Sensory Attributes of Juice from North American–Grown Elderberry Cultivars

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Abstract. Various elderberry (Sambucus sp.) cultivars, including Bob Gordon, Marge, Ocoee, Ozark, Wyldewood, and York, have been selected primarily for plant productivity in North America and are most often processed into juice-based products. This study was conducted to quantify juice characteristics and to evaluate sensory attributes of juice from six elderberry cultivars using descriptive analysis. Hue angle values of ‘Bob Gordon’ and ‘York’ juices were low as compared with others tested. Soluble solids and titratable acidity of juices from ‘Wyldewood’ and ‘York’ were lower than those from other cultivars. Trained panelists identified 24 terms for descriptive analysis of elderberry juices. Of these 24 attributes, juices were highly characterized by a processed aroma, and several flavors, including processed, elderberry, fruity, and sweet. Unique juice descriptors for North American–grown elderberry cultivars included apple, beet, caramelized, fermented, processed, and pomegranate flavors, as well as astringent mouthfeel. Juices from elderberry cultivars differed in intensity ratings of nine attributes, including fruity, floral, sweet aromatics, bitter, sour, and sweet flavors, bitter and sweet aftertastes, and astringent mouthfeel. ‘York’ juice generally had high intensity ratings for sweet aromatics and sweet flavors, and relatively lower ratings for bitter aftertaste and astringent mouthfeel as compared with juices from other cultivars. This study provided key elements for future elderberry sensory research in the development of a formal lexicon for juice with defined attributes.

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In a 2009 survey, elderberry products also ranked eighth in sales (over $6.8 million) among botanical dietary supplements in the United States (Cavaliere et al., 2010). ‘Bob Gordon’, ‘Ocoee’, ‘Ozark’, and ‘Wyldewood’ are American elderberries (Sambucus nigra L. ssp. canadensis (L.) Bolli) selected from the wild in Missouri, Tennessee, Arkansas, and Oklahoma, respectively, that have been available for commercial production since 2011 (Thomas et al., 2015a). The cultivar York is also an American elderberry that was released by the New York Agricultural Experiment Station in 1964 (Greene et al., 1997). More recently, ‘Marie’ was selected from Kansas and is a highly productive European elderberry (Sambucus nigra ssp. nigra) (Thomas et al., 2015b). When nine elderberry cultivars were grown in research trials conducted at three Missouri sites, ‘Marge’ plants produced the greatest number of cymes and were the highest yielding (Thomas et al., 2015b).

Total anthocyanin content, phenolics, and other compounds extracted from elderberry fruit and juice have been studied due to their potential use in dietary supplements and medicinal products. Kaack et al. (2008) identified neochlorogenic acid, chlorogenic acid, cyanidin-3-sambubioside, cyanidin-3-glucoside, cyanidin-3,5-diglucoside, cyanidin-3-sambubioside, cyanidin-3-glucoside, quercetin-3-rutinoside (rutin), and quercetin-3-glucoside (isoquercetin) in juice preparations from selected European elderberry genotypes. Other studies evaluated total polyphenols and total monomeric anthocyanin contents to assess variability among American elderberry accessions and cultivars (Lee and Finn, 2007; Nakatani et al., 1995; Ozgen et al., 2010; Perkins-Vecazie et al., 2015; Thomas et al., 2013; Wu et al., 2015). Although phenolic and anthocyanin contents differed by genotype, production site, and annual climatic conditions, ‘Bob Gordon’ had high levels of these compounds as compared with other cultivars tested in North America (Lee and Finn, 2007; Perkins-Vecazie et al., 2015; Thomas et al., 2013; Wu et al., 2015).

In addition to polyphenols, the aromatic composition of elderberry has been characterized. Fifty-nine volatile compounds were identified from processed juice of European elderberries grown in Denmark (Kaack et al., 2005). Compounds associated with elderberry, fruity, floral, and green aromas, as well as other odors were correlated with elderberry flavor intensity. The characteristic elderberry aroma was attributed to nonanal, dihydrododecane, and δ-damasconene. Fruity aromas were associated with esters of lower carboxylic acids and alcohols; floral and floral green odors with 2-hexenal, (E)-2-hexenal, and (Z)-3-hexen-1-ol, (E)-2-hexenal, and hexanal (Jensen et al., 2001; Kaack, 2008; Kaack et al., 2005; Poll and Lewis, 1986).

