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Fruit Composition of Elderberry (*Sambucus* spp.) Genotypes Grown in Oregon and Missouri, USA

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Abstract

Twelve *Sambucus nigra* subsp. *canadensis* genotypes were grown at two Missouri and one Oregon (USA) locations to characterize fruit composition in 2004, 2005, and 2006. Fruit was also sampled from an additional 10 genotypes of subsp. *canadensis* and *nigra* grown in Oregon. Soluble solids content ranged from 8.9 to 12.5 °Brix, and titratable acid (as citric acid) was 0.4 to 1.7 g/100ml. Ferric ion reducing activity potential (FRAP) values were 15.6 to 30.7 µmol/g trolox equivalents. Total anthocyanin content ranged from 85 to 385 mg/100 g cyanidin-3-glucoside equivalents (C3GE) and total phenolic content was 421 to 719 mg/100 g gallic acid equivalents (GAE). Of the genotypes sampled in three locations, six genotypes were high (250–350), and four were very low in total anthocyanin (<150 mg/100 g C3GE), respectively. ‘Barn’ and ‘Scotia’ were highest, and ‘Nova’ lowest in total anthocyanin content among genotypes grown in Oregon. Of the total antioxidant tests used, total phenolics was the best quick test, as it is the easiest of the assays, showed the least change among years, and correlated highly with FRAP.

Keywords

anthocyanin; phenolics; antioxidant; acidity; FRAP; trolox

INTRODUCTION

While the European elderberry (*Sambucus nigra* L. subsp. *nigra*) is well known and cultivated domestically in Europe and elsewhere, the native North American elderberry [*Sambucus nigra* L. subsp. *canadensis* (L.) Bolli] is a niche crop (Charlebois et al., 2010). The unique anthocyanins in both subspecies (cyanidin sambubiosides) have generated interest for use in pharmaceuticals and dietary supplements (Mohebalian et al., 2012). Elderberries possess anti-inflammatory and anti-viral properties (Zakay-Rones et al., 1995; Roschek et al., 2009). Additionally, the acylated anthocyanins common in American elderberry are prized for imparting color stability to food products (Nakatani et al., 1995; Lee and Finn, 2007). In this paper, we examine the fruit composition characteristics of elderberries grown in diverse geographic locations.

MATERIALS AND METHODS

Plantings of 12 American elderberry genotypes were established in 2003 at three U.S. locations: Mt. Vernon, Missouri (latitude 37°4'N; longitude 93°53'W), Mountain Grove, Missouri (latitude 37°13'N; longitude 92°26'W), and Corvallis, Oregon (latitude 44°30'N; longitude 123°28'W). Orchard and experimental details, including genotypes, sites, environmental conditions, horticultural methods, harvest protocols, etc. are described in Thomas and Byers (2000), Finn et al. (2008) and Thomas et al. (2013). Fruit from replicated plots at the three sites was harvested 2004, 2005, and 2006. An additional 10 genotypes were sampled from Corvallis in 2004 and 2005. All fruit was harvested at peak ripeness, frozen, and held at -20°C until analyzed at the former USDA-ARS Wes Watkins Agricultural Research Laboratory, Lane, OK.

About 50 g berries were destemmed and thawed, pureed with double distilled water (1:1 wt./volume) using a blender cup, then ground and homogenized. Soluble solids content (SSC; °Brix) pH, titratable acidity, total anthocyanin and total phenolics content were measured as outlined in Thomas et al. (2013). Ferric reducing activity potential using trolox substrates was measured on the same extracts used for total phenolics following methods of Benzie and Strain (1999).

Data were subjected to analysis of variance (Proc GLM; SAS Institute, Cary, NC) and means separated by least significant difference test at $p = 0.05$. Linear regression was performed using SAS to determine relationships between compositional assays.

RESULTS AND CONCLUSION

When averaged across locations in all years, genotypes varied in all fruit composition characteristics evaluated (Table 1). The pH, SSC, and acidity of elderberry genotypes grown in the three locations averaged 4.92, 10.9 °Brix, and 0.53 g/100 ml citric acid, respectively. Among genotypes grown at all locations, 'Highway O' and 'Johns' were highest in pH, but low to lowest in SSC and acidity. 'Johns' and 'Netzer' were consistently low in anthocyanin content, appearing brown in color (Thomas et al., 2013). This effect was also seen in total phenolics content, where 'Johns' and 'Netzer' were lowest (439 and 514 mg/100 g, respectively) while 'Adams 2' was highest (719 mg/100 g). Lee and Finn (2007) also reported high total anthocyanin and phenolic values for 'Adams 2'. The *canadensis* genotypes used in this study were found to be somewhat lower in total anthocyanins compared with values reported for *nigra* by Veberic et al. (2009).

Genotypes with the highest FRAP values were 'Adams 2', 'Wyldeewood', 'Bob Gordon', and 'Eridu 1'. The first three are commercially-available cultivars, and these results support their value as cultivars for use in dietary supplements and other products. 'Johns', another commercial cultivar, had very low FRAP values. As reported in Thomas et al. (2013), 'Johns' productivity was poor at both Missouri sites. The poor productivity plus poor fruit composition of 'Johns' makes it an unsuitable cultivar for the midwestern US.

