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Brief Report

Composition of Coriander Seed Grown in Virginia, USA †

Anwar A. Hamama and Harbans L. Bhardwaj *

Agricultural Research Station, Virginia State University, Petersburg, VA 23806, USA
* Correspondence: hbhardwaj@vsu.edu; Tel.: +1-804-524-6723

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Abstract: Coriander (*Coriandrum sativum* L.) is an aromatic member of the Apiaceae with a wide diversity of uses. Its rapid life cycle allows it to fit into different growing seasons, making it possible to grow the crop under a wide range of conditions. Even though extensive demand for this herb exists among ethnic communities, its' production in the eastern USA is essentially non-existent. We are interested in facilitation of commercial production of this herb and to characterize its' composition. We have previously observed that coriander can be commercially produced in Virginia but composition of coriander seed produced in Virginia (Mid-Atlantic region of the United States of America) is unknown. To remedy this situation, we conducted two experiments during 2015 and 2016 with three cultivars ('Santo', 'Santo Monogerm', and 'Marino-Organic'). Coriander seed in this study had 7.6 and 8.7 percent oil and 17 and 15 percent protein in winter (planted in December 2015 and harvested in July, 2016) or summer crop (planted in May, 2016 and harvested), respectively whereas mean concentrations (g per 100 g) of P, K, S, Mg, Ca, and Na were 501, 830, 140, 332, 620, 10, respectively. Concentrations of B, Zn, Mn, Fe, and Cu (mg per 100 g) were 1.10, 2.71, 2.81, 8.96, and 1.29, respectively. Coriander seed in this study contained approximately 19, 63, and 17 percent total saturated, MUFA, and PUFA fatty acids, respectively. Coriander seed contained 0.179, 0.877, and 0.219 percent fructose, glucose, and sucrose, respectively. Our results indicated that coriander seed produced in Virginia has seed composition, generally, similar to that produced elsewhere.

Keywords: *Coriandrum sativum* L.; composition of seed; oil and fatty acid concentrations; protein concentration; sugar concentrations

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1. Introduction

Cilantro (*Coriandrum sativum* L.) is a crop of worldwide importance [1,2]. It is an annual herb that is part of the Apiaceae family of plants, which also includes carrots, fennel, parsley, celery, anise, and cumin. It is commonly featured in Asian, Latin American, Caribbean, and Mediterranean cuisine, and is sometimes referred to as 'Mexican' or 'Chinese parsley.' 'Cilantro' generally refers to the leaves/stems of the plant, which can be used fresh or dried, while 'Coriander' refers to the seeds of the plant, which are usually ground and used as a spice.

Coriander is an ancient crop—it was mentioned by Hippocrates around 400 BC as well as Dioscorides around 65 AD [3]. Coriander is native to regions spanning from Southern Europe and Northern Africa to Southwestern Asia. It is a soft plant growing to 50 cm (20 in) tall. The leaves are variable in shape, broadly lobed at the base of the plant, and slender and feathery higher on the flowering stems. The flowers are borne in small umbels, white or very pale pink, asymmetrical, with the petals pointing away from the center of the umbel longer (5–6 mm) than those pointing toward it (only 1–3 mm). The fruit is a globular, dry schizocarp 3–5 mm in diameter [4]. The word "coriander" derives from the Old French "coriander", which comes from Latin "Coriandrum". The fresh leaves and the dried seeds of this plant are the parts most commonly used in cooking, but all parts of the plant are edible and the roots are an important element of Thai cooking. Coriander is used in cuisines throughout the world [5].

Coriander grows wild over a wide area of Western Asia and Southern Europe, prompting the comment: "It is hard to define exactly where this plant is wild and where it only recently established itself." Recent works suggested that coriander accessions found in the wild in Israel and Portugal might represent the ancestor of the cultivated coriander. They have low germination rates and a small vegetative appearance. The accession found in Israel has an extremely hard fruit coat [6].