Sensory attributes for juice flavor have received less attention than analysis of their aroma profiles, especially for American elderberry. In the Czech Republic, 17 European elderberry cultivars were evaluated for appearance, juiciness, aroma, flavor, and overall taste (Kaplan et al., 2015). ‘Dana’, ‘Heidegg 13’, ‘Samdal’, and ‘Weihenstephan’ generally had the highest overall taste ratings among the elderberry cultivars tested. However, with the exception of ‘Samdal’, many of the elderberry cultivars grown in Europe are unavailable in North America. In addition, intensities of specific sensory attributes have not been quantified by descriptive analysis for elderberry cultivars commonly grown in North America. Therefore, the objectives of this study were to identify and evaluate aroma, flavor, and mouthfeel of these American elderberry cultivars.
attributes of juice from six elderberry cultivars using descriptive sensory analysis and to compare juice color and composition (soluble solids, pH, and titratable acidity).

**Materials and Methods**

Plant material and sample collection. A planting of elderberry cultivars was established in April 2008 at the University of Missouri Southwest Research Center near Mount Vernon, MO. The soil at this site is a Hoberg silt loam (fine-loamy, siliceous, mesic Mollic Fragiudalfs), which is moderately well drained with a fragipan at 40 to 90 cm below the soil surface. Four replications of four plant plots of each cultivar (Bob Gordon, Marge, Ocoee, Ozark, York, and Wyldewood) were arranged in a completely randomized design using a 1.2 m x 2.4 m spacing. Nitrogen fertilizer was applied in March at 56 kg ha⁻¹ annually. Plants were irrigated weekly to provide 2.5 to 4.0 cm water. Weeds were controlled manually and the escape groundcover was mowed. Fruit was harvested at peak ripeness (e.g., all fruit in cyme dark purple color) from 4 to 18 Aug. 2014. Immediately after harvest, berries were washed, destemmed, sealed in polyethylene bags, and stored at −20 °C until juice extraction.

**Juice color and fruit compositional analysis.** For color measurements, a 200-g berry sample of each cultivar (composite sample from all harvest dates) was thawed and pressed in a sieve for juice extraction. A 10-mL juice sample was then placed in a cuvette in a cell holder attached to a handheld spectrophotometer (CM-2600d; Konica Minolta, Ramsey, NJ) with a 6-mm-diameter aperture. For each measurement, the D65 illuminant, a 10° observer setting, and the specular light excluded mode of the spectrophotometer were used, as well as the standardized Commission Internationale de l’Eclairage color values (Konica Minolta, 2007). The L* value ranges from 0 (black) to 100 (white) (Voss, 1992). Chroma (C) is the departure from white toward pure hue color and represents brightness (McGuire, 1992). Hue angle quantifies color, where 0° = red, 90° = yellow, 180° = green, and 270° = blue (Konica Minolta, 2007). Two readings of juice color values (L*, chroma, and hue angle) for each sample were determined, anchored to the scale, and reviewed to ensure understanding of the terms. Each panelist was presented with a selection of elderberry juice samples to taste and identify sensory characteristics that discriminated the samples. Each of the attributes was evaluated using a 0- to 150-mm line scale (0 = none to 150 = extreme) with 1-mm increments (intensity of references were provided for the attributes). Panelists’ understanding and ability to use the identified sensory characteristics were assessed during orientation sessions. Discrepancies regarding the understanding of terms were discussed and resolved during these sessions. In the fourth session, the panel came to consensus on 24 attributes (Table 1) to describe the samples, which were placed on the ballot for the blind evaluations.

After orientation sessions were completed, panelists evaluated samples in a well-lit (natural and fluorescent lighting) room at 22 ± 1 °C and 55% relative humidity. All juice samples were evaluated in triplicate over three 2-h sessions, with each of the six cultivars presented at each session. A randomized complete block design was used to determine the serving order of the juice samples for each cultivar for each of the three sessions. Before serving, 200-mL juice samples of each cultivar were thawed 6 h at 22 °C. Each 20-mL sample was placed in a 30-mL plastic cup and covered with a lid for 10 min before serving. Panelists were instructed to sniff three times for the aroma descriptors and take a sip of each juice sample for flavor, aftertaste, and mouthfeel evaluations. Deionized water and unsalted crackers were served as palate cleaners. A minimum break of 2 min was taken between each sample. Ratings were collected using paper ballots.

