Effect of Cultivar and Growing Location on the Mineral Composition of Canola Sprouts

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Abstract. Sprouts from seeds of cruciferous plants, such as brussels sprouts, broccoli, and cauliflower (*Brassica* sp.) are considered desirable for human diets. However, no information is available about sprouts made from seeds of canola (*Brassica napus* L.), a cruciferous crop that is increasing in acreage in the United States and is considered a source of healthful, edible oil. This study reports contents of aluminum (Al), boron (B), calcium (Ca), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), phosphorus (P), sulfur (S), and zinc (Zn) in sprouts made from seeds of four canola cultivars (Banjo, KS 8200, KS 8227, and Virginia) grown at three locations (Orange, Petersburg, and Suffolk) in Virginia during two crop seasons (2001–02 and 2002–03). The contents of protein, oil, P, K, Ca, Mg, S, and Na (expressed as percent on a dry weight basis) in canola sprouts were 27.33, 25.1, 0.61, 0.43, 0.43, 0.31, 0.57, and 0.01, respectively. The contents of B, Cu, Fe, Mn, and Zn (expressed as mg·kg⁻¹) in canola sprouts were 12.35, 5.69, 88.46, 45.44, and 48.98, respectively. Contents of various minerals in canola sprouts were greater than those in sprouts of alfalfa, brussels sprouts, mungbean, and radish reported in the literature. It was concluded that canola sprouts are a potential component of diets for superior human nutrition.

We previously reported that canola (*Brassica napus* L.) sprouts, on average, contained 27.3% oil, 25.1% protein, and 10.8% crude fiber on a dry weight basis (Bhardwaj and Hamama, 2007). Fresh yield of canola sprouts, from 20 g seed, averaged 111.1 g, whereas moisture content averaged 80.3%. Effects of cultivars on yield and moisture content of fresh canola sprouts were not significant. Locations, where seeds were grown, had significant effects on all traits of canola sprouts except for yield of fresh sprouts. Canola sprouts made from seed of Virginia cultivar had the highest protein content (26.2%), whereas those made from seeds of KS 8227 cultivar had the highest oil content (28.7%). We also reported that canola sprouts compared well with sprouts of alfalfa, brussels sprouts, mungbean, and radish for overall nutritional quality.

Although it is well established that sprouts from seeds of cruciferous plants (*Brassica* sp.) such as brussels sprouts, broccoli, and cauliflower

are rich in essential nutrients (Chu and Jeffery, 2001; Fahey et al., 1997; Murillo and Mehta, 2001), no information is available about mineral composition of sprouts made from canola seeds. The term “canola” is a registered trademark of the Canola Council of Canada (<http://www.canola-council.org/>) and refers to cultivars of oilseed rapeseed (*Brassica napus* L. and *B. rapa* L.) that produce seed oils with less than 2% erucic acid and meals with less than 30 µmol of aliphatic glucosinolates per gram (Raymer, 2001). Current canola cultivars are essentially free of erucic acid and glucosinolates.

The objectives of this study were to ascertain effects of cultivars and growing locations on contents of aluminum (Al), boron (B), calcium (Ca), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), phosphorus (P), sulfur (S), and zinc (Zn) in canola sprouts. These elements were selected because the commercial laboratory offered to analyze canola sprouts for these nutrients as an economical package and because these nutrients were previously evaluated in similar studies [canola greens: Bhardwaj et al., 2003; Tepary bean (*Phaseolus acutifolius* A. Gray): Bhardwaj and Hamama, 2004; Lupin (*Lupinus albus* L.): Bhardwaj et al., 1998]. We also compared the contents of various nutrients in canola sprouts with those reported in the literature for sprouts of alfalfa, brussels sprouts, mungbean, and radish.

Materials and Methods

Mature seeds of four canola cultivars (Banjo, KS 8200, KS 8227, and Virginia),

grown during each of 2001–02 and 2002–03 crop seasons at three Virginia locations (Orange, Petersburg, and Suffolk) were used in these studies. During the 2001–02 crop season, the soil type and soil pH at Orange, Petersburg, and Suffolk locations were: Star silty clay loam and 5.9, Abel sandy loam and 6.2, and Rains fine sandy loam and 5.6, respectively. During the 2002–03 crop season, the soil type and soil pH at Orange, Petersburg, and Suffolk locations were Star silty clay loam and 6.9, Abel sandy loam and 6.2, and Rains fine sandy loam and 5.6, respectively. These experiments were conducted at experimental farms of Virginia Tech and Virginia State University. The plots were grown under conventional tillage and fertilized with 100 pounds each of nitrogen (N), P, and K.

