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ORIGINAL RESEARCH PAPER

Oriental brassica vegetables – alternatives for a higher intake of health-promoting substances

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Abstract

Brassica vegetables are one of the most important groups of vegetables in terms of their nutritional composition. The aim of this work was to evaluate the lesser known Asian species from the family Brassicaceae cultivated in the conditions of the Czech Republic and to carry out a comparison with cabbage as a reference species. For the evaluation, two species of Chinese broccoli, two cultivars of Chinese cabbage ('Dwarf milk cabbage' and improved 'Tahtsai') and mizuna were selected. Among the properties evaluated were dry matter production, crude fiber content, vitamin C, carotenoids, TAC, flavonoids, phenols, and mineral composition (K, Na, Ca, and Mg). The highest contents of vitamin C were found in mizuna and the lowest in Chinese Cabbage 2. In comparison to the reference species, the majority of the properties of Chinese cabbage had higher values in comparison to traditional cabbage (range: 101–577%). Positive results were also found for mizuna. The worst brassica was Chinese Cabbage 2 in which the majority of the properties measured were lower in comparison to traditional cabbage.

Keywords

Brassicaceae; Chinese cabbage; mizuna; Chinese broccoli; bioactive compounds

Introduction

The World Health Organization is running a campaign which should help to increase the range, accessibility, and consumption of fruit and vegetables. Vegetables, like fruit, are a significant source of substances that are essential for a healthy human diet. Despite this, their consumption is at an insufficient level in many countries. World Health Organization guidelines recommend the consumption of at least 160–240 g or 2–3 portions of vegetables per day [1]. The greatest influence on the consumption of individual foods is the price, which is the result of increasing energy costs, seeds, feed, fertilizer, treatment preparations, the high profit margins of retail chains, and ultimately the purchasing power of the population. Also to be taken into account is health education, the accessibility of various types of food in the market, and mass advertising. The consumption of fresh vegetables in the Czech Republic in 2016 reached a value of 87.3 kg/person/year [2]. According to the European Health Interview Survey in 2014, in the EU-28 on average a third (34.4%) of the population aged 15 or over did not consume any fruit or vegetables in a day, half (51.4%) of the population ate daily from one to four portions of fruit and vegetables, whilst the remaining 14.3% consumed five or more portions a day. The situation in the Czech Republic falls within the results obtained for the EU average – zero portions: 46.3%, one–four portions: 44.6%, five and more portions: 9.1% [3].

Poor nutrition is a significant contributory factor in many chronic diseases (cancer, heart disease, and diabetes) that currently seriously impact the developed countries

[4]. It is generally accepted that a diet rich in fruit and vegetables can reduce the risk of cancer and most forms of heart disease [5]. Along with the increased public interest in the area of nutrition and health, there has also been an increase in demand for foods with added value [6].

Brassica vegetables are considered to be a significant source of nutrients and bioactive compounds in the daily diet because of their widespread and frequent consumption [7]. The beneficial health properties of brassica crops are due to the presence of health-promoting compounds such as vitamins, carotenoids, phenols, flavonoids, and glucosinolates [8–10]. High intakes of brassica vegetables have been associated with reduced risk from various cancers [11,12]. Vegetables traditionally consumed in Asia are now also being sought out and consumed more frequently by people in western countries [13].

Chinese broccoli (*Brassica oleracea* var. *albiflora*) is reported as an originally Chinese vegetable. It is grown widely in Southern China and Southeast Asia and also is grown in relatively small quantities in Japan, Europe, and America [14]. Chinese broccoli is cultivated in the same way as traditional broccoli [15]. It is grown for its young flowering stems and has a slightly bitter taste and is used in soups, fried or eaten as a steamed vegetable [16]. This brassica is a rich source of vitamin C and bioactive substances such as glucosinolates [14].

Mizuna (*Brassica rapa* ssp. *japonica*), considered a delicious vegetable, originally from China, has been cultivated since ancient times in Japan. Mizuna is a very vigorous plant. It is both heat and cold tolerant. It has become prized as an off-season salad vegetable; the leaves are valued for their high content of vitamin C, potassium, and calcium [17]. According to Kudrnáčová and Kouřimská [18], the leaves are used mostly for preparing fresh salads, cooking or pickling.

Chinese cabbage (*Brassica rapa* var. *chinensis*) is one of the most widely used and popular vegetables in China [19] and also in many other countries in Asia [20]. It is characterized by its high nutritional value and increasing relevance for human nutrition [21].

The suitability of the above-mentioned species in terms of production in the conditions of the Czech Republic has already been verified by previous studies [22,23]. The aim of the present study was to determine their nutritional properties and to compare with traditional vegetables consumed in the Czech Republic from the perspective of the intake of health-promoting substances.