Of the elderberries grown only in Oregon, pH, SSC, and acidity ranged from 4.03 to 4.75; 8.9 to 12.5 °Brix; and from 0.73 to 1.65 g/100 ml, respectively (Table 2). The genotypes

‘Haschberg’, ‘Korsør’, and ‘Golden City’ were low in pH and high in acidity while SSC was highest in ‘Barn’, ‘Scotia’, and ‘Korsør’. Total anthocyanin content ranged widely, from 85 to 385 mg/100 g. ‘Barn’ was high in total anthocyanin, phenolic, and FRAP values. In contrast, ‘York’ and ‘Nova’ were low in total anthocyanin and FRAP values relative to the other genotypes. The representation of *nigra* genotypes in this study was small but indicates that both subspecies may have similar processing characteristics when cultivated in Oregon.

When total anthocyanin or total phenolic contents were regressed to FRAP values, strong linear relationships were seen among these variables (Fig. 1). Regression fit was similar between total anthocyanin and FRAP ($r^2=0.66$), total phenolic content and FRAP ($r^2=0.63$), and total anthocyanin and total phenolic content ($r^2=0.61$).

Results from this study support earlier findings (Finn et al., 2008; Özgen et al., 2010; Thomas et al., 2013) that the fruit composition character of elderberry is influenced by both genetic and environmental factors. Correlations of antioxidant tests and fruit composition assays indicate that pH, SSC, and titratable acidity cannot be used as simple predictors of total phenolic, total anthocyanin, or FRAP values (data not shown). Of the total antioxidant tests used, total phenolics appears to be the best quick test, as it is the easiest of the assays, showed the least change among years, and correlated highly with FRAP.

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Fig. 1.

(A) Regression of total monomeric anthocyanin content to trolox values, (B) regression of total phenolic content to trolox values, (C) regression of total monomeric anthocyanin to total phenolic content, all across multiple elderberry genotypes and locations.

Table 1

Fruit composition of twelve American elderberry genotypes, averaged across three U.S. locations and three harvest seasons (2004–2006); portions of this table excerpted from Thomas et al. (2013) for comparison.

Genotype	<i>n</i>	pH ^z	SSC (°Brix)	TA (g/100 ml citric acid)	Total anthocyanins (mg/100 g C3GE)	Total phenolics (mg/100 g GAE)	FRAP (μmol/g trolox equiv.)
Adams 2	41	4.90 cd ^y	11.8 ab	0.58 abc	312 ab	719 a	30.7 a
Bob Gordon	41	4.86 cde	11.1 c	0.55 c	334 a	649 b	27.6 bc
Competition 5	35	4.73 g	12.2 a	0.60 a	224 c	609 de	25.3 de
Eridu 1	35	4.77 fg	11.3 c	0.59 ab	328 ab	642 bc	26.3 cd
Gordon E	36	4.82 ef	11.3 bc	0.49 ef	246 c	587 ef	18.7 g
Harris 4	35	4.84 def	9.9 d	0.58 abc	300 b	616 d	23.2 f
Highway O	29	5.19 a	9.3 e	0.47 f	315 ab	604 de	23.8 ef
Johns	39	5.17 a	10.4 d	0.42 g	105 e	439 i	12.9 i
Netzer	38	4.91 c	12.2 a	0.56 bc	116 e	514 h	15.8 h
Votra	35	5.04 b	10.4 d	0.46 f	237 c	561 g	18.2 g
Walleye	30	5.01 b	11.1 c	0.51 de	156 d	564 fg	15.6 h
Wyldeewood	35	4.83 def	9.4 e	0.53 d	313 ab	622 cd	28.0 b
Overall mean	429	4.92	10.9	0.53	250	595	22.3

^z Abbreviations: SSC=soluble solids concentration; TA=titratable acidity; C3GE=cyanidin-3-glucoside equivalents; GAE=gallic acid equivalents; FRAP=ferric reducing activity potential.

^y Means within columns with the same letters are not significantly different according to the least significant difference (LSD) test ($p = 0.05$).

Table 2

Mean fruit composition of elderberries grown at Corvallis, OR in 2004 and 2005.

Genotype	n	pH ^z	SSC (°Brix)	TA (g/100 ml citric acid)	Total anthocyanins (mg/100 g C3GE)	Total phenolics (mg/100 g GAE)	FRAP (µmol/g trolox equiv.)
<i>Subsp. canadensis</i>							
Adams 1	16	4.32 bcd ^y	10.1 bc	1.12 cd	291 bc	559 b	23.4 b
Bam	6	4.30 bcd	12.5 a	1.07 de	385 a	672 a	31.7 a
Golden City	8	4.16 dce	10.9 ab	1.29 bc	234 cd	525 bcd	21.2 b
Maxima	10	4.37 de	10.7 abc	0.92 de	166 de	546 bc	21.9 b
Nova	10	4.75 a	10.2 bc	0.76 deb	85 f	421 d	14.0 c
Scotia	12	4.49 ab	11.0 ab	0.91 e	323 ab	532 bc	24.6 b
York	13	4.72 a	10.5 bc	0.73 e	121 ef	443 cd	13.7 c
Mean		4.60	11.0	0.84	193	518	20.2
<i>Subsp. nigra</i>							
Haschberg	8	4.03 e	8.9 c	1.65 a	233 cd	497 bcd	26.4 ab
Korsør	18	4.08 de	11.0 ab	1.38 b	191 de	500 bcd	23.0 b
CSAM14	6	4.22 cde	9.4 bc	1.61 a	189 de	542 bc	24.0 b
Mean		4.35	10.6	1.27	207	521	22.4

^z Abbreviations: SSC=soluble solids concentration; TA=titratable acidity; C3GE=cyanidin-3-glucoside equivalents; GAE=gallic acid equivalents; FRAP=ferric reducing activity potential.

^y Means within columns with the same letters are not significantly different according to the least significant difference (LSD) test ($p = 0.05$).