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Characterization of Nutritional Quality of Canola Greens

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Abstract. **Lack of adequate processing facilities has been a major hindrance in the adoption of canola (*Brassica napus* L. and *Brassica rapa* L.) as an alternative oilseed crop in the southern United States. Therefore, development of alternative uses could be instrumental in facilitating adoption of canola by American farmers. We evaluated chemical composition of greens from four canola cultivars ('Dixie', 'Falcon', 'HN120-91', and 'Jetton') grown during 1995–96 and 1996–97 at Petersburg, Va., to determine their potential as a food and feed source. The results indicated potential yield of ≈11 t·ha^{-1} of fresh greens and ≈1 t·ha^{-1} of dry matter. The canola greens contained 3.4% oil and 30.6% protein on a dry weight basis. Canola greens contained 0.52%, 4.14%, 0.35%, 1.59%, and 0.20% (dry weight basis) of phosphorus, potassium, magnesium, calcium, and sodium, respectively. Canola greens also contained 0.94, 2.02, 5.47, 14.65, 28.61, 0.74, and 31.92 (mg/100 g dry weight basis) of sulfur, boron, zinc, manganese, iron, copper, and aluminum, respectively. The oil in canola greens contained 18.79%, 81.14%, 15.36%, and 65.78% saturated, unsaturated, monounsaturated, and polyunsaturated fatty acids, respectively. Based on these values, canola greens compared favorably with mustard and turnip greens.**

The demand for canola oil, which is considered healthy for human nutrition due to its low concentration of saturated (5% to 8%) and moderate concentration of polyunsaturated fatty acids (FA), is increasing in the United States at a tremendous rate. Canola is a genetically altered form of rapeseed with low erucic acid, a 22-carbon chain fatty acid, and low glucosinolate concentration. Canola (CANada-Oil-Low-Acid) is an international registered trademark owned by the Canola Council of Canada. Canola and rapeseed (*Brassica napus* L. and *Brassica rapa* L.) are members of the mustard family and are closely related to turnip (*Brassica rapa* L.), cabbage (*Brassica oleracea* L., var. capitata), cauliflower (*Brassica oleracea* L., var. botrytis), broccoli (*Brassica oleracea* L., var. italica), and mustard (*Brassica juncea* L.). Even though canola evaluations in Virginia have been ongoing since 1985, a concerted effort has been under way at two land grant universities in Virginia since 1993, with support from the National Canola Research Program of the U.S. Dept. of Agriculture (USDA). This effort has resulted in the development/identification of suitable cultivars and a production system and has demonstrated the feasibility of growing canola in Virginia and other states of the mid-Atlantic region of the United States (Starner et al., 1996, 1999, 2002).

Canola production in the United States has increased dramatically over the last decade, increasing from 62,727 ha in 1991 to 608,249 ha in 2000 (Raymer, 2002). Even with this production, consumption of canola oil in the United States still outpaces production at the rate of nearly 3 to 1 (Rife, 2001). Most of the United States' demand for canola oil is met with imports from Canada. During 1998, the United States imported ≈419,000 t of canola oil from Canada, with a 7-year average of ≈355,000 t (www.canola-council.org/stats/oilmealexport.html). The demand for canola oil in the United States has grown from virtually zero in 1985, when domestic markets for canola oil were first created in the United States, to almost 1 million tonnes in 2001 (Raymer, 2002). The efforts to increase domestic canola production in the southeastern United States are hindered by lack of processing facilities. Development of alternative uses of canola, such as on-farm use and/or development of locally marketable products, could help alleviate this problem by establishing the crop and indirectly helping to increase the availability of this crop as an oilseed.

The objective of this study was to ascertain the possibility of using preflowering canola foliage similar to mustard or turnip greens. Specifically, we wanted to characterize the chemical composition of preflowering canola foliage, compare the nutritional quality of preflowering canola foliage to other leafy greens, and assess the potential of preflowering canola foliage as a food and feed source.

