low-resolution mass spectral analyses.

**Registry No.** Verruculogen, 12771-72-1; penitrem A, 12627-35-9; fumigaclavine C, 62867-47-4; fumigaclavine A, 6879-59-0; festuclavine, 569-26-6.

LITERATURE CITED

Arp, L. H.; Richard, J. L. *J. Am. Vet. Med. Assoc.* **1979**, *175*, 565.
Cole, R. J. *J. Food Prot.* **1981**, *44*, 715.
Cole, R. J.; Kirksey, J. W.; Dorner, J. W.; Wilson, D. M.; Johnson, J. C., Jr.; Johnson, A. N.; Bedell, D. M.; Springer, J. P.; Chexal, K. K.; Clardy, J. C.; Cox, R. H. *J. Agric. Food Chem.* **1977**, *25*, 826.
Fayos, J.; Lokensgard, D.; Clardy, J.; Cole, R. J.; Kirksey, J. W. *J. Am. Chem. Soc.* **1974**, *96*, 6785.
Maes, C. M.; Steyn, P. S.; van Heerden, F. R. *J. Chromatogr.* **1982**, *234*, 489.
Pitt, J. I. "The Genus *Penicillium* and Its Teleomorphic States Eupenicillium and Talaromyces"; Acedemic Press: London, 1979.
Ramirez, C. "The Manual and Atlas of the Penicillia"; Elsevier Biomedical Press: Amsterdam, The Netherlands, 1982.
Richard, J. L.; Arp, L. H. *Mycopathologia* **1979**, *67*, 107.
Samson, R. A.; Stolk, A. C.; Hadlok, R. *Stud. Mycol.* **1976**, *11*, 1.
Smith, D. F.; Lynch, G. P. *J. Dairy Sci.* **1973**, *56*, 828.
Spilsbury, J. F.; Wilkinson, S. *J. Chem. Soc.* **1961**, 2085.
Wilson, B. J.; Wilson, C. H.; Hayes, A. W. *Nature (London)* **1968**, *220*, 77.
Yamano, T.; Kishino, K; Yamatodani, S.; Abe, M. *Takeda Kenkyusho Nempo* **1962**, *21*, 95.

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# Nutrient Composition of Chinese Vegetables

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Data on the levels of water, protein fat, sugars (glucose, fructose, sucrose), starch, dietary fiber, organic acids, ash, sodium, potassium, calcium, iron, magnesium, zinc, vitamin C, thiamin, riboflavin, niacin, carotenes, and energy content are reported for 15 Chinese vegetables—Chinese chives, Chinese spinach, Chinese white cabbage, mustard cabbage, Chinese flowering cabbage, Chinese cabbage, garland chrysanthemum, water spinach, watercress, hairy melon, wax gourd, angled luffa, bitter melon, bean sprouts, and yard-long beans.

Vegetables traditionally consumed by the Chinese population in many countries are now consumed more frequently by people of non-Chinese origin, not only in Asia but also in Western countries along with the increased general popularity of Chinese food. However, there are few data in the literature on the nutrient composition of these Chinese vegetables. Vitamin C, crude fiber, sugar, and dry matter of the major Chinese cabbage variety (*Brassica pekinensis*) have been reported [e.g., AVRDC (1975, 1980)], but in other studies [e.g., Wuensch (1975) and Kayukova, 1977) there is inadequate identification of what botanical species is meant by "Chinese cabbage". Germinated mung bean sprouts [*Vigna radiata* (L.) R. Wicz (*Phaseolus aureus roxb.*; *phaseolus radiatus* L.; *Phaseolus sublobatus* Roxb.)] have been examined for protein content (AVRDC, 1975, 1976, 1979), with considerably more compositional data available on the unsprouted bean seed [e.g., Del Rosario et al., 1980; Creswell, 1981). Data available on mustard cabbage (*Brassica juncea*) is mostly on the composition of the seeds (Gambhir et al., 1979; Singh et al., 1979) rather than the leafy vegetable (Sreeramula, 1982). There are a number of studies on various vegetables that only report values for a single nutrient, particularly protein (Grubben, 1975; Rodriguez et al., 1975; Bruemmer, 1980), and Chen et al. (1982) have determined neutral detergent fiber in a number of vegetables. The most comprehensive data on Chinese vegetables are contained in the food tables produced for use in East Asia (FAO, 1972), but as with many national or regional food tables, the values are an amalgum of data from various unknown sources without any guide as to the reliability of individual values. In this study we have analyzed 15 types of Chinese vegetables grown in market gardens in Sydney, Australia, for proximate composition and a range of vitamins and minerals.

