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Chemical characterization of Chinese chive seed (*Allium tuberosum* Rottl.)

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Abstract

Chinese chive seeds (*Allium tuberosum* Rottl.) (grown in China) were investigated. Density, thousand-grain weight, and hectolitre weight of seeds were 1.27 g/cm^3, 4.9 g, and 71 kg/100 l, respectively. The results showed that Chinese chive seeds contained high amounts of oil (15.8%), dietary fibre (18.2%) and crude protein (12.3%). Oil of seeds was composed of 10.1% saturated and 90.0% unsaturated fatty acids. Linoleic(69.1%) and palmitic (7.0%) were the most abundant unsaturated and saturated fatty acids, respectively. Chinese chive seeds contained 4.5 mg/kg of thiamin, 2.8 mg/kg of riboflavin and 55.1 mg/kg of niacin. The mineral contents of the seed of *A. tuberosum*, for iron, calcium and zinc, were 580 mg/kg, 1328 and 80.8 mg/kg, respectively. Analysis of the amino acid content of Chinese chive seed revealed that it was a rich source of the essential amino acids, isoleucine, tryptophan and lysine. The study revealed that Chinese chive seeds had high levels of nutritionally important components, such as oil, minerals and essential amino acids.

Keywords: Chinese chive seeds; *Allium tuberosum*; Characterization; Chemical

1. Introduction

Since ancient times, many *Allium* species, such as onion, garlic, leek, and chives, have been used as foods, spices, and herbal remedies in widespread areas of the world, especially in the northern hemisphere. It is well known that the *Allium* genus, with about 500 species, is a rich source of steroidal saponins, alkaloids, as well as sulfur-containing compounds (Hostettmann & Marston, 1995; Zou, Yu, & Cong, 1999). The scientific name of Chinese chive is *Allium tuberosum* Rottl. ex Spreng (Chinese chive, Liliaceae). Chinese chive is one of the daily edible green vegetables for Chinese people. *A. tuberosum* Rottl. ("791" is the most widely cultivated of all varieties) is distributed all over mainland China and used, not only as food, but also as medicine.

China is the largest Chinese chive-producing country. Chive is widely cultivated in China, and the seeds have been reputedly used as a traditional Chinese medicine for treating both impotence and nocturnal emissions (Jiangsu New Medicinal College, 1979). According to the dictionary of Chinese drugs (Jiangsu New Medical College, 1986), the leaves have been used for treatment of abdominal pain, diarrhea, hematemesis, snakebite and asthma, while the seeds of this plant are used in Chinese folk medicine as a tonic and aphrodisiac. Chinese chive seed has been consumed as food and medicine in China for a long time. It was accepted for human consumption as a food and medicine by the Chinese government in 2001. With regard to the constituents of the *A. tuberosum*, some new steroidal saponins, alkaloids and amides have been reported (Sang, Lao, Wang, & Chen, 1999; Sang, 2000a; Sang, Mao, Lao, & Chen, 2000b; Zou, Yu, & Cong, 2001) in the *Allium*

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genus seed. However, no chemical analysis has been carried out on the nutrients of this plant seed up to now. In order to clarify its bioactive compounds, we systematically studied the chemical constituents of the seeds of *A. tuberosum*. The objective of the present investigation was to characterize chemical and nutritional properties of Chinese chive seeds grown in China.

2. Materials and methods

2.1. Materials

2.1.1. Raw materials

A. tuberosum Rottl. seed ("791") that had been cultivated in the Qingpu district (31°14′N, 121°29′E) of Shanghai, China, in 2002, were purchased from Shanghai Shun-Feng-Tang Group, China in July 2003. Before chemical analysis, the seed of *A. tuberosum* was milled into fine powder.

2.1.2. Chemicals

The vitamin standards were purchased from Sigma (St. Louis, Missouri, USA). HPLC grade methanol, benzene, 2,2-dimethoxypropane, *n*-hexane and *n*-heptane were obtained from Sigma (St. Louis, Missouri, USA). The other chemicals were of analytical grade.

2.2. Methods

2.2.1. Physical characterization of Chinese chive seeds

Physical properties of Chinese chive seeds were characterized by measuring dimensions and densities of seeds, thousand-grain weight, and hectolitre weight (Elgün, Ertugay, & Certel, 1999).