Material and methods

Plant material

The study was carried out during the 2017 season in an experimental field at the Faculty of Horticulture in Lednice, Mendel University in Brno, the Czech Republic. The following potential genotypes, collected in China in previous years were selected for testing:

- Chinese broccoli – a leafy vegetable cultivated for its young flowering stems. It is a perennial herb but commercially it is often grown as an annual. It is appropriate for cultivation in a moderate climate and has a level of frost tolerance.
- Chinese cabbage – exists in a great number of types and forms which differ in appearance and size. The first employed here was 'Dwarf milk cabbage' with larger leaves. The second is described as improved 'Tahtsai', and in contrast has a small-leaved rosette with dark leaves.
- Mizuna – described as "Jing Shui Cai", forms a dense clump of gently pinnatisect, serrated leaves which are dark green and smooth.

Plants were grown in trays with a cell volume of 49 mL. Sowing was carried out on July 4. Profimix (Klasmann, Germany) was used as a substrate for the propagation of the seedlings.

They were fertilized twice with Kristalon (NPK 20–5–10) preparation (0.1%) and then planted out on the test plot on August 8. A spacing of 0.3×0.3 m was selected and after planting, the plants were covered with a nonwoven textile (19 g m^{-2}). The experimental design was a system of controlled randomization with four replications. Throughout the period, plants were irrigated using a Meganet sprinkler (Netafim, Israel) as needed. Neither any fertilizing nor chemical protection were used. Harvesting took place on October 18. Selected plants were prepared for consumption (removing roots and old or damaged leaves) and further processed in the laboratory for nutritional analysis.

Nutritional analysis

Total dry matter was determined after drying samples at 105°C until a constant weight was achieved on a digital balance (KERN 400-2; Kern, Germany). The results are expressed in percent of fresh weight (FW). Crude fiber was determined from dried and ground samples by oxidative hydrolysis using FibreBags (Gerhardt, Germany) and expressed in percent of FW. Vitamin C levels were ascertained by RP-HPLC with a LCO-101 column at 254 nm using a UV-VIS detector (Ecom, the Czech Republic). The amount of vitamin C was expressed as mg kg^{-1} FW. The total carotenoids were determined by spectrometry at a wavelength of 440 nm, using a Jenway 6100 (Great Britain) spectrophotometer and expressed as mg kg^{-1} FW, according to the method of Holm [24]. Cation (K, Na, Ca, and Mg) concentrations (mg kg^{-1} FW) were determined by electromigration (capillary isotachophoresis) using an Ionosep Analyzer 2002 (Recman, the Czech Republic). Total flavonoid contents were measured using a modified colorimetric method [25], where the absorbance was measured after 15 minutes against the blank at 510 nm. The flavonoid content was expressed as mg catechin equivalents (CE) × 100 mg^{-1} FW. The total phenolic content was estimated using a modified Folin–Ciocalteu photometric method [25], where the absorbance was measured at 750 nm. It was expressed as mg gallic acid equivalents (GAE) × 100 mg^{-1} FW. The total antioxidant capacity (TAC) of samples was determined using a modified DPPH (2,2-diphenyl-1-picrylhydrazyl) assay [26]. These data are expressed as mM Trolox equivalents (TE) × 1,000 g^{-1} FW. All the laboratory analyses were replicated four times.

The results of the nutritional analyses were compared with reference values for traditional white cabbage according to various sources [27–31].

Data were analyzed using Statistica CZ software (StatSoft, Prague, the Czech Republic). The data were subjected to analysis by the Kruskal–Wallis test. Statistical differences ($\alpha = 0.05$) were determined according to the multiple comparisons test.

Results

The results show a difference in the content of the individual nutritional properties between the species tested. The mean values are given in Tab. 1 and Tab. 2. An overall comparison of ascorbic acid levels is shown in Fig. 1. All the brassicas varied in vitamin C content between 230 and 672 mg kg^{-1}. It can be also seen that Chinese Cabbage 2 showed lower variability in values obtained compared to the other species. Chinese broccoli, Chinese Cabbage 1, and mizuna contained more vitamin C than traditional white cabbage.

A similar evaluation is shown in Tab. 1 and Tab. 2 where the values obtained are compared to the reference values for white cabbage and the difference is expressed as a percentage. For better visualization, the higher value is marked with green and the lower value with orange. It can be seen that there is much variability in the concentrations of all the nutritional properties tested.

Crude fiber, total antioxidant capacity, and Mg were lower in all the brassica species compared with traditional cabbage. Other properties varied according to the genotypes. In general, mizuna and Chinese Cabbage 1 showed the best results from this evaluation followed by Chinese broccoli and the lowest was Chinese Cabbage 2.

