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Pungency levels of white radish (*Raphanus sativus* L.) grown in different seasons in Australia

R.C. Coogan[a,*], R.B.H. Wills[a], V.Q. Nguyen[b]

[a]*Department of Food Technology, University of Newcastle, PO Box 127, Ourimbah, NSW 2258, Australia*
[b]*NSWAgriculture, Horticultural Research & Advisory Station, PO Box 581, Gosford, NSW 2250, Australia*

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Abstract

White Radish, or daikon *(Raphanus sativus)* is a popular root vegetable in East Asian countries but there are increasing export opportunities for lower cost agricultural countries such as Australia. The Japanese processing white radish cultivar, Hoshiriso, was grown in spring, summer, autumn and winter on the Central Coast of New South Wales, Australia and accumulation of the characteristic pungent flavour component, 4-methylthio-3-trans butenyl isothiocyanate (MTBITC) during growth was determined. MTBITC concentration was found to be higher in roots grown in autumn and spring than in winter and summer. There was considerable change in MTBITC concentration during growth in all seasons with a maximum concentration occurring 9 weeks after sowing for roots grown in autumn and winter, and after 13 weeks for spring- and summer-grown roots.

1. Introduction

White Radish, or daikon, (*Raphanus sativus* L.) is used widely throughout East Asia as a wide range of fresh, soaked, brined, fermented and dried products (Carlson, Daxenbichler, Van Etten, Hill & Williams, 1985). The taste of raw white radish involves some irritation in the nasal cavity and a burning sensation on the tongue (Lindsay, 1985). The primary compound responsible for the characteristic sulphurous, pungent flavour and aroma has been identified as 4-methylthio-3-trans-butenyl isothiocyanate (MTBITC) (Friis & Kjaer, 1966). MTBITC is produced from the hydrolysis of 4-methylthio-3-trans-butenyl glucosinolate (MTBGSL) by the enzyme myrosinase (Friis & Kjaer). The reaction occurs when cells in the root are disrupted, allowing the enzyme and substrates to mix (Visentin, Tava, Iori & Palmieri, 1992).

Okano, Asano and Ishii (1990) found that the level of MTBITC in 38 white radish cultivars varied widely, ranging from 100 to 1735 μmol/100 g fresh weight with more than half the cultivars in the range 200–300 μmol/100 g. Carlson et al. (1985) determined that the level of MTBGSL in 23 cultivars grown under the same conditions ranged from 109 to 488 μmol/100 g fresh weight. Since MTBGSL is quantitatively converted to MTBITC during processing (Okano et al.), these levels can also be considered as the MTBITC level in processed products. Ishii et al. (1989) found the level of MTBGSL in 20 cultivars to range from 41 to 369 μmol/100 g fresh weight. They also found no significant difference between the level in different roots of the same variety.

Neil and Bible (1973) found that white radish grown under a short photoperiod of 8.5 h had a higher MTBITC content of 344 μmol/100 g than roots grown under a long photoperiod of 15 h (943 μmol/l00 g). They also found a significant difference in MTBITC levels in the same cultivar grown on two soil types. MTBITC levels in radish roots are thus influenced by photoperiod and soil type.

The concentration of MTBITC in white radish is not uniformly distributed and is highest in the distal end of the root, decreasing in upper root sections with the lowest level in vegetative tops (Esaki & Onozaki, 1980; Kazoku et al., 1989). Ishii (1991), in sensory studies, found pungency levels to be higher in the lower sections of root, suggesting higher concentrations of MTBITC. This was supported by measurement of MTBGSL, which was 1127 μmol/100 g fresh weight in the lower tip

* Corresponding author.

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phloem region of roots and 26 μmol/100 g in the top xylem region. Higher concentrations of MTBGSL were found in the epidermal and sub-epidermal layers of the root than in the xylem, phloem and cortex regions (Carlson et al., 1985).

The increasing urbanisation and ageing agricultural population in Japan, Korea and Taiwan has restricted the production of many food crops in these countries. East Asian traders are increasingly seeking to source a wide range of horticultural crops from lower-cost agricultural countries such as Australia which now exports $10 million in Asian vegetables (Lee, 1995). While the varieties of white radish being grown in Australia originate from East Asia, nothing is known of the influence of Australian climate and soil type on development of the pungent flavour. There are also few published data in East Asia on changes in pungency during growth. This work reports on the levels of MTBITC in Hoshinso, a cultivar being promoted to the Australian industry by Japanese traders, that was grown at different times of the year on the Central Coast of New South Wales, Australia.

2. Materials and methods

Crop trials were at the Somersby research farm of the Gosford Horticultural Research & Advisory Station (latitude 33°S, yellow earth with sandy loam) on the NSW Central Coast. The growing seasons studied were spring, summer, autumn and winter with sowing dates being October, December, February and April. The Japanese processing cultivar, Hoshiriso, was planted out in a randomised incomplete block design. Plots were thinned after emergence to a spacing of 15 cm. Roots were harvested at five 2-weekly intervals from 7 weeks after sowing. A sample of 2.5 cm of the distal end of each of four roots was collected and analysed separately. Each sample was hand-grated using a traditional Japanese radish grater that converted root tissue into a pulp. This method was found by Okano et al. (1990) to give the most complete conversion of MTBGSL to MTBITC.