## MATERIALS AND METHODS

Two samples each of 15 types of vegetable were obtained from a market garden in Sydney, Australia, as commercially mature produce either in March (summer grown) or July (winter grown) during 1982. On arrival at the laboratory, each food was identified, initially with reference to Dahlen and Phillipps (1980) and confirmed with the procedure of Nicholas (1974). The inedible portion was removed and the proportion of edible weight determined. The edible portion was homogenized in a blender. Samples were removed for determination of total vitamin C by the

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Table I. Nomenclature, Edible Portion, and Harvest Date of Vegetables Analyzed

| botanical name | plant part | common name: English | common name: Cantonese | harvest time | item as purchased: edible portion, % | item as purchased: inedible part |
|---|---|---|---|---|---|---|
| leafy vegetables | | | | | | |
| *Allium tuberosum* | leaf | Chinese chives | gau choi | July | 97 | lower stem |
| *Amaranthus tricolor* | leaf, stem | Chinese spinach | een choi | March | 89 | lower stem |
| *Brassica chinensis* | leaf, stem | Chinese white cabbage | baak choi | July | 98 | lower stem |
| *Brassica juncea* var. rugosa | leaf, stem | mustard cabbage (Indian mustard) | gaai choi | March | 94 | roots |
| *Brassica parachinensis* | leaf, stem, flower | Chinese flowering cabbage | choi sum | July | 94 | lower stem |
| *Brassica pekinensis* | leaf, stem | Chinese cabbage (celery cabbage) | wong-baak | July | 92 | lower stem |
| *Chrysanthemum coronarium* | leaf, stem | garland chrysanthemum | tong ho | July | 92 | lower stem |
| *Ipomoea aquatica* | leaf, stem | water spinach | ong choi | March | 100 | |
| *Rorippa nasturtium-aquaticum* | leaf, stem | watercress | sai yeung choi | July | 100 | |
| vegetable fruits | | | | | | |
| *Benincasa hispida* | fruit (small) | hairy melon | tseet gwa | March | 98 | skin |
| *Benincasa hispida* | fruit (large) | wax gourd (winter melon) | dong gwa | March | 68 | skin, seeds |
| *Luffa acutangula* | fruit | angled luffa (silk gourd) | sze gwa | March | 54 | skin, seeds |
| *Momoridica charantia* | fruit | bitter melon (balsam pear, bitter gourd) | foo gwa | March | 84 | seeds |
| legumes | | | | | | |
| *Vigna radiata* | seed | bean sprouts | ah choi | July | 100 | |
| *Vigna sesquipedalis* | seed, pod | yard-long bean (string bean) | dau gok | March | 92 | tips, stem |

Table II. Vitamin and Mineral Composition of Chinese Vegetables (mg/100 g of Edible Portion)