Materials and Methods

Four canola cultivars ('Dixie', 'Falcon', 'HN120-91', and 'Jetton') were grown at Randolph Farm of Virginia State Univ., located in Ettrick (37°15´N and 77°30.8´W) during 1995–96 (two replications) and 1996–97 (four replications) in a randomized complete-block design. Each plot consisted of three 3-m-long rows spaced 30 cm apart. The experiments were planted on 23 Oct. during both 1995 and 1996 on Abel sandy loam (fine loamy mixed thermic aquatic hapludult) using seed at the rate of ≈4 kg·ha^{-1}. All plots received 100 kg·ha^{-1} of N, P, and K. No insecticides were used prior to harvest of these plots for greens. The total foliage was harvested, ≈5 cm above the ground level, before appearance of yellow petals, from a 2-m length of the middle row of each plot . Fresh weights were recorded and converted to fresh yield in t·ha^{-1}. The foliage was dried at 70 °C for 72 h before recording of dry weights. The moisture concentration and dry matter yield (t·ha^{-1}) were calculated.

Protein, ash, and mineral concentrations of canola greens were determined according to standard methods [Association of Official Analytical Chemists (AOAC), 1995] (976.05, 942.05, and 968.08, respectively). The lipids were extracted from 20 g of ground foliage 3 times at room temperature by homogenization with 3 hexane : 2 isopropanol (v/v) (St. John and Bell, 1989). The FA methyl esters (FAME) of the lipid were prepared (Dahmer et al., 1989) and analyzed in a Varian model Vista 6000 gas chromatograph equipped with a fused silica capillary column (SupelcoWax 10 capillary column 25 m × 0.25 mm i.d. and 0.25-μm film thickness, Supelco, Bellefonte, Pa.), a flame ionization detector (Varian, Sugar Land, Texas), and a Spectra Physics Model 4290 integrator. Carrier gas was He at a column flow rate 0.8 mL·min^{-1} with a split ratio of 1: 80. Oven, injector, and detector temperatures were maintained at 210, 240, and 260 °C, respectively. Peaks were identified by comparison to retention of FAME standards and quantified by the aid of a 17:0 FAME as an internal standard.

Data were analyzed by procedures in version 6.11 of SAS (SAS, 1996). Least significant difference procedure with a significance level of 5% was used for mean separation. The nutritional data from preflowering canola foliage were compared to the values for mustard and turnip greens that are available in the literature (USDA, 2001).

Results and Discussion

The effects of years on traits of canola foliage were, generally, significant (Table 1). The effects of cultivars were, generally, nonsignificant for traits of canola foliage except for concentrations of Al, Cu, Fe, Mg, and Na. More importantly, all interactions between year and cultivars were nonsignificant except those for concentrations of Al and Fe (Table 1). On an average, canola foliage yield was 10.7 t·ha^{-1} fresh with 89.1% moisture and 1.1 t·ha^{-1} dry (Table 2). The fresh yield levels of

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canola greens, in our studies, were lower than those of processing mustard greens [18–22 t·ha^{-1}, originally reported from Oklahoma by Motes et al. (2002) as 8–10 tons per acre] and processing turnip greens [13–27 t·ha^{-1}, originally reported from Oklahoma by Motes et al. (2002) as 6–12 tons per acre], and fresh market mustard [12.3–19.7 t·ha^{-1}, originally reported from Oklahoma by Motes et al. (2002) as 500–800 bushels per acre] and fresh turnip greens [12.3–25.0 t·ha^{-1}, originally reported from Oklahoma by Motes et al. (2002) as 500–1000 bushels per acre] in Oklahoma (Motes et al., 2002). The canola foliage, on average, contained 3.4% oil and 30.6% protein on a dry weight basis (Table 2).

The greens of four cultivars differed only for the concentrations of Mg, Ca, Na, Al, and Fe (Table 2). 'Jetton' had the highest concentrations of Mg and Ca (0.40 and 1.95 g·100 g^{-1} dry weight, respectively), whereas the other three cultivars had similar concentrations of these minerals. 'HN120-91' had significantly higher concentration of Na (0.24 g·100 g^{-1} dry weight) as compared to the other three cultivars. The highest Al and Fe concentrations (per 100 g dry weight) of 44 and 39 mg, respectively, were observed for 'Falcon', whereas the lowest concentrations of 18 and 23 mg, respectively, were observed for 'HN120-91'. The Fe concentrations in 'Dixie', 'Jetton', and 'HN120-91' were similar. The Al concentrations of 'Falcon' and 'Jetton' (39 mg), and those in 'Dixie' (27 mg) and 'HN120-91' were similar. Even though significant differences existed between years for 17 out of 29 traits under study, the cultivar × year interactions were significant only for Fe and Al concentrations.