These cultivars were common to the National Winter Canola trials in both years. Canola seeds (20 g), from Replications 1 and 2 of the original field trial, were sprouted for 6 d in a wide mouth jar (9 cm × 9 cm × 16 cm) covered with a mesh screen top to insure sufficient air ventilation under laboratory conditions (22 °C temperature and 98% relative humidity and room lighting, 375 lx for 10 h). After initial hydration (seeds were first soaked in water at room temperature overnight), seeds were kept moist by rinsing and draining twice a day and the jars inverted at a slight angle until the next rinse (after 8 to 10 h). At the end of sprouting, the fresh weights were recorded and expressed as fresh yield in grams. The sprouts were then dried at 65 °C until constant weight was reached.

Protein and crude fiber concentrations of sprouts were determined according to AOAC standard methods (AOAC, 1995). The oil was extracted from 2 g each of ground, dried canola sprouts at room temperature by homogenization with hexane/isopropanol (3:2, v/v) as described by Hamama et al. (2003). The oil was extracted three times from each sample and bulked to ensure full oil recovery. The oil content was determined gravimetrically after drying under vacuum at 40 °C and stored under nitrogen at 10 °C until analysis. The contents of oil, protein, and various macro nutrients (Ca, K, Mg, Na, P, and S) in canola sprouts were expressed as percentage on a dry weight basis, whereas contents of micronutrients (Al, B, Cu, Fe, Mn, and Zn) were expressed as mg·kg⁻¹. The contents of macro- and micronutrients in whole dried sprouts were determined by a commercial laboratory (A&L Eastern Agricultural Laboratory, Richmond, VA) as per AOAC (1995) methods.

All data were analyzed by analysis of variance procedures (PROC GLM) in version 6.11 of SAS (SAS, 1996). Fisher's protected least significant difference test was used for mean separation with a significance level of 5%. The composition of canola sprouts was compared with the values for sprouts of alfalfa, brussels sprouts, mungbean, and radish sprouts reported in the Nutrient Database for Standard Reference, Release 21 (USDA, 2007).

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Table 1. Partial analysis of variance (mean squares) for composition of sprouts² produced from seed of four canola cultivars grown at three locations in Virginia during 2001–02 and 2002–03 crop seasons.

	L ^z	C ^z	L*C			
Traits		Mean squares		R ²	cv (%)	Mean
Proximates (%)						
Protein	83.4**	7.3*	2.8	96.5	5.5	25.1
Oil	44.8**	21.6*	1.4	83.2	7.9	27.3
Macronutrients (%)						
Phosphorus	0.179**	0.002	0.010*	96.1	8.7	0.61
Potassium	0.053**	0.012	0.004	89.9	17.4	0.43
Calcium	0.042**	0.016**	0.001	95.6	8.2	0.43
Magnesium	0.012**	0.004**	0.002*	96.1	6.7	0.31
Sulfur	0.014	0.286**	0.009	95.5	13.8	0.57
Sodium	0.001**	0.000*	0.000*	95.8	27.8	0.01
Micro-nutrients (mg·kg ⁻¹)						
Aluminum	161.7**	5.08	19.08	81.4	39.5	9.81
Boron	38.8	10.6	36.9	76.8	34.7	12.35
Copper	28.00**	15.2**	9.9**	97.2	15.2	5.69
Iron	1,835*	282	208	81.9	20.0	88.5
Manganese	187.9*	114*	19.08	82.0	11.6	45.4
Zinc	417**	3.13	49.5	96.1	9.1	48.98

²L = location; C = cultivar. Means over three locations, two replications, and 2 years.

*, **Significant at 5% and 1% levels, respectively.

Results and Discussion

Analysis of variance (Table 1) indicated that growing locations had significant effects on all minerals except B and S. It was interesting to note that none of the mean squares were significant for B. It was attributable, probably, to the limited number of cultivars in these studies. The effects of cultivars were significant for six of 12 minerals (Ca, Cu, Mg, Mn, Na, and S). The cultivar × location interaction mean squares were either not significant or were considerably smaller in magnitude than the location mean squares. The cultivar mean squares for six minerals showing significance were of higher magnitude than location × cultivar mean squares except for Na. Therefore, all data from locations and cultivars were combined for statistical analyses. The *R*² values ranged from 77 to 97 indicating that statistical analysis and experimental practices were satisfactory.