Tab. 1 Nutritional properties of mizuna and Chinese broccoli.

Evaluated factor	Reference value for cabbage	Source of reference	Mizuna		Chinese broccoli	
			Value	% share	Value	% share
Dry matter %	7.82	[27]	6.7 ±0.3	85.7	6.4 ±0.3	81.8
Crude fiber (%)	2.5	[27]	1 ±0.0	40.0	1.5 ±0.2	60.0
Vitamin C (mg kg^{-1} FW)	366	[27]	672.3 ±28.3	183.7	554.7 ±27.7	151.6
Carotenoids (mg kg^{-1} FW)	10	[28]	26.0 ±1.1	260.0	6.4 ±1.0	64.0
TAC (mM Trolox × 1,000 g^{-1} FW)	9	[29]	2.0 ±0.4	22.2	0.5 ±0.0	5.5
Flavonoids (mg × 100 g^{-1} FW)	10.6	[30]	23.6 ±3.0	222.6	7.6 ±0.9	71.7
Phenols (mg × 100 g^{-1} FW)	24.6	[31]	104.5 ±15.9	424.8	25.8 ±2.4	104.9
K (mg kg^{-1})	1,700	[27]	3,077.4 ±204.1	181.0	1,899.4 ±126.8	111.7
Na (mg kg^{-1})	180	[27]	45.8 ±3.7	25.4	77.3 ±16.7	42.9
Ca (mg kg^{-1})	400	[27]	496.0 ±72.1	124.0	187.8 ±23.0	47.0
Mg (mg kg^{-1})	120	[27]	89.1 ±6.0	74.3	118.2 ±13.6	98.5

Mean values are expressed with ± standard error.

Tab. 2 Nutritional properties of Chinese Cabbage 1 and 2.

Evaluated factor	Reference value for cabbage	Source of reference	Chinese Cabbage 1		Chinese Cabbage 2	
			Value	% share	Value	% share
Dry matter %	7.82	[27]	7.1 ±0.5	90.8	4.6 ±0.2	58.8
Crude fiber (%)	2.5	[27]	1.0 ±0.1	40.0	0.5 ±0.0	20.0
Vitamin C (mg kg^{-1} FW)	366	[27]	620.6 ±31.7	169.6	230.5 ±9.4	63.0
Carotenoids (mg kg^{-1} FW)	10	[28]	57.7 ±4.5	577.0	1.8 ±0.5	18.0
TAC (mM Trolox × 1,000 g^{-1} FW)	9	[29]	1.8 ±0.1	20.0	1.0 ±0.1	11.1
Flavonoids (mg × 100 g^{-1} FW)	10.6	[30]	21.0 ±0.7	198.1	10.7 ±1.3	100.9
Phenols (mg × 100 g^{-1} FW)	24.6	[31]	77.4 ±4.4	314.6	46.8 ±5.9	190.2
K (mg kg^{-1})	1,700	[27]	3,035.7 ±212.7	178.6	1,350.4 ±44.5	79.4
Na (mg kg^{-1})	180	[27]	181.1 ±46.9	100.6	69.9 ±5.9	38.8
Ca (mg kg^{-1})	400	[27]	414.8 ±29.7	103.7	182.5 ±19.0	45.6
Mg (mg kg^{-1})	120	[27]	91.5 ±9.4	76.3	67.1 ±3.3	55.9

Mean values are expressed with ± standard error.

Discussion

A high fiber content in brassica vegetables has been described by Tanongkankit et al. [32]. In our experiment, lower values were found in all the genotypes tested than in traditional cabbage.

Particular attention was paid to vitamin C, since it is considered to be the most important vitamin for humans in horticultural crops [33]. The red line in Fig. 1 represents the reference value for white cabbage. From this comparison it is obvious that Chinese broccoli, Chinese Cabbage 1, and mizuna are richer in vitamin C, whereas Chinese Cabbage 2 does not reach the value for white cabbage.

Higher carotenoid content, compared to traditional cabbage, was found in the case of mizuna and Chinese Cabbage 1. A higher carotenoid intake in food is desirable since, as stated by Kopsell and Kopsell [34], a higher intake of carotenoids is negatively correlated with cardiovascular diseases and cancer due to the antioxidant properties of these compounds. In all genotypes, the antioxidant capacity was lower. However,

