH was dose dependent, and the scavenging capacity of the total flavonoids was stronger than that of BHT.

It can be inferred from of Fig. 1B. that the total flavonoids of *A. princeps* had ABTS$^+$• scavenging capacity. Within the experimental concentration range, the scavenging rate of ABTS$^+$• showed an upward trend. When the concentration was 320 mg/L, the maximum scavenging rate was 99.03%, and its IC_{50} was 96.02 mg/L. Meanwhile, the maximum scavenging rates of BHT and vitamin C were 98.61% and 100.00%, respectively, and their IC_{50} were 53.36 and 16.06 mg/L, respectively. The data indicated that the total flavonoids of *A. princeps*, BHT, and vitamin C had the maximum scavenging rates on ABTS$^+$• and were basically the same; the IC_{50} of ABTS$^+$• was greater than that of BHT and vitamin C. The scavenging capacity of *A. princeps* on ABTS$^+$• was dose dependent.

3.3.2 *Experimental effect of total reducing capacity*

As shown in Fig. 2A, the total flavonoids of *A. princeps* had a total reduction capacity, and the absorbance value within the experimental concentration range showed an upward trend. Under the condition of 1.25–320 mg/L, the order of the reducing capacity of each substance was vitamin C > total flavonoids of *A. princeps* > BHT, indicating that *A. princeps* had a total reducing capacity that was weaker than that of vitamin C. The total reducing capacity of *A. princeps* was dose dependent.

As seen in Fig. 2B, within the experimental concentration range, the absorbance value of the total flavonoids of *A. princeps* showed an upward trend, and the FRAP of BHT gradually became stronger. Within the concentration range of 1.25–320 mg/L, the FRAP of vitamin C gradually became stronger. The order of experimental effect of FRAP of each substance was BHT > vitamin C > total flavonoids of *A. princeps*, and their FRAP had a certain dose-effect relationship with the concentration. When the concentration was greater than 320 mg/L, the FRAP of the total flavonoids of *A. princeps* was better than that of vitamin C and continues to be less effective than that of BHT. The FRAP of

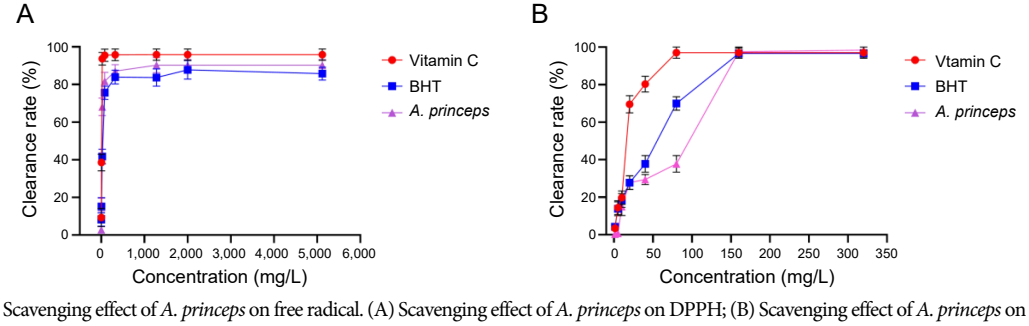

Figure 1 Scavenging effect of *A. princeps* on free radical. (A) Scavenging effect of *A. princeps* on DPPH; (B) Scavenging effect of *A. princeps* on ABTS$^+$.