Of six traits for which cultivars indicated significance, ‘Virginia’ had the highest con-

tents of Ca, Cu, and Mg (Table 2), whereas ‘KS 8227’ had the highest content of Na, which was significantly greater than that in the sprouts made from seed of other three cultivars. Considering that higher Na is implicated in health problems related to hypertension, sprouts made from seeds of ‘Banjo’, ‘KS 8220’, and ‘Virginia’ may be nutritionally healthful. The contents of Fe and Zn, two elements with worldwide deficiency in human diets, were unaffected by cultivars. Two cultivars developed at Kansas State University (‘KS 8200’ and ‘KS 8227’) had significantly higher S content (725 and 687 mg/100 g, respectively) as compared with the other two cultivars (Banjo and Virginia). Based on overall mineral contents, we concluded that sprouts made from seeds of Virginia cultivar produced most nutritional sprouts because it was ranked number one for three of six minerals.

Nutritional quality of sprouts was greatly influenced by the location where seeds were produced. Orange location, located in the

submountainous northern Piedmont region of Virginia, was considered the better location over Petersburg and Suffolk locations for nutritional quality of canola sprouts. The sprouts made from seeds produced at the Orange location were ranked number one for six, whereas sprouts made from seeds produced at the Petersburg location were ranked number one for four of 10 traits for which analysis of variance indicated locations to be a significant source of variation (Table 3). The Orange location is considered cooler as compared with the other two locations; thus, it is concluded that canola seed produced under cooler environments may be conducive for better nutritional quality of canola sprouts.

Correlation analysis (Table 4) indicated that a significantly negative correlation existed between oil content and contents of Ca and Cu, whereas a significantly positive correlation existed between contents of oil and S. Protein content exhibited a significantly negative correlation with contents of Al, B, Mn, and Na, whereas a significantly

Table 2. Canola cultivar effects on composition of sprouts produced from seed of four cultivars grown at three locations in Virginia during 2001–02 and 2002–03 crop seasons.

Trait	Banjo	KS 8200	KS 8227	Virginia	Mean	LSD (0.05)
Proximates (%)						
Protein	25.0 ²	24.7	24.4	26.2	25.1	1.2
Oil	26.9	28.0	28.7	25.7	27.3	1.9
Macronutrients (%)						
Phosphorus	0.60	0.62	0.60	0.61	0.61	NS
Potassium	0.46	0.41	0.39	0.45	0.43	NS
Calcium	0.42 (2)	0.40 (4)	0.40 (3)	0.48 (1)	0.43	0.03
Magnesium	0.32 (2)	0.31 (3)	0.29 (4)	0.33 (1)	0.31	0.02
Sulfur	0.43 (4)	0.69 (2)	0.72 (1)	0.45 (3)	0.57	0.07
Sodium	0.014 (3)	0.013 (4)	0.018 (1)	0.014 (2)	0.01	0.003
Micronutrients (mg·kg ⁻¹)						
Aluminum	9.58	9.67	10.75	9.25	9.81	NS
Boron	13.25	11.50	13.08	11.58	12.35	NS
Copper	5.58 (2)	5.33 (3)	4.58 (4)	7.25 (1)	5.69	0.77
Iron	92.25	91.42	81.58	88.58	88.5	NS
Manganese	43.67 (3)	49.92 (1)	45.00 (2)	43.17 (4)	45.4	4.69
Zinc	49.50	48.33	48.83	49.25	48.98	NS

²Means over three locations, two replications, and 2 years. Ranking among four cultivars for traits that were significantly affected by cultivars are presented in parentheses.

LSD = least significant difference; NS = nonsignificant.

Table 3. Growing location effects on composition of sprouts produced from seed of four cultivars grown at three locations in Virginia during 2001–02 and 2002–03 crop seasons.

Trait	Orange	Petersburg	Suffolk	Mean	LSD (0.05)
Proximates (%)					
Protein	23.6 ^z	27.7	23.9	25.1	1.1
Oil	26.0	26.8	29.2	27.3	1.7
Macronutrients (%)					
Phosphorus	0.62 (2)	0.70 (1)	0.49 (3)	0.61	0.04
Potassium	0.47 (1)	0.45 (1)	0.36 (3)	0.43	0.06
Calcium	0.45 (2)	0.46 (1)	0.37 (3)	0.43	0.03
Magnesium	0.32 (2)	0.33 (1)	0.28 (3)	0.31	0.02
Sulfur	0.56	0.61	0.55	0.57	NS
Sodium	0.02 (2)	0.02 (1)	0.01 (3)	0.01	0.00
Micronutrients (mg·kg ⁻¹)					
Aluminum	13.4 (1)	8.5 (2)	7.5 (3)	9.81	3.0
Boron	13.1	13.4	10.6	12.4	NS
Copper	7.2 (1)	5.2 (2)	4.7 (3)	5.7	0.7
Iron	98.5 (1)	89.7 (2)	77.2 (3)	98.1	13.6
Manganese	49.4 (1)	43.1 (3)	43.8 (2)	45.4	4.1
Zinc	52.8 (1)	50.9 (2)	43.2 (3)	49.0	3.4

^zMeans over four cultivars, two replications, and 2 years. Ranking among three locations for macro- and micronutrient traits that were significantly affected by locations are presented in parentheses.