| vegetable | vitamins: vitamin C | thiamin | riboflavin | niacin | carotene,[a] μg: α | β | cryptoxanthin | minerals: Na | K | Ca | Fe | Mg | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| leafy vegetables | | | | | | | | | | | | | |
| Chinese chives | 55 | 0.01 | 0.20 | 0.9 | 15 | 3260 | 150 | 3 | 400 | 52 | 2.4 | 20 | 0.4 |
| Chinese spinach | 55 | 0.20 | 0.21 | 0.8 | 210 | 1710 | 100 | 6 | 630 | 110 | 3.9 | 85 | 0.2 |
| Chinese white cabbage | 29 | 0.01 | 0.05 | 0.5 | 10 | 490 | 20 | 10 | 260 | 60 | 1.3 | 8 | 0.1 |
| mustard cabbage | 100 | 0.06 | 0.09 | 0.6 | 140 | 1550 | 40 | 3 | 450 | 130 | 0.7 | 11 | 0.1 |
| Chinese flowering cabbage | 46 | 0.01 | 0.10 | 0.8 | 15 | 1360 | 20 | 13 | 340 | 70 | 1.7 | 12 | 0.5 |
| Chinese cabbage | 20 | 0.03 | 0.04 | 0.4 | 0 | 190 | 0 | 6 | 250 | 25 | 0.3 | 8 | 0.2 |
| garland chrysanthemum | 19 | 0.01 | 0.18 | 0.6 | 20 | 1440 | 55 | 32 | 620 | 100 | 3.2 | 25 | 0.4 |
| water spinach | 28 | 0.01 | 0.15 | 0.8 | 30 | 1180 | 35 | 25 | 460 | 68 | 2.4 | 29 | 0.2 |
| watercress | 101 | 0.02 | 0.16 | 0.8 | 20 | 1980 | 40 | 48 | 570 | 85 | 3.0 | 23 | 0.7 |
| vegetable fruits | | | | | | | | | | | | | |
| hairy melon | 69 | 0.07 | 0.05 | 0.2 | 0 | 20 | 0 | 2 | 250 | 12 | 0.3 | 15 | 0.2 |
| wax gourd | 27 | 0.02 | 0.05 | 0.4 | 20 | 10 | 0 | 1 | 77 | 5 | 0.3 | 4 | 0.2 |
| angled luffa | 18 | 0.05 | 0.01 | 0.2 | 40 | 65 | 15 | 0 | 160 | 14 | 0.3 | 14 | 0.2 |
| bitter melon | 50 | 0.05 | 0.03 | 0.4 | 30 | 40 | 10 | 3 | 260 | 22 | 0.9 | 16 | 0.1 |
| legumes | | | | | | | | | | | | | |
| bean sprouts | 12 | 0.03 | 0.11 | 0.5 | 10 | 10 | 10 | 1 | 150 | 10 | 0.4 | 14 | 0.6 |
| yard-long bean | 32 | 0.04 | 0.11 | 0.6 | 25 | 450 | 35 | 1 | 150 | 23 | 0.5 | 26 | 0.4 |

[a] Limit of detection = 10 μg/100 g.

microfluorometric method (AOAC, 1980) and water by vacuum drying at 70 °C. The remaining homogenate was frozen and stored at −18 °C. The frozen homogenate was analyzed for protein by an automated Kjeldahl procedure, fat was analyzed by acid hydrolysis, sugars were analyzed by high-performance liquid chromatography (HPLC), and starch was analyzed by enzymic hydrolysis of the residue from the sugar analysis and estimation of the glucose by HPLC. Dietary fiber was determined gravimetrically on the residue remaining from the starch analysis with corrections being made for residual protein and ash. Organic acids were analyzed by HPLC. Ash was determined in a muffle furnace at 600 °C, and the levels of sodium, potassium, calcium, iron, magnesium and zinc were determined on an acid solution of the ash by atomic absorption spectrophotometry. Thiamin was measured as thiochrome, riboflavin by fluorometry, and niacin after reaction with cyanogen bromide by using standard AOAC (1980) methods. Carotenes were determined as α-crotene, β-carotene, and cryptoxanthin following separation by column chromatography. Energy content was calculated. Details of all these methods have been given in Wills et al. (1980, 1984).

## RESULTS AND DISCUSSION

Details of Chinese vegetables analyzed in this study are given in Table I. The proximate composition of the vegetables is given in Table III. Water was the major constituent in all vegetables with an average value of about