**Data analysis.** Juice color (L*, chroma, hue angle), soluble solids, pH, and titratable acidity data were subjected to analysis of variance (ANOVA) using SAS (version 9.3; SAS Institute, Cary, NC) and means were separated by Tukey’s honestly significant difference (HSD) at P ≤ 0.05. ANOVA was also conducted for each sensory attribute with cultivar, replicate, and panelist, as well as all two-way interactions of these factors using PROC GLIMMIX. Panelists and replicates were treated as random effects. HSD tests were performed post hoc for those attribute means found significantly different across the samples by ANOVA (P ≤ 0.05). Data from chemical and sensory attributes that significantly discriminated among the samples were used in a principal components analysis (PCA). PCA was performed on the correlation matrix using JMP (version 9.3; Cary, NC). Following PCA, attributes with vectors in close proximity on the first two components were further analyzed using multiple regression.

**Results and Discussion**

**Juice color and fruit compositional analysis.** Undiluted juice samples had similar L* values when evaluated for color (Table 2). However, chroma values were significantly higher for ‘York’ and ‘Bob Gordon’ juices than ‘Ocoee’, ‘Ozark’, and ‘Wyldewood’ samples. ‘Bob Gordon’ and ‘York’ juices had the lowest hue angle values and were visually browner than samples of other cultivars with a strong correlation found between hue angle and chroma values (R² = 0.89, P = 0.005). ‘Wyldewood’ and ‘York’ juices had the lowest soluble solids and titratable acidity (Table 2). Juice from ‘Wyldewood’ had a higher pH than that of other samples, except for ‘York’. Results for soluble solids and pH in the present study are consistent with those reported in another 3-year study in which juice composition was compared for the same cultivars (Thomas et al., 2015b). Because soluble solids of elderberry juice are generally low, processors typically add high concentrations of sweeteners to their products, including sucrose, sorghum syrup, agave nectar, or pear juice. Products such as Elderberry Herbal Cordial (Elderberry Life, Pittsboro, NC), Biotta Elderberry Juice (CAJ Food Products, Carmel, IN), and Sanso Springs Elderberry Juice (Nebraska, MO) range from 43 to 47 °Brix (M.R. Warmund, unpublished data), indicating these elderberry products are sweeter than the juice tested in the present study.

Sensory attributes. A total of 24 sensory attributes were used to qualify and quantify the juice from the elderberry cultivars in this study, including six aroma descriptors (fruity, elderberry, sweet, processed, fermented, and green/viney), 14 flavor attributes (apple, beet, caramelized, elderberry, fruity, fermented, processed, floral, pomegranate, sweet aromatics, green, bitter, sour, and sweet), three
Table 1. Descriptive terms, definitions, and references used in the sensory analysis of juices from six North American–grown elderberry juices.