The world exports of coriander exceeded USD 196 million in 2020, with India (32 percent), Italy (12.4 percent), Russia (11.3 percent), Bugaria (8.9 percent), Morocco (5.8 percent) being top exporters. United States of America accounted for 5.7 percent of world imports worth approximately USD 11 million in 2020 [7].

This study was part of a larger study that aimed to evaluate cilantro and coriander for introduction and establishment of these crops in Virginia (Eastern United States of America) as alternative crops. We have observed that both cilantro and coriander are potential commercial crops for Virginia but there is a lack of information about composition of coriander seed produced in Virginia. Therefore, objectives of present study were to characterize composition of coriander seed in Virginia and to compare it to the values in the literature.

2. Materials and Methods

Seeds for this study were obtained from two field experiments: one planted on 15 December 2015 and harvested on 26 July 2016—Winter crop; the second planted on 26 May 2016 and harvested on 2 August 2016—Summer crop. The mean ambient air temperature for winter crop of coriander was 56.8 °F (December to July) whereas that for summer crop of coriander was 75.5 °F (May to August). Monthly mean ambient air temperatures (°F) for January, February, March, April, May, June, July, August, September, October, November, and December over last 20 years have been 38.4, 41.4, 49.4, 59.1, 67.7, 76.0, 79.8, 78.5, 72.0, 61.2, 50.3, and 42.6, respectively.

These experiments were planted with three coriander cultivars ('Santo', 'Santo Monogerm', and 'Marino-Organic'). Seeds of all cultivars were purchased from Johnny's Selected Seeds (955 Benton Ave, Winslow, ME, USA). These cultivars were planted in the field using a randomized complete block design with four replications. The soil type was Abel sandy loam (fine loamy, mixed, thermic Aquatic Hapludult). Each plot consisted of four rows with inter-row spacing of 37.5 or 75 cm. Approximately 100 seeds were planted in each 3 m long row with an Almaco research planter (99 M Ave, Nevada, IA, USA). The experimental area received a preplant incorporated treatment of trifluralin herbicide (Treflan 4EC; DowElanco, Indianapolis, IN, USA) at the rate of 1 L ha^{-1} active ingredient. These plots received 250 kg ha^{-1} of 10N-4.4P-8.3K as per our previous results [8].

Coriander seeds from two replications, after harvest—Each treatment was harvested separately, were dried to constant weights and used to determine mineral concentrations according to AOAC methods [9] by Waypoint Analytical Laboratory (7621 Whitepine Rd., Richmond, VA, USA). Total protein concentration was calculated by multiplying N content with 6.25. Additionally, concentrations of oil, fatty acids, and total carbohydrates were also determined.

The oil and fatty acid concentrations were determined in the Common Laboratory of Agricultural Research Station of Virginia State University. The oil was extracted from ground material (5 g) three times at room temperature by homogenization for 2 min in 20 mL hexane/isopropanol (3:2, *v*/*v*) with a Biospec Model 985-370 Tissue Homogenizer (Biospec Products, Inc. Racine, WI, USA) and centrifuged at 4000× *g* for 5 min, as described by Hamama et al. [10]. The three extractions were combined and the hexane-lipid layer was separated from the combined extract after shaking with 10 mL of 1% solution of equal amounts of $CaCl_2$ and NaCl in 50% methanol. The hexane lipid layer was removed by aspiration and dried over anhydrous Na_2SO_4. The oil percentage (g/100 g dry basis) was determined gravimetrically after drying under vacuum at 40 °C and stored under nitrogen at −10 °C until analysis.

Sugars were extracted from ground material (1 g) and analyzed by HPLC following the methods optimized by Johansen et al. [11]. Sugars in the extracts were identified by comparing their retention times with standard sugars. For quantification, Trehalose was used as internal standard and the sugar concentration was expressed as g/100 g meal [12].

All data were analyzed using SAS [13] using 5% level of significance.