2.2.2. Determination of crude protein, moisture, ash, Oil, and dietary fibre

The recommended methods of the Association of Official Analytical Chemists (AOAC, 1984) were adopted to determine the levels of crude protein, moisture, ash, and oil. Nitrogen content was determined by using the Kjeldahl method (Kjeldahl, 1883) and multiplied by a factor 6.25 to determine the crude protein content. Moisture content was determined by drying the samples at 105 °C to a constant weight. Ash was determined by the incineration of 1.0 g samples placed in a muffle furnace, maintained at 550 °C for 5 h. Crude fat was determined by the Soxhlet method. Crude fat was obtained by exhaustively extracting 5.0 g of each sample in a Soxhlet apparatus using petroleum ether (boiling point range 40–60 °C) as the extractant. Dietary fibre content of the defatted samples was determined by decomposing starches with acids and proteins, with base, and then filtering (Nielsen, 1998). Total carbohydrate was obtained by difference. The energy content was determined by multiplying the percentages of crude protein, crude fat and total carbohydrate by the factors of 4, 9 and 4, respectively (Osborne & Voogt, 1978). The water-holding capacity and swelling capacity were determined according to the method described by Hu and Huang (2000). All results were expressed on a dry weight basis.

2.2.3. Determination of vitamins

Three grams of Chinese chive seeds flour were mixed with 5 ml *n*-hexane and 20 ml HPLC grade water. The mixture was homogenized using an Ultraturrax macerator at 12,000 rpm and then centrifuged at 3500*g* for 30 min. The aqueous phase was filtered through a Whatman 42 filter paper and 0.45 μm membrane filter sequentially, as described previously (Erbas, Certel, & Uslu, 2005). Then, 15 μl of supernatant were injected into the HPLC system equipped with a UV–Vis detector, which was set to 254 nm in absorbance mode. The vitamin standards were prepared in mobile phase. Peaks were verified by adding the standard vitamins to some samples and each peak area was calculated in relation to the standard vitamin peak. The results were calculated on a dry weight basis.

2.2.4. Determination of minerals

Ash obtained from ash determination was carefully transferred into a 100 ml beaker using 20 ml of 1 M HCl and digested on a boiling water bath for 30 min. The suspension was filtered with Whatman's No. 1 filter paper into a 100 ml volumetric flask and made to the mark with distilled water. This was done for the samples and served as stock solution for the various mineral determinations. The filtrate was made up to 50 ml with double-distilled water and used for determination of total phosphorus, calcium, iron, zinc, copper and manganese. Calcium, iron, zinc, copper and manganese in the acid-digested samples were determined by atomic absorption spectrophotometry, using a 2380, Perkin–Elmer (USA) atomic absorption spectrophotometer.

2.2.5. Determination of fatty acids

Methyl esters of fatty acids from the seed were prepared by using a reaction mixture consisting of methanol, benzene, 2,2-dimethoxypropane (37:20:5:2) and *n*-heptane, as described previously (Erbas et al., 2005; Garces & Mancha, 1993). The seed of *A. tuberosum* (250 mg) were weighed into a glass tube, then, 3 ml of reaction mixture and 2 ml *n*-heptane were added to the sample. Headspace of the tube was filled with carbon dioxide gas and it was covered with a teflon lid. The tube was shaken strongly and placed in a water bath at 80 °C for 2 h. Then, the tube was allowed to reach room temperature until two phases formed. The upper phase (*n*-heptane, 1 μl), containing methyl esters of fatty acids, was injected into a gas chromatograph. The fatty acid composition of the oil was determined by using a gas chromatography(Agilent 6890)–mass spectroscopy (GC–MS) technique under the following operating conditions: chromatogram column (DB-5, Agilent), length, 60 m; column diameter, 0.25 mm; film thickness, 0.25 μm; carrier gas, helium; oven temperature, 35 °C for 3 min, rising to 240 °C at 8 °C/min and held for 10 min; injector temperature, 240 °C; scanning scope, 30–800 a.m.u.; ionization voltage, 70 eV; ionization electric current, 30 μA. A library search was carried out using the Wiley GC–MS Library. The percent fatty acid composition was calculated from the ratio of individual peak area to total definable peak area.

2.2.6. Amino acid analysis

Amino acids were determined using a Mikrotechna AAA 881 automatic amino acid analyzer according to the method described by Moore and Stein (1963). Hydrolysis of the seed samples was performed in the presence of 6 M HCl at 110 °C for 24 h under nitrogen atmosphere. Tryptophan content was determined colorimetrically, as described by Miller (1967). Sulfur-containing amino acids were determined after performing acid oxidation, as described by Moore (1963). Analyses were performed in duplicate.

2.2.7. Determination of Antinutritional factors

Trypsin inhibitor activity determination was performed as described by Liu and Markakis (1989). Total tannins (Methods No: 9.098, 9.099, 9.100) were determined colorimetrically, as described by AOAC (1990). Wheeler and Ferrel (1971) procedure was followed for analysis of phytic acid.