In order to determine suitability of using canola greens as food, we compared the composition of canola greens to those of mustard and turnip greens using the data from the USDA Nutrient Database (USDA, 2001). Canola greens were more nutritious than either mustard or turnip greens based on numerical superiority of oil and protein concentrations. The protein concentration of canola greens (30.65%, dry weight basis) was 4% and 82% higher than that of mustard and turnip greens, respectively. For oil concentration, the canola greens were 57% and 1% greater than mustard and turnip greens, respectively (Table 3).

The P, K, Zn, Mn, and Fe concentrations of canola foliage were considerably higher than those in either mustard or turnip greens. On the other hand, the concentrations of Na and Cu in canola foliage were lower than those in either mustard or turnip. The Mg concentrations in canola, mustard, and turnip greens were similar. The Ca concentration of canola greens was intermediate between mustard and turnip greens. The USDA Nutrient Database (USDA, 2001) did not contain any information about S, B, and Al concentrations of either mustard or turnip greens. The concentrations of these minerals are included in Table 3 for future reference. Based on lower Na concentration, a case could be made that canola greens could be healthier for consumption by those persons who suffer from hypertension and are interested in lowering their Na intake. With regards to

Table 1. Partial analysis of variance for characteristics of canola greens grown at Petersburg, Va., during 1995–96 and 1996–97.

Variable	Mean squares: Year	Cultivar	Year × cultivar	R^2	CV (%)
Fresh yield	29.50	7.41	11.54	77.2	26.0
Dry yield	0.14	0.04	0.13	74.8	23.0
Proximates					
Ash	82.58**	0.21	0.37	93.7	8.5
Oil	0.09	0.16	0.12	65.5	6.5
Protein	59.10**	5.64	18.95	72.9	7.8
Water	1.08	1.38	0.27	83.9	0.8
Minerals					
P	0.02	0.00	0.01	70.9	14.1
K	4.67	0.07	0.17	69.7	12.5
Ca	0.01	0.26	0.03	68.0	15.1
Mg	0.00	0.01*	0.00	57.8	13.9
Na	0.16**	0.00*	0.00	94.7	15.0
Cu	0.07	0.07*	0.12	68.3	25.5
S	0.39**	0.00	0.02	69.9	14.6
B	0.96	0.10	0.05	51.0	33.3
Zn	71.79**	1.27	2.33	85.2	21.4
Mn	1588.15**	16.92	12.11	88.2	30.2
Fe	513.52*	498.48**	270.76*	75.7	30.4
Al	1882.51*	1393.30*	1045.10*	80.4	48.7
Fatty acids in the oil					
14:0	9.17**	0.00	0.13	73.0	24.1
16:0	195.82**	2.82	1.09	89.1	11.3
18:0	0.72*	0.11	0.04	65.1	20.7
18:1	122.50**	3.72	1.91	81.8	26.9
18:2	12.60**	4.61*	0.80	80.8	7.2
18:3	7.18	1.25	1.71	76.9	4.9
22:1	1240.94**	1.31	1.39	99.3	16.9
Saturated	319.25**	3.41	1.21	91.6	9.4
Unsaturated	323.96**	3.62	1.21	92.1	2.1
Monounsaturated	527.35**	2.50	1.24	93.2	12.2
Polyunsaturated	24.65	11.93	4.90	76.6	3.8

*, **Significant at $P \leq 0.05$ and 0.01, respectively.

Table 2. Characteristics of greens from four canola cultivars grown at Petersburg, Va., during 1995–96 and 1996–97.