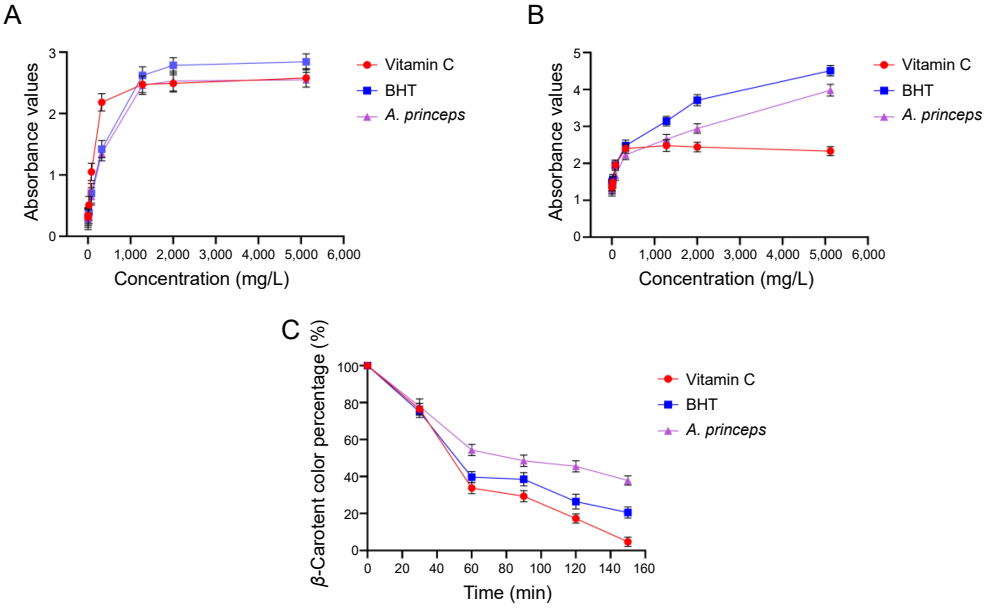

Figure 2 Reduction ability of *A. princeps*. (A) Total reducing capacity; (B) FRAP; (C) Inhibition of carotene fading.

A. princeps was dose dependent, and the FRAP of the total flavonoids of *A. princeps* was better than that of vitamin C when over a certain concentration range.

As shown in Fig. 2C, at a concentration of 20 mg/L, when the relative absorbance of carotene drops to 50%, the time required by the group with vitamin C, BHT, and total flavonoids of *A. princeps* was 48.23, 51.47, and 68.34 min, respectively. According to the results, *A. princeps* could effectively delay the fading of *β*-carotene.

3.3.3 *Experimental effect of FTC and TBA*

Figure 3A shows that the absorbance value of the normal control group increased with time and reached its maximum on the 7th day. The absorbance value of BHT did not change significantly over time, indicating that BHT has the best ability to inhibit lipid peroxidation. The absorbance values of vitamin C and the total flavonoids of *A. princeps* increased over time but were always lower than those of the normal control group. Of the two, the absorbance value of the total flavonoids of *A. princeps* was always lower than that of vitamin C. These results indicated that both vitamin C and *A. princeps* have a certain ability to inhibit lipid peroxidation, and the ability of the total flavonoids of *A. princeps* was better than that of vitamin C.

It could be inferred from Fig. 3B. that the inhibition rates of BHT and the total flavonoids of *A. princeps* and vitamin C were compared with the normal control group, and the ratios were 94.36%, 82.61%, and 48.66%, respectively. This indicates that *A. princeps* had a stronger ability to inhibit lipid peroxidation than vitamin C.

4 Discussion

Compared with the results of a previous study[13], vitamin C was not previously detected in dehydrated *A. princeps*, but it was detected in the fresh sample (64.36–90.58 mg/100 g), indicating that dehydration would cause serious loss of vitamin C in *A. princeps*. It could be inferred that *A. princeps* actually contains four vitamins: A, C, E, and B_2. *A. princeps* contained 25 mineral elements, among which the content of K was the highest, at 38,311.76 mg/kg, followed by Ca, Mg, Fe, Al, Mn, and Na, the contents of which were 10,552.39, 2,290.05, 350.04, 299.37, 116.89, and 121.55 mg/kg, respectively. In addition, according to the national limit standards (GB 2762–2017), the limits of toxic heavy metals, such as Pb, As, Hg, and Sn, are ≤5.0, ≤0.5, ≤0.1, and ≤250 mg/kg, respectively. The Pb, As, Hg, and Sn contents in *A. princeps*, measured on a wet basis according to national limit standards, were 1.94, 0.26, 0.02, and 0.03 mg/kg, respectively, which were within the national limit and thus meet the food safety requirements. It can be inferred that there are rich and diverse mineral elements in *A. princeps*, the raw material plant of "Haocaibaba" in Xiangxi, and that this plant is safe and