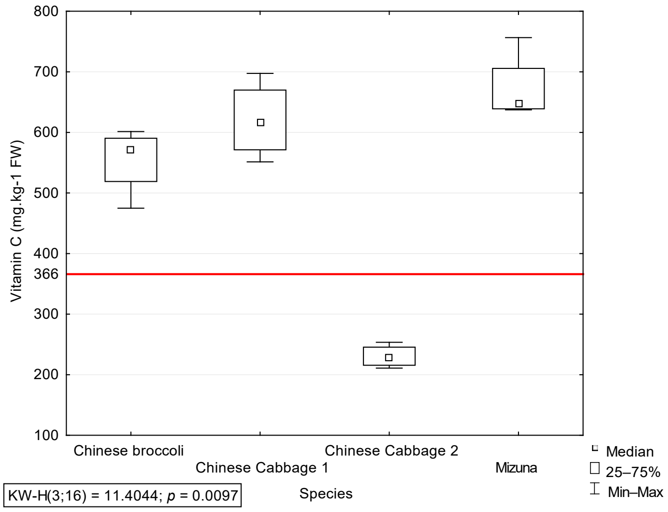

Fig. 1 Vitamin C concentrations for different brassica vegetable species. The red line represents the reference value for white cabbage according to the USDA database.

individual groups of antioxidants (vitamin C, flavonoids, and phenols) reached high values. It is clear that the DPPH method also includes other groups of substances with antioxidant properties for the determination of total antioxidant capacity.

The content of flavonoids was significantly higher only in the cases of mizuna and Chinese Cabbage 1. In Chinese Cabbage 2, there were comparable values. The flavonoid content differed between genotypes, which agrees with the data of Bell and Wagstaff [35], who pointed to differing flavonoid profiles between various genera in the Brassicaceae family.

From our results, it is apparent that all the brassica crops tested are rich in polyphenols. All values are higher compared to white cabbage and also vary between the other brassicas. This is in line with the findings of Amron and Konsue [36], who stated that polyphenol composition can be quite different between *Brassica* species and even among crops from the same species, which was clear when comparing Chinese Cabbage 1 and 2 in this study.

Brassica vegetables generally have a high content of mineral substances [37]. However, the values for the elements measured here showed only a slight elevation compared to traditional cabbage. Amongst the more significant differences is the content of K in mizuna, Chinese Cabbage 1, and Chinese broccoli. For the other elements, the values were similar to or lower than in traditional cabbage.

From the overall evaluation of the nutritional properties, it can be stated that in seven out of the 11, Chinese Cabbage 1 had higher values compared to traditional cabbage. Most of the values significantly exceed the reference values (101–577% of the values for traditional cabbage). A positive difference was also found in mizuna (six out of 11). For the other genotypes, the majority of the properties measured were below the level of the reference material . The poorest evaluation was for Chinese Cabbage 2, in which nine out of 11 properties were lower than those of traditional cabbage.

Conclusion

In the results of this study we can see a range of interesting facts on the content of substances beneficial to health in selected genotypes of Asian vegetables from the Brassicaceae family. The contents were compared to a related reference vegetable species – traditional cabbage, which is one of the most frequently consumed vegetables in the Czech Republic. From the data obtained, Chinese Cabbage 1 and mizuna can be recommended as a good substitute for traditional cabbage, especially in terms of the content of vitamin C, carotenoids, flavonoids, total phenols, and mineral substances.

These vegetable species contain a whole range of the evaluated substances at increased levels and so can provide consumers with important nutrients and antioxidants for a smaller amount consumed than the recipient would get from traditional cabbage. This fact could play an important role in maintaining the intake of substances beneficial to health in a time when generally the amount of fruit and vegetables consumed is falling.

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Azjatyckie warzywa kapustne źródłem związków istotnych dla promocji zdrowia

Streszczenie

Warzywa kapustne charakteryzują się dużym zróżnicowaniem wartości odżywczych. Celem pracy była ocena wartości odżywczej mniej znanych azjatyckich gatunków z rodziny Brassicaceae uprawianych w Czechach oraz porównanie wartości odżywczej tych warzyw z kapustą głowiastą białą. Obiektem badań był brokuł chińska kapusta chińska w typie Tahtsai (odmiany 'Dwarf milk cabbage' i ulepszona 'Tahtsai') oraz kapusta chińska *mizuna*. Analizowano zawartość suchej masy, błonnika surowego, witaminy C, karotenoidów, fenoli, flawonoidów, aktywność antyoksydacyjną ogółem oraz skład mineralny (K, Na, Ca i Mg). Największą zawartością witaminy C charakteryzowała się kapusta chińska *mizuna*, a najniższą 'Tahtsai'. W porównaniu do tradycyjnie uprawianej kapusty głowiastej białej, kapustę chińską charakteryzował wyższy poziom analizowanych parametrów składu chemicznego (pomiędzy 101% a 577%). Najmniej korzystny skład chemiczny w porównaniu do kapusty głowiastej białej charakteryzował kapustę chińską 'Tahtsai'.