Variable	Dixie[z]	Falcon	H120-91	Jetton	Mean	LSD$_{(0.05)}$
Fresh yield (t·ha^{-1})	11.70	9.95	12.01	9.17	10.71	NS
Dry yield (t·ha^{-1})	1.21	1.05	1.23	1.00	1.13	NS
Proximates (% of dry wt)						
Ash	7.92	8.05	8.24	8.56	8.19	NS
Oil	3.27	3.40	3.63	3.34	3.41	NS
Protein	29.36	30.57	30.39	32.29	30.65	NS
Water	89.22	88.81	89.69	88.69	89.10	ns
Minerals (g·100 g^{-1} dry wt)						
P	0.49	0.54	0.54	0.50	0.52	NS
K	4.11	4.14	4.30	3.99	4.14	NS
Mg	0.32	0.34	0.32	0.40	0.35	0.06
Ca	1.47	1.53	1.42	1.95	1.59	0.30
Na	0.19	0.17	0.24	0.18	0.20	0.04
Minerals (mg·100 g^{-1} dry wt)						
S	0.92	0.93	0.95	0.96	0.94	NS
B	2.08	2.07	1.78	2.15	2.02	NS
Zn	4.95	5.18	5.28	6.47	5.47	NS
Mn	13.07	13.40	14.17	17.98	14.65	NS
Fe	25.28	39.32	22.78	27.05	28.61	10.93
Cu	0.83	0.65	0.73	0.73	0.74	NS
Al	27.03	43.52	18.18	38.97	31.92	13.57
Fatty acids in the oil (%)						
14:0	2.47	2.54	2.45	2.45	2.48	NS
16:0	15.52	14.24	15.40	13.91	14.77	NS
18:0	1.50	1.32	1.61	1.65	1.52	NS
18:1	7.26	6.23	7.40	5.75	6.66	NS
18:2	13.60	14.67	12.52	14.59	13.85	1.26
18:3	43.41	43.76	44.62	43.32	43.78	NS
22:1	5.33	5.11	4.65	5.34	5.11	NS
Saturated	19.51	18.12	19.47	18.03	18.79	NS
Unsaturated	80.39	81.85	80.43	81.89	81.14	NS
Monounsaturated	16.17	14.90	15.71	14.66	15.36	NS
Polyunsaturated	64.22	66.95	64.71	67.23	65.78	NS

[z]Cultivar means from six observations, two replications during 1995–96 and four replications during 1996–97.

Table 3. Comparison of nutritional quality of canola, mustard, and turnip greens.

Variable	Canola[z]	Mustard[y]	Turnip[x]
Proximates (% of dry wt)			
Oil	3.41	2.17	3.36
Protein	30.65	29.34	16.80
Ash	8.19	15.22	15.68
Minerals (g·100 g^{-1} dry wt)			
P	0.52	0.47	0.47
K	4.14	3.85	3.31
Mg	0.35	0.35	0.35
Ca	1.59	1.12	2.12
Na	0.20	0.27	0.45
Minerals (mg·100 g^{-1} dry wt)			
S	0.94	---	---
B	2.02	---	---
Zn	5.47	2.17	2.13
Mn	14.65	5.22	5.22
Fe	28.61	15.87	12.32
Cu	0.74	1.60	3.92
Al	31.92	---	---
Fatty acids in the oil (%)			
14:0	2.48	0.00	1.00
16:0	14.77	2.50	18.00
18:0	1.52	1.00	3.33
18:1	6.66	7.50	1.67
18:2	13.85	10.00	12.00
18:3	43.78	9.00	28.00
22:1	5.11	29.00	0.00
Saturated	18.79	5.00	23.30
Unsaturated	81.14	95.00	76.70
Monounsaturated	15.36	46.00	6.67
Polyunsaturated	65.78	19.00	40.00

[z]Means from 24 observations (4 cultivars, 2 years, and 2 replications during 1995–96 and four replications during 1996–97).
[y]Values obtained from USDA Nutrient Database for Standard Reference at: http://www.nal.usda.gov/fnic/cgi-bin/nut_search.pl?Mustard+Greens.
[x]Values obtained from USDA Nutrient Database for Standard Reference at: http://www.nal.usda.gov/fnic/cgi-bin/nut_search.pl?Turnip+Greens.

higher Fe concentration, canola greens could be helpful in alleviating worldwide Fe deficiency in human diets.