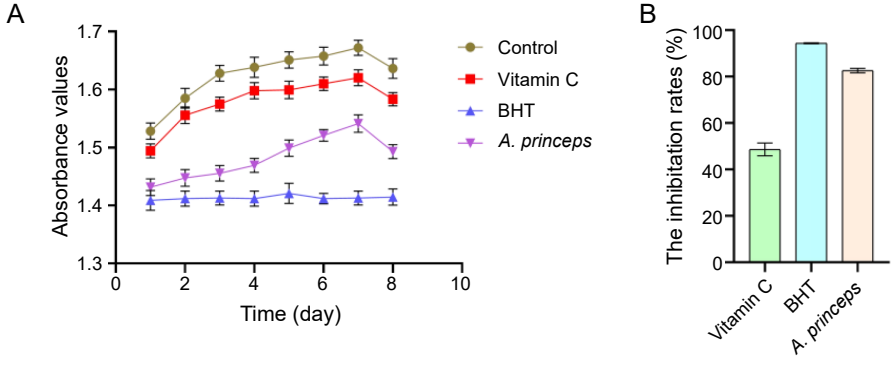

Figure 3 Lipid peroxidation experiment. (A) FTC experimental determination; (B) TBA experimental determination.

pollution-free.

Compared with *O. sativa*, which was the original main material of "Haocaibaba," *Z. mays* and *S. tuberosum*, which are common minor cereals in mountainous areas, and *B. pekinensis*, *S. oleracea*, and *C. sativum*, three common vegetables[24], the protein and fat contents of *A. princeps* were higher than that of *O. sativa*, *S. tuberosum*, *B. pekinensis*, *S. oleracea*, and *C. sativum*. To be more specific, the protein content of *A. princeps* was higher than *Z. mays* and was 2–3 times that of *O. sativa* and *S. tuberosum*, but the fat content was lower than that of *Z. mays*. The ash content of *A. princeps* was higher than that in *Z. mays*, *O. sativa*, *S. tuberosum*, and *S. oleracea* and lower than that in *B. pekinensis* and *C. sativum*. The moisture content in *A. princeps* was higher than that in *S. oleracea* and was lower than that in *Z. mays*, *O. sativa*, *S. tuberosum*, *B. pekinensis*, and *C. sativum*. The energy and carbohydrate contents of *A. princeps* were lower than those of the other six crops evaluated. Therefore, *A. princeps* can be considered a characteristic plant with high protein and fat content, rich minerals, low energy, and low carbohydrates, and it has the potential to be a new resource of plant-derived protein.

The crude fiber content of *A. princeps* was lower than previously reported[13]. The TDF content was higher than that in *Z. mays*, *O. sativa*, *S. tuberosum*, *B. pekinensis*, *S. oleracea*, and *C. sativum*[22], being 40 times higher than that in *O. sativa* and at least 2 times higher than in the other crops. Therefore, *A. princeps* can be considered an ideal source of crude and dietary fiber, with good functional value. Eating foods rich in crude fiber has a good preventive effect on diabetes, hyperlipidemia, and cardiovascular diseases, and proper crude fiber consumption will not reduce the utilization of other nutrients; dietary fiber can regulate human intestinal health and prevent and effectively cure cardiovascular diseases, diabetes, and colon cancer[24]. The higher the content of TDF, the better the physiological function of dietary fiber.

In addition, among the contents of Ca, K, Na, Mg, Fe, Zn, Se, Cu, and Mn of *A. princeps*, except for the content of Na, which was lower than that of *B. pekinensis*, *S. oleracea*, and *C. sativum* and higher than that of *Z. mays*, *O. sativa*, and *S. tuberosum*, the contents of other elements were higher in *A. princeps* than in the other six crops evaluated. This indicates that *A. princeps* is a resource plant rich in Ca, K, Na, Mg, Fe, Zn, Se, Cu, and Mn. Among the trace elements of *A. princeps*, the contents of Fe, Mn, and Zn were relatively high and contained 0.20 mg/kg Se. The four elements of Fe, Mn, Zn, and Se are important to the physiological functions of the body, and *A. princeps* has a certain functional value. In addition, the values of K/Na, Zn/Cu, and Zn/Fe of *A. princeps* were 315.18, 3.11, and 0.15, respectively. Foods with a K/Na value greater than 1 are high-K and low-Na foods and are considered to have certain effects on preventing atherosclerosis and cardiovascular and cerebrovascular diseases[25]. When the value of Zn/Cu is greater than 10 and the value of Zn/Fe is greater than 1, there is antagonism[26]. *A. princeps* is rich in nutrients, such as Mg, K, and Ca, and is a high-K and low-Na food, which are of medicinal value; it also contains appropriate amounts of Zn, Cu, and Fe. In addition, vitamin B_2 content in *A. princeps* was higher than that of the other crops evaluated. The vitamin C content was higher than that of *Z. mays*, *O. sativa*, *S. tuberosum*, *S. oleracea*, and *C. sativum* but lower than that of *B. pekinensis*; the content of vitamin E was higher than that of *O. sativa*, *S. tuberosum*, and *B. pekinensis* but lower than that of *Z. mays*, *S. oleracea*, and *C. sativum*. The vitamin A content was higher in *A. princeps* than that in *Z. mays*, *O. sativa*, *S. tuberosum*, and *B. pekinensis* but lower than that in *S. oleracea* and *C. sativum*. Among these vitamins, vitamin B_2 can prevent many uncomfortable symptoms of the body, and vitamins C and E have pharmacological effects, including antioxidant and anti-aging activities[27]. *A. princeps* may have pharmacological effects, such as preventing body discomfort symptoms and antioxidant and anti-aging effects, which are beneficial.