| Attribute and definition | References and anchors |
|--------------------------|------------------------|
| Aroma                    |                        |
| Fruity: a general term used to describe the sweet, floral, fruity aromatics associated with a blend of fruits | Black elderberry syrup (Gaia Herbs, Brevard, NC), 350 g L⁻¹ solution = 25 |
| Elderberry: aromatics associated with elderberry fruit | Elderberry extract (Dynamic Health Laboratories, Brooklyn, NY), 50% solution = 25 |
| Sweet: aromatic associated with sweet material | Clover honey (Great Value, Wal-Mart, Bentonville, AR) = 35 |
| Processed: aromatic associated with processed, canned fruits, or vegetables | Peach juice (Minute Maid, Sugar Land, TX) = 75 |
| Fermented: aromatics associated with fermented fruits or vegetables | Dried figs (David Lewis orchards, Garden Grove, GA) = 35 |
| Green/viney: aromatics associated with green vegetables and newly cut vines and stems | Stems of Forsythia xintermedia Zab. = 30 |
| Flavor                   |                        |
| Apple: a sweet, light, fruity, somewhat floral aroma commonly associated with processed apple juice and cooked apples | Apple juice (Great Value, Wal-Mart, Bentonville, AR) = 70 |
| Beet: the slightly sweet flavor commonly associated with canned/cooked beets | Canned beets (Kroger, Cincinnati, OH) = 70 |
| Caramelized: cooked flavor that may include the character notes identified as caramelized and associated with dates or other cooked fruit | Elderberry jelly (Dutch Kettle, Hamptonville, NC) = 20 |
| Elderberry: flavor associated with elderberry fruits | Elderberry extract (Dynamic Health Laboratories, Brooklyn, NY), 50% solution = 85 |
| Fruity: a general term used to describe the sweet, floral, fruity flavor associated with a blend of fruits | Dates (Sunsweet, Yuba City, CA) = 45 |
| Fermented: flavor associated with fermented fruits or vegetables | Dried figs (David Lewis Orchards, Garden Grove, GA) = 35 |
| Processed: flavor associated with processed, canned fruits or vegetables | Peach juice (Minute Maid, Sugar Land, TX) = 75 |
| Floral: sweet, light, slightly perfumery impression associated with flowers | Clover honey (Great Value, Wal-Mart, Bentonville, AR) = 50 |
| Pomegranate: flavor associated with pomegranate fruit | Pomegranate arils (DJ Forry, Reedley, CA) = 35 |
| Sweet aromatics: flavor associated with sweet material | Clover honey (Great Value, Wal-Mart, Bentonville, AR) = 35 |
| Green: flavor associated with the green material | Homogenized, filtered parsley (25 g fresh parsley and 300 mL water) = 40 |
| Bitter: the amount of bitter taste left on palate after expectoration | Caffeine (Sigma-Aldrich, St. Louis, MO), 0.8 g L⁻¹ solution = 20 |
| Sour: the basic taste associated with citric acid | Citric acid (Sigma-Aldrich, St. Louis, MO), 0.5 g L⁻¹ solution = 20 |
| Sweet: the basic taste associated with a sucrose solution | Sucrose (Kroger, Cincinnati, OH), 50 g L⁻¹ sucrose solution = 50 |
| Bitter aftertaste: the amount of bitter taste left on the palate after expectoration | Caffeine (Sigma-Aldrich, St. Louis, MO), 0.8 g L⁻¹ solution = 20 |
| Sour aftertaste: the amount of sour taste left on the palate after expectoration | Citric acid (Sigma-Aldrich, St. Louis, MO), 0.5 g L⁻¹ solution = 20 |
| Sweet aftertaste: the amount of sweet taste left on the palate after expectoration | Sucrose (Kroger, Cincinnati, OH), 50 g L⁻¹ sucrose solution = 50 |
| Mouthfeel                |                        |
| Astringent: the puckering or drying sensation on the mouth or tongue surface | Alum (McCormick & Co., Hunt Valley, MD), 20 g L⁻¹ alum solution = 20 |

*Reference values anchored to a scale of 0 (no perception) to 150 (extreme perception).

Astringent: the puckering or drying sensation on the mouth or tongue surface.

Table 2. Mean juice color (L*, chroma, hue angle) and fruit composition of six North American–grown elderberry cultivars.

| Cultivar       | L*    | Chroma | Hue angle | Soluble solids (°Brix) | pH    | Titratable acidity (g/100 mL as citric acid) |
|----------------|-------|--------|-----------|------------------------|-------|---------------------------------------------|
| Bob Gordon     | 27.46 | 1.03 b | 27.8 b    | 12.4 a                 | 4.72 b| 0.28 a                                      |
| Marge          | 27.26 | 1.00 bc| 32.93 a   | 12.4 a                 | 4.51 d| 0.32 a                                      |
| Ocoee          | 27.35 | 0.97 cd| 32.69 a   | 12.1 a                 | 4.70 c| 0.30 a                                      |
| Ozark          | 27.33 | 0.93 d | 35.35 a   | 12.3 a                 | 4.59 cd| 0.31 a                                      |
| Wyldewood      | 27.28 | 0.94 d | 33.44 a   | 10.4 b                 | 4.99 a| 0.21 b                                      |
| York           | 27.45 | 1.08 a | 26.22 b   | 9.9 b                  | 4.87 ab| 0.25 b                                      |