The saturated FA concentration of canola greens was higher than that in mustard greens but lower than that in turnip greens (Table 3), whereas the concentration of unsaturated FA in canola greens was higher than that in turnip but lower than that in mustard greens. The concentrations of total polyunsaturated (66%), 14:0 (2%), 18:2 (14%), and 18:3 (44%) FA in canola greens were considerably higher as compared to those in mustard or turnip greens. Based on the concentrations of 16:0, 18:0, 18:1, 22:1, saturated, and monounsaturated FA, the canola greens were intermediate between mustard and turnip greens.

These results indicate that preflowering foliage of canola has potential as food and feed. Use of canola to provide greens for human consumption has the potential to provide an alternate crop for production to small and mid-sized farmers in general and to winter wheat farmers, in particular, in the mid-Atlantic region. Similar to Virginia, where ≈99% of the 50,000 farms are classified as small or mid-sized with average income of ≈$48,000 (Virginia Agricultural Statistics, 2000), most farms in the mid-Atlantic region are classified as small or mid-sized. In this region, wheat is a common winter crop. During 1999, winter wheat was harvested in Delaware, Maryland, Pennsylvania, and Virginia from ≈283,400 ha with an approximate production of 1.1 million tonnes [National Agricultural Statistics Service (NASS), 2001]. In this region, the returns from winter wheat have declined from ≈$146.8 to $73.4 per tonne from 1995 to 1999 (NASS, 2001), causing a severe decline in income and profitability of wheat producers. Diversification of the production system with a suitable crop, such as canola, for production of greens could help farmers in this region. On the other hand, it could be expected that canola would get established as an oilseed crop, thus giving a further boost to the farm economy in this region.

Literature Cited

Association of Official Analytical Chemists (AOAC). 1995. Official methods of analysis. Assn. Offic. Anal. Chemists. 16th ed. Arlington, Va.

Dahmer, M.L., P.D. Fleming, G.B. Collins, and D.F. Hildebrand. 1989. A rapid screening technique for determining the lipid composition of soybean seeds. JAOCS 66:543–549.

Motes, J.E., B. Cartwright, and J.P. Damicone. 2002. Greens production (spinach, turnip, mustard, collard, and kale). Oklahoma Coop. Ext. Serv., Div. Agr. Sci. and Natural Resources, Oklahoma State Univ., Stillwater. OSU Ext. Facts, F-6031.

National Agricultural Statistics Service. 2001. Agricultural prices. http://www.usda.gov/nass/pubs/estindx3.htm#wheatw.

Raymer, P.L. 2002. Canola: An emerging oilseed crop, p. 122–126. In J. Janick and A. Whipkey (eds.). Trends in new crops and new uses. ASHS Press, Alexandria, Va.

Rife, C. 2001. Department report: 2000 National winter canola variety trial. Kansas State Univ., Agr. Expt. Stn. and Coop. Ext. Serv., Manhattan.

SAS. 1996. SAS system for windows, version 6.11. SAS Inst., Cary, N.C.

St. John, L.C. and F.P. Bell. 1989. Extraction and fractionation of lipids from biological tissues, cell, organelles, and fluids. Biotechniques 7: 476–481.

Starner, D.E., H.L. Bhardwaj, A.A. Hamama, and M. Rangappa. 1996. Canola production in Virginia, p. 300–303. In J. Janick (ed.). Progress in new crops. ASHS Press, Alexandria, Va.

Starner, D.E., A.A. Hamama, and H.L. Bhardwaj. 1999. Canola oil yield and quality as affected by production practices in Virginia, p. 254–256. In: J. Janick (ed.). Perspectives on new crops and new uses. ASHS Press, Alexandria, Va.

Starner, D.E. and H.L. Bhardwaj. 2002. Prospects of canola as an alternative winter crop in Virginia, p. 127–130. In J. Janick and A. Whipkey (eds.). Trends in new crops and new uses. ASHS Press, Alexandria, Va.

U.S. Dept. of Agriculture (USDA). 2001. USDA nutrient database for standard reference. Release 14. Nutrient Data Laboratory Home Page, http://www.nal.usda.gov/fnic/foodcomp. U.S. Dept. Agr., Agr. Res. Serv.

Virginia Agricultural Statistics. 2000. Virginia agricultural statistics bulletin and resource directory, 1999. No. 73. Richmond, Va.