Table III. Proximate Composition of Chinese Vegetables (g/100 g of Edible Portion)

| vegetable | water | protein[a] | fat | sugars: glucose | sugars: fructose | sugars: sucrose | starch | dietary fiber | organic acids: malic | organic acids: citric | organic acids: oxalic | organic acids: total | ash | energy, kJ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| leafy vegetables | | | | | | | | | | | | | | |
| Chinese chives | 90.6 | 2.7 | 0.5 | 0.4 | 0.3 | 0.3 | 0.0 | 3.2 | 0.10 | 0.09 | 0 | 0.19 | 0.9 | 83 |
| Chinese spinach | 91.7 | 2.9 | 0.4 | 0.0 | 0.2 | 0.0 | 0.1 | 4.5 | 0.03 | 0.01 | 0.16 | 0.20 | 1.9 | 71 |
| Chinese white cabbage | 95.5 | 1.1 | 0.2 | 0.6 | 0.4 | 0.0 | 0.0 | 2.7 | 0.14 | 0.03 | 0 | 0.17 | 0.7 | 44 |
| mustard cabbage | 93.8 | 2.3 | 0.3 | 0.4 | 0.3 | 0.0 | 0.0 | 1.8 | 0.09 | 0.05 | 0 | 0.14 | 1.6 | 62 |
| Chinese flowering cabbage | 94.2 | 1.3 | 0.3 | 0.5 | 0.3 | 0.0 | 0.1 | 2.8 | 0.05 | 0.01 | 0.01 | 0.07 | 1.1 | 49 |
| Chinese cabbage | 95.7 | 1.1 | 0.0 | 0.6 | 0.3 | 0.0 | 0.0 | 1.1 | 0.08 | 0.11 | 0 | 0.19 | 0.4 | 35 |
| garland chrysanthemum | 93.9 | 1.7 | 0.4 | 0.2 | 0.1 | 0.0 | 0.1 | 3.4 | 0.14 | 0.08 | 0 | 0.22 | 1.5 | 52 |
| water spinach | 92.2 | 2.9 | 0.5 | 0.2 | 0.3 | 0.0 | 0.5 | 3.0 | 0.20 | 0.18 | 0.01 | 0.39 | 1.4 | 89 |
| watercress | 90.8 | 2.9 | 0.4 | 0.4 | 0.1 | 0.2 | 0.1 | 3.8 | 0.16 | 0.15 | 0 | 0.31 | 1.4 | 80 |
| vegetable fruits | | | | | | | | | | | | | | |
| hairy melon | 93.8 | 0.7 | 0.0 | 0.9 | 0.8 | 0.0 | 0.3 | 2.1 | 0.03 | 0.01 | 0 | 0.04 | 0.7 | 44 |
| wax gourd | 96.8 | 0.3 | 0.0 | 0.5 | 0.5 | 0.0 | 0.0 | 1.5 | 0.11 | 0.07 | 0 | 0.18 | 0.3 | 23 |
| angled luffa | 94.9 | 1.2 | 0.1 | 0.7 | 0.8 | 0.0 | 0.2 | 2.4 | 0.08 | 0.06 | 0 | 0.14 | 0.4 | 53 |
| bitter melon | 93.8 | 0.9 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 3.3 | 0.09 | 0.02 | 0 | 0.11 | 0.6 | 20 |
| legumes | | | | | | | | | | | | | | |
| bean sprouts | 92.3 | 3.1 | 0.1 | 0.5 | 0.5 | 0.0 | 0.6 | 2.8 | 0.07 | 0.02 | 0 | 0.09 | 0.4 | 84 |
| yard-long bean | 89.5 | 3.3 | 0.3 | 0.7 | 0.6 | 0.1 | 0.2 | 4.6 | 0.08 | 0.11 | 0 | 0.19 | 0.6 | 95 |

[a] $N \times 6.25$.

93 g/100 g. Most of the dry matter consisted of protein and dietary fiber. Protein was highest in the legumes (3.1–3.3 g/100 g) and lowest in the vegetable fruits (0.3–1.2 g/100 g). Dietary fiber content ranged from 1.1 to 4.6 g/100 g, being highest in yard-long bean and Chinese spinach. Total sugars were low and generally present at about 1 g/100 g or less with glucose and fructose being the major sugars in all vegetables. Fat and starch levels were always low. Total organic acids were also low with the highest levels being in water spinach (0.39 g/100 g) and watercress (0.31 g/100 g). In common with most fruit and vegetables, malic and citric acids were the dominant acids except for Chinese spinach where oxalic acid was present at 0.16 g/100 g and comprised 80% of the total acids. The energy content was low in all vegetables.