3. Results and Discussion

Results of this study are presented in Table 1. Coriander seed produced in Virginia contained approximately 8, 16, 19, 63, 17, and 2 percent oil, protein, saturated fatty acids, mono-unsaturated fatty acids, poly-unsaturated fatty acids, and C18:3 fatty acids. In general, these concentrations are similar to those in the literature [14–21].

Production period significantly affected the concentrations of oil, protein, P, K, Ca, Mn, Fe, fructose, glucose, sucrose, and some fatty acids (C14:0, C20:0, C22:0, C16:1, and C18:2). Magnitudes of nine of these components were significantly higher when coriander was grown as a winter crop whereas magnitudes of six components (oil, K, Mn, C20:0, C16:1, and C18:2) were significantly higher when coriander was grown as a summer crop. Based on this observation we speculate that temperatures during coriander growth significantly affects composition of seed—Higher oil from summer crop whereas higher protein concentration from winter crop. We observed that nine components of coriander seed were significantly more from winter crop as compared to summer crop leading us to speculate that winter crop of coriander might be better. This observation is significant if coriander is produced as a dual-purpose crop to supply both cilantro and coriander as we have observed that cooler temperatures help in delayed bolting.

Effects of coriander cultivars on seed composition traits were, generally, non-significant (Table 1). Our results indicated that performance of cultivar 'Santo-Monogram' was superior to those of the other two cultivars. In our experiments, effects of closer (37.5 cm) and wider (75 cm) row spacings were not significant indicating that depending upon the planting equipment either row spacing could be used for commercial coriander production. However, we believe that closer row spacings may be desirable as it helps to suppress weeds due to canopy shading.

One of our objectives was to determine if quality of coriander seed produced in eastern USA is similar to that produced elsewhere. We accomplished this by comparing mean composition of coriander produced in our experiments to that from the eight sources of literature (Table 2). We observed that extensive information about several seed composition traits of coriander was not available. We present our results in the hope that these results will help other researchers in the future. Coriander seed produced in our experiments had lower oil and higher protein concentrations than the literature values.

An interesting observation was related to the concentration of C18:3 fatty acid (The fatty acid that is considered healthy for human nutrition) being higher in magnitude in coriander seed produced in our experiments as compared to literature values. Saini et al. [22] reported that coriander seed contained 0.35 percent C18:3 fatty acid as compared to our study where concentration of this fatty acid was 2.1 percent. Higher concentration of C18:3 while desirable for human nutrition is also responsible for enhanced oxidation. Oils rich in poly-unsaturated fatty acids (especially linolenic acid) are considered very healthy for human nutrition but these oils are also known to be highly unstable due to auto-oxidation resulting from unsaturation [23]. During lipid oxidation, unsaturated fatty acids react with oxygen to form colorless, tasteless, and odorless fatty acid peroxides [24] which further degrade to form low-molecular-weight compounds with distinctive odors and flavors. In addition to causing rancidity in oils, lipid oxidation has been implicated in the pathogenesis of atherosclerosis [25], coronary heart disease [26], and congestive heart failure [27].

Table 1. Chemical composition of coriander seed from winter and summer crops grown in Virginia (USA).