This composition was similar to that of vegetables, such as *Erythropalum scandens*, Cangyuan *Dendrocalamus giganteus*, and *Dendrocalamus latiflorus* Munro[28, 29]. This indicates that *A. princeps* is a resource plant rich in Asp and Glu. In addition, the amino acid composition of *A. princeps* was similar to that of *G. max*[22, 23], the main source of plant-derived protein, although the content of protein and the TAA of *A. princeps* were comparatively lower. Modern research has confirmed that Asp and Glu can regulate brain and nerve metabolism, promote protein synthesis in the body, and improve self-immunity, and Arg helps the proliferation and synthesis of fibers and collagen, which can promote wound healing[15]. *A. princeps* is rich in a variety of amino acids; therefore, it is a healthy food and an ideal dietary resource for people recovering from surgeries.

In addition to three restrictive amino acids (Lys, Ile, and Val in order of RC), there are two restrictive amino acids, Met and Cys. Of the two, the minimum RC of Met + Cys was 0.58; therefore, Met + Cys was the first limiting amino acid. The SRC value of *A. princeps* was 77.64, which indicates that there was a certain difference in the protein amino acid composition of *A. princeps* and that prescribed by FAO/WHO, but it was higher than that of the food crop soybean[22, 23], the wild vegetable papaya ficus[30], and edible mushrooms, such as Bachu mushroom and hairy fungus[31, 32]. Thus, protein from *A. princeps* can still be considered of high nutritional value. In addition, the protein of *A. princeps* also had a high Trp content (RC up to 1.30), which can help to improve the body's nutritional balance when used in the daily diet in conjunction with foods that relatively lack Trp. From the perspective of amino acids, *A. princeps* is a source plant for high-quality protein.

Crude polysaccharides, total polyphenols, and total flavonoids are important characteristics of food raw materials and have specific active functions. Among them, crude polysaccharides are widely found in fungi and plants and have a variety of health benefits, such as antioxidation, anti-tumor, hypoglycemic, and immune regulation activities. Polyphenols are called "the seventh category of nutrients" with multiple activities, such as antioxidation, anti-cancer, and anti-aging activities[17] and have broad market prospects in industries, such as medicine, food, and cosmetics. Flavonoids, an effective ingredient of many Chinese medicinal materials, have a variety of biological activities. *A. princeps* contained 1.50 g/100 g crude polysaccharides, 3.90 g/100 g total polyphenols, and 7.97 g/100 g total flavonoids.

5 Conclusions

A. princeps is rich in nutrients, and its high nutritional value, and antioxidant activity have confirmed the rationality of using it to make "Haocaibaba" in the Xiangxi region.

The basic nutrients of *A. princeps* are high in protein, ash, fat, TDF, and IDF and can meet the nutritional needs of the human body, similar to *Z. mays*, *O. sativa*, *S. tuberosum*, *B. pekinensis*, *S. oleracea*, and *C. sativum*. *A. princeps* is also rich in mineral elements. *A. princeps* is also rich in trace elements, such as Fe, Mn, and Zn, and constant elements, such as Mg, K, and Ca. *A. princeps* contains four indispensable vitamins for humans: vitamins A, C,

E, and B_2. Among the four vitamins, B_2, C, and E are the most abundant, and they are excellent sources of vitamin supplements.

A. princeps also has antioxidant activity. Within a certain concentration range, the scavenging effect of the total flavonoids of *A. princeps* on DPPH, $ABTS^{+}$• and reducing capacity were positively correlated with mass concentration. The total flavonoids of *A. princeps* can effectively delay the fading of carotene and have a good inhibitory effect on lipid peroxidation.

Conflicts of interest

The authors declare that there are no conflicts of interest in this work.

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