The vitamin and mineral composition is given in Table II. The level of vitamin C in watercress and mustard cabbage was about 100 mg/100 g and in hairy melon about 70 mg/100 g, and these vegetables are therefore good sources of vitamin C in relation to recommended daily dietary allowances (NH&MRC, 1970; NRC, 1980). All the other vegetables contained 12–55 mg/100 g vitamin C and can be considered as useful sources. $\beta$-Carotene was the major carotene present and was highest in Chinese chives (3260 $\mu$g/100 g). Seven of the nine leafy vegetables contained >1000 $\mu$g/100 g $\beta$-carotene and can be considered to be useful sources of vitamin A. The levels of thiamin, riboflavin, and niacin in all vegetbles were low in relation to dietary allowances.

All the non-*Brassica* leafy vegetables had useful levels of iron ranging from iron levels of 0.3–1.7 mg/100 g. The level of potassium was higher in the leafy vegetables than in the vegetable fruits and legumes with Chinese spinach, garland chrysanthemum, and water cress containing about 600 mg/100 g. Calcium was present at >100 mg/100 g in mustard cabbage, Chinese spinach, and garland chrysanthemum; however, much of the calcium in Chinese spinach could be in the form of calcium oxalate and hence biologically unavailable since 160 mg/100 g oxalic acid was present (Table III). The levels of calcium in the other leafy vegetables, except Chinese cabbage, were higher than in the vegetable fruits and legumes. The level of magnesium was much higher in Chinese spinach (85 mg/100 g) than in the other vegetables.

Meaningful comparison of the data generated in this study with literature values is difficult due to the fragmented scope of the published data. The values presented here for dietary fiber, individual sugars, starch, organic acids, magnesium, and zinc are the first set of comprehensive data published for Chinese vegetables while the data for most nutrients on Chinese chives and hairy melon are original. Comparison with the East Asia food tables (FAO, 1972) shows some discrepancies, the most prominent being that the values for carotenes in this study are markedly lower. This would seem to be due to the previous use of AOAC methods that result in overestimation (Gebhardt et al., 1977; Wills et al., 1984). Vitamin C levels were higher in this study for a number of vegetables, notably watercress, mustard cabbage and Chinese spinach. These differences could also be due to methodology as the commonly used dye–titration method (AOAC, 1980) does not estimate dehydroascorbic acid but differences could also be due to maturity and cultivars.

Overall, many Chinese vegetables can be considered to be useful sources of various nutrients. Vitamin C was present in all vegetables at nutritionally significant levels and a number are good sources. The five non-*Brassica* leafy vegetables (Chinese chives, Chinese spinach, garland chrysanthemum, water spinach, and watercress) and mustard cabbage are of particular interest as they also contain useful levels of β-carotene, iron, potassium, calcium, and dietary fiber.

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**Registry No.** D-Glucose, 50-99-7; D-fructose, 57-48-7; sucrose, 57-50-1; malic acid, 6915-15-7; citric acid, 77-92-9; oxalic acid, 144-62-7; vitamin C, 50-81-7; thiamin, 59-43-8; riboflavin, 83-88-5; niacin, 59-67-6; sodium, 7440-23-5; potassium, 7440-09-7; calcium, 7440-70-2; iron, 7439-89-6; magnesium, 7439-95-4; zinc, 7440-66-6; starch, 9005-25-8.