3. Results and discussion

Thousand grain weight, hectolitre weight, and density of seeds were found to be 4.9 ± 0.21 g, 71 ± 1.2 kg/100 l and 1.27 ± 0.014 g/cm^3, respectively. The chemical composition of Chinese chive seeds is presented in Table 1. Chinese chive seeds flour had a high amount of dietary fibre (18.2%). These fibres have many desirable properties, including high water-holding capacity (9.5 ± 0.65 g H_2O/g) and swelling capacity (10.1 ± 0.79 g H_2O/g).

Niacin, thiamin and riboflavin contents of Chinese chive seeds were determined in the present study and compared with soybean and wheat (Table 2). Among the foods listed in Table 2, niacin content (55.1 mg/kg) was the highest in Chinese chive seeds. However, their thiamin content was lower than those of soybean and wheat. Riboflavin content of Chinese chive seeds was higher than that of wheat but it was lower than that of soybean. Daily requirement of the human for niacin, thiamin and riboflavin are 6.6, 0.4 and 0.6 mg/4200 kJ (1000 kcal), respectively (Eastwood, 1997). Chinese chive seeds (100 g) can satisfy ≈40% of niacin, 50% of thiamin and 25% of riboflavin requirements for a diet of 8400 kJ/day (2000 kcal/day).

The mineral contents of the seed of *A. tuberosum*, expressed as mg/kg on a dry weight basis, are shown in Table 3. Data presented indicate that the seed of *A. tuberosum* contains many dietary essential minerals, such as calcium, iron, zinc, copper, manganese and sodium. The mineral contents of the seed of *A. tuberosum* for iron, calcium and zinc were 580, 1328 and 80.8 mg/kg, respectively. Because of the high content, Chinese chive seed flour could be used in the human diet for supplying these important minerals. The high content of minerals including zinc, may be an important reason that *A. tuberosum* seed have been reputedly used as a traditional Chinese medicine for treating both impotence and nocturnal emissions. Some research work should be carried out on the minerals of this seed in order to identify the bioactive substance.

The physicochemical properties of the seed oils of *A. tuberosum* are shown in Table 4. The fatty acid compositions for the oils are shown in Table 5. The oil content (15.8%) is similar to the oil content of grapeseed, soybean and corn (Wang, Liao, & Zhang, 1996). It can be seen that

Table 1
Chemical composition of Chinese chive seeds

Components	Value[a] (%)
Moisture	7.8 ± 0.27
Crude protein	12.3 ± 0.31
Dietary fibre	18.2 ± 0.30
Crude fat	15.8 ± 0.12
Ash	2.4 ± 0.09
Total carbohydrate	43.5 ± 0.15
Calorific value (kcal/100 g sample)	365

[a] Values are means ± standard deviations of triplicate determinations.

Table 2
B vitamin contents of Chinese chive seeds, soybean and wheat

Vitamin[a]	Chinese chive seeds[c]	Soybean[b]	Wheat[b]
Thiamin (B1)	4.5 ± 0.14	7.6	4.7
Riboflavin (B2)	2.8 ± 0.16	3.0	1.3
Niacin	55.1 ± 0.49	32.6	54.3

[a] Data are reported on a dry mater basis (mg/kg).
[b] Favier et al. (1995).
[c] Values are means ± standard deviations of triplicate determinations.

Table 3
Mineral contents of Chinese chive seeds

Mineral	Content[a] (mg/kg)
Na	245 ± 0.6
Mg	228 ± 0.9
K	7417 ± 4.9
Ca	1328 ± 3.5
Fe	580 ± 0.6
Cu	46.7 ± 0.34
Zn	80.8 ± 0.29

[a] Values are means ± standard deviations of triplicate determinations.

Table 4
Characteristics of *Allium tuberosum* seed oil

Parameter	Value[a] (%)
Oil content (%)	15.8 ± 0.12
Iodine value (g/100 g)	136.3 ± 0.38
Peroxide value (mEq/kg)	17.8 ± 0.25
Saponification value (mgKOH)	176 ± 0.34

[a] Values are means ± standard deviations of triplicate determinations.

Table 5
Fatty acid compositions of *Allium tuberosum* seed oil

Fatty acid	Value[a] (%)
Palmitic	7.0 ± 0.12
Linoleic	69.1 ± 0.32
Oleic	20.4 ± 0.21
Stearic	1.2 ± 0.17
11-Eicosadecanoic acid	0.5 ± 0.13
Arachidic	0.7 ± 0.08
Behenic	0.9 ± 0.06
Tricosanoic acid	0.11 ± 0.033
Lignoceric	0.22 ± 0.044
Total unsaturation	90.0 ± 0.36

[a] Values are means ± standard deviations of triplicate determinations.

the iodine values (IV) for the oils are consistent with the corresponding total unsaturation of the fatty acids (Table 5). The most abundant unsaturated acid for *A. tuberosum* was linoleic.