Trait	Production Period		Variety			Row Spacing	
	Winter Crop [a]	Summer Crop [a]	Marino-Organic	Santo	Santo-Monogerm	37.5 cm	75 cm
Oil *	7.651b [z]	8.67a	8.07	8.25	8.11	8.26	8.02
Protein *	16.94a	15.22b	15.88	15.99	16.37	18.25	15.92
P **	567a	435b	500	504	499	523	478
S **	0.141a	0.138a	0.135a	0.1376a	0.146a	0.142a	0.137a
K **	700b	964a	745c	844b	902a	839	822
Mg **	342	321	0.320	0.330	0.345	0.342	0.322
Ca **	727a	512b	610	615	635	634	606
Na **	11	11	11	10	10	11	10
B **	10.75a	11.33a	0.12b	11.12ab	11.87a	10.92a	11.17a
Zn **	2.85	2.57	2.5.4	2.66	2.92	2.87	2.55
Mn **	1.93b	3.69a	2.52b	2.77ab	3.14a	2.82	2.80
Fe **	9.73a	8.13b	9.74	8.30	8.84	8.42	8.96
Cu **	1.29	1.30	1.29ab	1.22b	1.37a	1.32	1.27
Fructose *	0.85a	0.56b	0.682	0.800	0.667	0.698	0.740
Glucose *	1.11a	0.60b	0.892	0.957	0.786	0.858	0.897
Sucrose *	0.329a	0.086b	0.211	0.232	0.211	0.203	0.234
Raffinose *	0.906	1.006	0.865	1.045	0.924	0.944	0.959
C14:0 *	0.195a	0.100b	0.132	0.135	0.147	0.131	0.147
C16:0 *	4.625	4.205	4.477	4.486	4.228	4.470	4.296
C18:0 *	1.21	0.82	1.03	0.96	0.97	1.08	0.89
C20:0 *	0.279b	0.377a	0.374	0.342	0.311	0.342	0.33
C22:0 *	0.171a	0.138b	0.138	0.159	0.138	0.158	0.134
C24:0 *	0.231	0.144	0.234	0.160	0.166	0.187	0.173
C16:1 *	0.641b	1.343a	1.048	0.932	0.862	1.051	0.823
C18:2 *	14.38b	15.5a	14.47	14.61	15.22	14.56	15.07
C18:3 *	2.456	1.850	2.800	1.930	1.845	2.190	2.019
SFA *	21.64	17.71	20.28	19.39	18.73	20.62	18.18
UFA *	78.36	82.29	79.72	80.61	81.27	79.39	81.82
MUFA *	61.42	64.86	62.11	63.70	63.98	62.35	64.42
PUFA *	16.94	17.43	17.61	16.90	17.23	17.04	17.40

a: Winter crop was grown from 15 December 2015 to 26 July 2016. The summer crop was grown from 26 May 2016 to 2 August 2016. The values under variety are means over row spacings and replications and values under row spacings are means over varieties and replications. The values in this table were derived from Analysis of Variance of data obtained from seeds produced in field experiments. *, **: values in g per 100 g, and mg per 100 g, respectively. z: Means followed by similar letters within sub-treatments were not significantly different according to Duncan's Multiple Range Test at 5 percent level.

Table 2. Chemical composition of coriander seed grown in Virginia (USA) relative to literature values.

Trait	A [a]	B [a]	C1[a]	D1 [a]	D2 [a]	E [a]	F [a]	G [a]	H [a]
Oil *	8.143	17.8		8.0–22.0	19.24	26.4	20.0		
Protein *	16.08	12.4			13.47				
P *	501	409							
K *	830	1270							
S *	140	-							
Mg *	332	330							
Ca *	620	709							
Na *	10	35							
B **	1.10	-							
Zn **	2.71	4.7							
Mn **	2.81	1.9							
Fe **	8.96	16.3							
Cu **	1.29	0.975							
Fructose *	0.179								
Glucose *	0.877								
Sucrose *	0.219								
Raffinose *	0.952								
C14:0 *	0.139	0.02	0.0–0.2	0.08					
C16:0 *	4.378	0.81	3.8–4.0	3.48	1.55	3.6	3.49	5.3	3.35
C18:0 *	0.981	0.11	0.7–0.8	0.77	3.70	0.7	0.84	3.1	0.71
C20:0 *	0.337		0.1–0.2	0.15	0.23	0.2			0.09
C22:0 *	0.145		0.1–0.2						0.03
C24:0 *	0.180								
C20:1 *	4.981								0.04
C22:1 *	0.566								
C16:1 *	0.93	0.10	0.2–0.2	0.23	0.44	0.1	0.128	0.3	0.22
C18:1	-	13.5	79.4–80.2	81.81	81.15	81.1	79.44	77.1	81.07
C18:2 *	14.8	1.75	14.7–14.8	13.5	12.06	13.6	15.35	13.0	13.63
C18:3 *	2.100		0.2–0.2	0.15	0.88	0.7	0.22		0.15
SFA*	19.32	0.99	4.8–5.3	4.44	5.48	4.5	4.42	8.4	4.86
MUFA*	63.44	13.6	79.6–80.4		81.59	81.2	79.94	77.4	
PUFA*	17.23	1.75	14.9–15.1		12.94	14.3	15.57	13.0	