LITERATURE CITED

AOAC "Official Methods of Analysis", 13th ed.; Association of Official Analytical Chemists: Washington, DC, 1980.
AVRDC "Annual Report for 1975"; The Asian Vegetable Research and Development Center: Taiwan, 1976.
AVRDC "Annual Report for 1978"; The Asian Vegetable Research and Development Center: Taiwan, 1979.
AVRDC "Annual Report for 1979"; The Asian Vegetable Research and Development Center: Taiwan, 1980.
Bruemmer, J. H.; Roe, B. *Proc. Fla. State Hortic. Soc. 1979* **1980**, *92*, 140.
Chen, M. L.; Chang, S. C. Guoo, J. Y. *Nutr. Rep. Int.* **1982**, *26*, 1053.
Creswell, D. C. *Poult. Sci.* **1981**, *60*, 1905.
Dahlen, M.; Phillipps, K. "A Guide to Chinese Market Vegetables"; South China Morning Post: Hong Kong, 1980.
Del Rosario, R. R.; Lozano, Y.; Noel, M. G. *Philipp. Agric.* **1980**, *63*, 267.
FAO "Food Composition Table for Use in East Asia"; Food and Agriculture Organisation and U.S. Department of Health, Education and Welfare: Rome, 1972.
Gambhir, P. N.; Narain, A.; Tiwari, P. N. *Exp. Agric.* **1979**, *15*, 411.
Gebhardt, S. E.; Elkins, E. R.; Humphrey, J. *J. Agric. Food Chem.* **1977**, *25*, 629.
Grubben, G. J. H. *Meded. Landbouwhogesch. Wageningen* **1975**, *75*, 1.
Kayukova, V. A.; Rozov. N. F. *Isv. Timiryazeusk. Skh. Akad.* **1977**, *1*, 217; *Biol. Abstr.* **1977**, *64*, 022878.
NH&MRC. "Dietary Allowances for Use in Australia"; National Health and Medical Research Council: Canberra, 1970.
Nicholas, E. H. "Check List of Hong Kong Plants"; Hong Kong Herbarium: Hong Kong, 1974.
NRC. "Recommended Dietary Allowances", 9th ed.; National Research Council, National Academy of Sciences: Washington, DC, 1980.
Rodriguez, D. B.; Lee, T. H.; Chichester, C. O. *Plant Physiol.* **1975**, *56*, 626.
Singh, S. B.; Chabra, R.; Abrol, I. P. *Agron. J.* **1979**, *71*, 767.
Sreeramula, N. *J. Plant Foods* **1982**, *4*, 139.
Wills, R. B. H.; Balmer, N.; Greenfield, H. *Food Technol. Aust.* **1980**, *32*, 198.
Wills, R. B. H.; Scriven, F. M.; Greenfield, H. *J. Sci. Food Agric.* **1984**, in press.
Wuensch, A. *Landwirtsch. Forsch.* **1975**, *28*, 345.

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# COMMUNICATIONS

## High-Pressure Liquid Chromatographic Analysis of Tebuthiuron in Soil

A procedure is described for the extraction of tebuthiuron [*N*-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-*N*,*N*′-dimethylurea] from soil and its analysis by high-pressure liquid chromatography (HPLC) while using monuron [3-(*p*-chlorophenyl)-1,1-dimethylurea] as an internal standard for the extraction. Tebuthiuron was extracted from soil samples by shaking and sonicating the soil in water–methanol (45:55). The filtrate was recovered by suction filtration and tebuthiuron was partitioned into diethyl ether. Following evaporation of the ether, the tebuthiuron was solubolized into aliquots of water–methanol (45:55) and quantified by HPLC. The extraction efficiency was 86 ± 3% and the detector responded linearly to tebuthiuron concentration with high precision ($r^2$ = 0.98). The efficiency of tebuthiuron extraction was not influenced by the cation-exchange capacity (CEC), organic matter content, or clay content of the treated soil.

Tebuthiuron, *N*-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-*N*,*N*′-dimethylurea, is the active ingredient in the formulated herbicides Spike and Graslan (Elanco Products Co., Indianapolis, IN). Tebuthiuron is applied preemergence and postemergence for vegetation control on rights of way and industrial sites, for rangeland brush control, and for broad spectrum weed control in sugarcane (Pafford and Hobbs, 1974; Scifres et al., 1981; Walker et al., 1973). Tebuthiuron is presently being considered for use in management systems for converting woodland to grazing land and improved forests in the southeastern United States.

Analytical methods for substituted urea herbicides, such as tebuthiuron, generally include derivatization procedures to achieve thermal stability for gas chromatographic (GC) analysis. Saunders and Vanatta (1974) reported the derivatization of tebuthiuron with trifluoroacetic anhydride for electron capture detection. More recently, Loh et al. (1978) utilized flame photometric detection to quantitatively analyze tebuthiuron by measuring the product(s)

 