Table 5 shows that fatty acids of Chinese chive seeds are composed of 10.1% saturated fatty acids and 90.0% unsaturated fatty acids. The high content of oil in Chinese chive seeds (15.8%), with a high proportion of unsaturated fatty acids, is desirable for human nutrition. The seed oil of *A. tuberosum* contained 9 fatty acids. Linoleic (69.1%) and palmitic (7.0%) were the most abundant unsaturated and saturated fatty acids, respectively. The total unsaturation for the oil was 90.0%. In addition, the monounsaturated fatty acid (11-eicosadecanoic acid) was found in seed oil of *A. tuberosum*. The oil contained many essential fatty acids, and therefore, has potential nutritional value. The presence of unsaturated fatty acids, namely, linoleic, oleic and 11-eicosadecanoic acid confer considerable nutritional value. The total unsaturation of the fatty acids was similar to the seed oil of *Helianthus annuus* (Unsaturation: 91.3%, linoleic: 66.2%, oleic: 25.1%) (Fasman, 1975) and linseed oil (91.3%) (Tarandjiiska, Marekov, Nikolova-Damyanova, & Amidzhin, 1996). The total unsaturation of the fatty acids of *A. tuberosum* seed oil was comparable to the value for soybean (84.6%) (Tarandjiiska et al., 1996) and grapeseed (59–79%) (Wang et al., 1996), but the distribution of unsaturation in the former is slightly narrower. From the results, it is clear that *A. tuberosum* seed oil is of important nutritional value.

Analysis of the amino acid content of Chinese chive seed revealed that it was a rich source of the essential amino acids, isoleucine, tryptophan and lysine as compared with the FAO/WHO (1973) reference pattern (Table 6). Lysine is usually the limiting amino acid found in cereal grains. Chinese chive seed was also found to contain substantial amounts of the sulfur-containing amino acid methionine as well as arginine, an essential amino acid for infants.

Some antinutritional factors of Chinese chive seed are shown (Table 7). Screening for antinutritional components, such as trypsin inhibitor (trypsin inhibitor activity, 1.29 TUI/mg), revealed little measurable activity in Chinese chive seed. The contents of tannins and phytic acid were also very low in *A. tuberosum* seed. To the best of our knowledge there are no data reported in the literature regarding the antinutritional factors for Chinese chive seed.

Table 6
Amino acid composition of Chinese chive seed (g/16 g nitrogen)

Amino acid	Chinese chive seed[a]	FAO/WHO (1973)
Threonine	3.4	4.0
Tryptophan	1.3	1.0
Valine	4.3	5.0
Isoleucine	4.8	4.0
Leueine	7.1	7.0
Lysine	6.8	5.5
Cystine	1.0	–
Methionine	2.3	–
Total sulfur amino acids	3.3	3.5
Tyrosine	2.0	–
Phenylalanine	3.5	–
Total aromatic amino acids	5.5	6.0
Total essential amino acids	36.5	36.0
Aspartic acid	8.6	
Serine	5.2	
Glutamic acid	14.0	
Glycine	10.1	
Alanine	4.5	
Proline	6.7	
Histidine	2.3	
Arginine	12.1	
Total non-essential amino acids	63.5	

[a] Values are average of two determinations.

Table 7
Antinutritional factors of Chinese chive seed (g/100 g dry weight flour)

Antinutritional factors	Chinese chive seed[a]
Trypsin (TUI/mg protein)	1.29 ± 0.06
Tannins	0.11 ± 0.02
Phytic acid	0.15 ± 0.02

[a] Values are means ± standard deviations of triplicate determinations.

4. Conclusion

Chinese chive seeds (*A. tuberosum* Rottl.) (grown in China) were investigated. Density, thousand-grain weight, and hectolitre weight of seeds were 1.27 g/cm^3, 4.9 g, and 71 kg/100 l, respectively. The results showed that Chinese chive seeds contained high amounts of oil (15.8%), dietary fibre (18.2%) and crude protein (12.3%). Oil of seeds was composed of 10.1% saturated and 90.0% unsaturated fatty acids. Linoleic (69.1%) and palmitic (7.0%) were the most abundant unsaturated and saturated fatty acids, respectively. Chinese chive seeds contained 4.5 mg/kg of thiamin, 2.8 mg/kg of riboflavin and 55.1 mg/kg of niacin. The mineral contents of the seed of *A. tuberosum*, for iron, calcium and zinc were 580, 1328 and 80.8 mg/kg, respectively. Analysis of the amino acid content of total Chinese chive seed revealed that it was a rich source of the essential amino acids, isoleucine, tryptophan and lysine. It can be inferred that the seeds investigated are rich sources of unsaturated fatty acids, lysine, niacin and minerals.

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