*, **: values in g per 100 g, and mg per 100 g, respectively. a: A: Results from the current study—means over three cultivars, two years, two row spacings and two replications; B: Food Central, 2022; C: Nguyen et al., 2020, results from 2010 and 2011, respectively; D1 and D2: Sriti et al., 2009, and 2010, respectively; E: Msaada et al., 2009; F: Kozlowska et al., 2016: G: Moser and Vaughn, 2010; H: Balbino et al., 2021.

Coriander seed oil in our study contained approximately 0.6 percent erucic acid (C22:1). We were not able to find any information about concentration of this fatty acid in coriander seed in the literature. The content of erucic acid varied from 2.4 to 2.7% of the total FA. We had previously observed that content of erucic acid among 12 lupin genotypes, grown in Virginia during 1994, varied from 0.6 to 1.5% with a mean of 1.1%. This amount of erucic acid, which is considered an anti-quality factor, is of little significance for food or feed grains. As is known from research with canola (*Brassica napus* L.), a content of erucic acid up to 3% is not considered detrimental for human health [28]. Presence of Erucic acid in coriander oil may deserve attention in future studies.

Variations in coriander seed composition are known to exist based on production practices. Diederichsen [1] noted that coriander fruit presented an oil yield ranging from 9.9 to 27.7%; others reported values of 28.4% [29], and 17% [30]. These yield variations can be attributed to some factors like conditions of cultivation especially fertilizers use and irrigation [31]. Their moisture contents were 9.0% in pericarp, 7.0% in seed and 9.30% in whole fruit (NF V03-903). Similar results were found by Msaada et al. [17].

Potential production of coriander in Virginia (Eastern USA) has the potential to add a new crop to the cropping system. Increasing world populations would need increasing quantities of food, which may affect production of specialty crops such as coriander, thus, affecting imports and exports. Increased production of coriander in the United States could help ensure availability of coriander in the world market. We have previously reported that both cilantro and coriander can be successfully produced in Virginia using either 37.5 or 75 cm row spacings [32]. Most Virginia farmers own either 30-inch (75 cm) or 15-inch (37.5 cm) row planters indicating that coriander can be planted with existing equipment. Similarly, coriander can be harvested with soybean combines after minor adjustment in concave settings. Mean cilantro fresh yields from fall-planted experiments were observed to vary from 3301 to 5775 kg·ha^{-1} whereas those for summer-planted experiments varied from 4971 to 11,811 kg·ha^{-1}, corresponding values for dry cilantro yields varied from 274 to 1129 and 862 to 2280 kg·ha^{-1}, respectively indicating superiority of summer-planted cilantro. Mean coriander seed yields from fall-planted crop varied from 818 to 1554 kg·ha^{-1} and those for summer-planted crop varied from 869 to 1277 kg·ha^{-1} indicating superiority of fall planting. Based on these results, we had concluded that both summer and fall planting are possible in Virginia.

Results from the current study indicating that composition of coriander seed produced in Virginia is, generally, similar to that produced elsewhere support our conclusion that coriander is a potential alternative crop for farmers in Virginia (USA) both as a winter or summer crop. Production of coriander in Virginia can support in meeting domestic markets and help in meeting world demands via exports.

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