The method of extraction developed by Okano et al. (1990) for the gas chromatographic measurement of MTBITC was used. Juice was squeezed by hand from the pulp of grated samples. Juice (5 ml) and hexane (5 m1) were placed into a sealed 12 ml vial that was shaken vigorously for 40s on a Vortex mixer. The vials were centrifuged at 4000 rpm for 10 min and the solvent fraction removed with a Pasteur pipette into a sealed vial and stored at −20°C until analysis. The extract was injected into a Varian 3400 gas/liquid chromatograph (Walnut Creek CA) using a stainless steel, 2-m column packed with 8% SE-30, Chromosorb 100–120 mesh, DCMS-WAKS (Alltech, Sydney). The operating conditions were injector temperature 250°C, flame ionisation detector 300°C, nitrogen carrier gas flow rate 30 ml/min, hydrogen 40 ml/min and air 300 ml/min. The column temperature was programmed for 1 min at 135°C increasing at 20°C/min to 180°C. The retention time of MTBITC under these conditions was 4.6 min. MTBITC in the samples was measured against a working standard of MTBITC extracted from white radish and its purity quantified as 94% by mass spectrometry (Varian Saturn 3, Walnut Creek, CA) on a 10 μl aliquot of a 1 μl radish extract injected onto a capillary column (30 m × 0.25 mm) containing DB-15 (J & W, Folsom CA), using a split ratio of 20:1. The column temperature was 80°C for 1 min then programmed to 200°C at 5°C/min.

3. Results and discussion

Table 1 shows that the concentration of MTBITC in the distal section of Hoshiriso white radish roots varied greatly between seasons and root age and also between the four roots sampled at each harvest. The mean values for MTBITC at each harvest ranged between 178 and 1142 μmol/l00 g fresh weight of root with the mean level of MTBITC of roots from all harvests and growing periods being 555 μmol/l00 g. Applying a factor of 0.55 to convert the measurement on the distal sample to a whole root concentration (Coogan & Wills, unpublished data) gives a mean total root MTBITC level of 305

Table 1
MTB1TC concentration (μmol/100 g fresh weight) and root weight (kg) of 'Hoshiriso' white radish roots during growth in four seasons[a]

Age (weeks)	Spring		Summer		Autumn		Winter		Mean MTBITC
	Weight	MTBITC	Weight	MTBITC	Weight	MTBITC	Weight	MTBITC	
7	010	534±77	0.28	438±107	0.19	520±93	0.02	374±56	466±76
9	0.39	576±64	0.57	401±96	0.50	1142±162	0.15	620±173	685±138
11	0.90	618±116	1.13	458±68	0.73	702±40	0.30	545±94	581±84
13	1.57	697±97	1.92	499±126	1.06	594±58	0.52	505±63	574±90
15	2.05	695±161	2.08	407±144	1.69	615±127	0.65	151±100	474±134
Mean	1.00	624±108	1.20	441±111	0.83	714±105	0.33	440±106	555

[a] Each value for weight and MTBITC is the mean of samples taken from four roots. The standard deviation for each MTBITC value is also given.

μmol/100 g and a range of about 100–630 μmol/100 g. These values are in the range found for white radish in general and are similar to the value of 282 μmol/100 g for the single sample of Hoshiriso analysed by Carlson et al. (1985).

While white radish roots increased in size with age and larger roots were formed during spring and summer than in winter, there was no consistent pattern to the considerable changes in MTBITC levels. The mean concentration of MTBITC in roots grown in autumn (714 μmol/100 g) and spring (624 μmol/100 g) was significantly higher ($P < 0.0l$) than in roots grown in summer and winter (about 440 μmol/l00 g). The differences were, however, not related to growing temperature with the mean soil temperature being 18.6°C during spring growth, 20°C in autumn, 21°C in summer and 15.8°C in winter. The effect could, in part, be related to photoperiod with medium day length in spring and autumn favouring MTBITC accumulation in the root. The similar MTBITC level accumulating during summer and winter is, however, contrary to the findings of Neil and Bible (1973) who found that a short photoperiod resulted in higher levels of MTBITC than a long photoperiod.

The overall effect of root age was that the concentration of MTBITC was maximal after 9 weeks growth at about 680 μmol/100 g and significantly higher ($P < 0.01$) than at 7 and 15 weeks. However, this trend was only seen in autumn and winter-grown roots with maxima of about 1140 and 620 μmol/100 g, respectively. Spring-grown roots showed a much lower range in concentration over the season with a maximum MTBITC level of about 700 μmol/100 g occurring in the more mature roots ($P < 0.05$). Summer grown roots showed no significant change in MTBITC over the growing period.

From a crop yield perspective, the growth rate of roots was not dissimilar in summer, spring and autumn with root weights of 1.7–2.1 kg achieved after 15 weeks. The rate of growth in winter was much lower with a root weight of about 0.6 kg attained after 15 weeks. It would therefore seem more economically attractive to grow the crop in Australia during spring, summer or autumn. While there is considerable variation in the level of MTBITC during this growing period, there is no published literature that has determined the market preference for level of pungency in fresh white radish that will translate into the desired level in the final processed product. Thus it is not possible to define the preferred cropping time within the spring–autumn period until such data are generated.

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