LSD = least significant difference; NS = nonsignificant.

Table 4. Correlations between seed compositions traits in sprouts made from seeds of canola grown at three locations in Virginia over 2001–02 and 2002–03 crop seasons.

Trait	Oil	Protein
Oil (%)	—	–0.08
Protein (%)	–0.08	—
Aluminum	–0.20	–0.33*
Boron	–0.21	–0.31*
Calcium	–0.37**	0.52**
Copper	–0.42**	0.32*
Iron	–0.24	0.09
Potassium	–0.15	0.53**
Magnesium	–0.23	0.35*
Manganese	–0.13	–0.44**
Sodium	–0.26	–0.43**
Phosphorus	–0.27	0.47**
Sulfur	0.36*	0.39**
Zinc	–0.13	0.50**

*, **Correlation significantly different from zero at 5% and 1% level of significance, respectively.

positive correlation existed between protein content and contents of Ca, Cu, K, Mg, P, S, and Zn. These results should be taken into consideration for efforts aimed at increasing or decreasing contents of these traits. A positive correlation between contents of protein and Zn was encouraging because it indicates that these traits could be simultaneously enhanced in breeding programs aiming to enhance the contents of these nutrients in canola sprouts. Similarly, a negative correlation between protein and Na contents indicated that breeding efforts aimed to enhance protein content in canola sprouts should result in decreased content of Na. This observation is important because reduced intake of Na in the human diet is considered desirable as a result of the link between high Na intake and hypertension.

Canola sprouts contained 25% protein and 27% oil on a dry weight basis. The canola

sprouts had higher oil and protein contents than the literature values for sprouts of alfalfa, brussels sprouts, mungbean, and radish. Canola sprouts had higher contents of all nutrients under consideration as compared with the contents in sprouts of alfalfa, brussels sprouts, mungbean, and radish except for the content of Na (Table 5). Canola sprouts were considerably richer in Fe and Zn, two elements that are considered deficient in most human diets, as compared with sprouts from other crops.

Our results from this study and previous studies related to the potential of canola greens for human consumption (Bhardwaj et al., 2003), and preliminary information about suitability of canola sprouts for human consumption (Bhardwaj and Hamama, 2004) indicates that canola has potential as a source of edible portions for human consumption in addition to its use as a source of edible oil. These results indicate that canola has potential as a new cash crop in Virginia and elsewhere.

Conclusions

These results indicate that canola sprouts may provide nutrition far superior than sprouts of alfalfa, brussels sprout, mungbean, and radish. It is possible for consumers to grow canola sprouts in their own homes using sprouting technology that is commonly available to consume nutritious sprouts. This observation has the potential to reduce imports of various seeds into the United States for sprout production.

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Table 5. Composition of canola sprouts relative to composition of sprouts of alfalfa, brussels sprout, mungbean, and radish.

Trait	Canola ^z	Alfalfa ^y	Brussels sprout ^y	Mungbean ^y	Radish ^y
Proximates (%)					
Oil ^x	27.33	0.69	0.30	0.18	2.53
Protein	25.08	3.99	3.38	3.04	3.81
Macronutrients (%)					
Phosphorus	0.61	0.07	0.07	0.05	0.11
Potassium	0.43	0.08	0.39	0.15	0.09
Calcium	0.43	0.03	0.04	0.01	0.05
Magnesium	0.31	0.03	0.02	0.02	0.04
Sulfur	0.57	—	—	—	—
Sodium	0.01	0.01	0.02	0.01	0.01
Micronutrients (mg·kg ⁻¹)					
Aluminum	9.81	—	—	—	—
Boron	12.35	—	—	—	—
Copper	5.69	1.57	0.70	1.64	1.20
Iron	88.46	9.60	14.00	9.10	8.60
Manganese	45.44	1.88	3.37	1.88	2.60
Zinc	48.98	9.20	4.20	4.10	5.60

^zAverage of four cultivars (Banjo, KS 8200, KS 8227, and Virginia) grown at three locations in Virginia over 2001–02 and 2002–03 crop seasons.

^yValues from Nutrient Database for Standard Reference, Release 21. USDA-ARS Nutrient Data Laboratory (<<http://www.nal.usda.gov/fnic/foodcomp/>>). Accessed 23 July 2008.

^xContents of oil, protein, phosphorus, potassium, calcium, magnesium, sulfur, and sodium are percentages on dry weight basis; all others are as mg·kg⁻¹ on a dry weight basis.

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