*Values represent the mean of three replications. Means with different letters in a column are statistically significant at P ≤ 0.05 by Tukey’s honestly significant difference test. L* scale ranges from 0 = black to 100 = white. Chroma is the departure from white toward pure hue color and represents brightness. Hue angle quantities color where 0° = red, 90° = yellow, 180° = green, and 270° = blue.
The angle was strongly correlated with sour taste. 'Ocoee' juice was the most dissimilar from 'York' samples, differing in nine sensory characteristics. Relative to 'York', juice from 'Ocoee' was significantly less flavorful (fruity, floral, sweet aromatics, sweet, and sweet aftertaste attributes) and more bitter, and sour in taste, bitter in aftertaste, and astrigent in mouthfeel. Although sucrose was added to adjust juices to a similar soluble solids content, panelists perceived 'York' juice to have a sweeter initial flavor and aftertaste than juices from other cultivars. The reason for these perceptions is unclear, but may be related to the low titratable acidity and low intensity of bitter aftertaste of 'York' juice. Average intensity ratings for 'Ozark' juice were significantly more bitter (taste and aftertaste), sour, and astrigent than those ratings for 'York' juice. Sensory attribute ratings were not significantly different among juices from 'Bob Gordon', 'Marge', and 'Wyldewood', except for the more bitter flavor of 'Marge' samples. Results from the PCA showed that the first two principal components (C1 and C2) accounted for 79.7% of the variation (Fig. 1). Component 1 explained 60.6% of the variability and was positively related to bitter and sour flavors, bitter aftertaste, and astrigent mouthfeel, as well as hue angle. This component was strongly and negatively related to sweet flavor, sweet aromatics flavor, sweet aftertaste, and chroma. Component 2 explained 19.1% of the variability and was more heavily influenced by juice characteristics (pH, titratable acidity, and soluble solids). Fruity and floral flavors had relatively minor influences on C1 and C2. 'York' juice was separated from those of all other cultivars on C1, having the highest values for most of the taste attributes related to bitterness and sour flavors and astrigency. 'York' also had the highest chroma value with 'Ozark' and 'Wyldewood' among the lowest, further defining the separation of the juice from these cultivars on C1. Juice from 'Marge', the only European elderberry cultivar included in this study, did not separate from juices of other cultivars studied on C1. However, 'Marge' juice was distinguished on C2, which was defined predominantly by pH, soluble solids, and titratable acidity. When means of several of the important attributes for C1 were analyzed individually with chroma by linear regression, a strong negative correlation was found for bitter aftertaste ($R^2 = 0.73$, $P = 0.03$), sour taste ($R^2 = 0.83$, $P = 0.012$), and astrigency ($R^2 = 0.78$, $P = 0.014$). However, hue angle was strongly correlated with sour taste ($R^2 = 0.82$, $P = 0.013$).

This research demonstrated that elderberry juices from 'Bob Gordon' and 'York' fruit differed in hue angle (i.e., visually browner in color) as compared with juices from other cultivars. Also, 'Wyldewood' and 'York' juice samples had the lowest soluble solids and titratable acidity. Using highly trained panelists, 24 attributes were used to describe sensory characteristics of elderberry cultivars currently grown in North America. Although other research on elderberry juice has focused on volatiles to evaluate sensory characteristics of S. nigra ssp. nigra cultivars in Europe, this study identified unique descriptors for juices from North American-
grown cultivars not previously reported, including apple, beet, caramelized, fermented, processed, and pomegranate flavors, as well as astringent mouthfeel. In addition, elderberry juices produced in North America are most highly characterized by processed aroma and processed elderberry flavors, but varied in nine sensory attributes, including fruity, floral, sweet aromatics, bitter, sour, and sweet flavors, bitter and sweet aftertastes, and astringent mouthfeel. Surprisingly, juice from ‘Marge’, which is a European elderberry, was indistinguishable from that of ‘Bob Gordon’ and ‘Wyldewood’ (American elderberries) for all sensory attributes except bitter flavor. Relative to other cultivars in this study, ‘York’ may be favored by juice processors due to its relatively low astringency and bitter aftertaste.

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