Sensory Profiles of Carrot (*Daucus carota* L.) Cultivars Grown in Georgia

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Abstract. Descriptive analysis was used to compare sensory color, flavor, and textural attributes of Georgia-grown carrots. The relation between °Brix, total sugar, and intensity perception of sweetness was also studied. Significant differences existed in the perception of sweet taste and of color, and in levels of °Brix and percentage of sugar among all cultivars, but perceived intensity of sweetness was not related to the levels of °Brix or percentage of sugar. No significant differences were found among cultivars in harsh carrot, green, astringent, and earthy flavors, and in the perception of sour taste. Intensity ratings for perceived hardness were nonsignificant in either study. Differences in sensory profiles existed among all cultivars, but no trend was evident in the relation of sweetness to harsh flavor.

Quality is important in the marketing of carrots, and flavor is one of the important factors in assessing carrot quality. To be profitable in Georgia, carrots must be characterized to determine their competitive advantage in the marketplace. Carrots grown in California, Florida, and Texas have been characterized in an effort to improve carrot quality (Simon et al., 1980).

Descriptive analysis involves the detection and description of both qualitative and quantitative sensory aspects of a product by trained panelists who are able to detect perceived sensory attributes that define the product (Meilgaard et al., 1991). McLellan et al. (1983) used Quantitative Descriptive Analysis (QDA) and factor analysis to analyze overall aroma and nine major aroma components of raw carrots (Table 1) that may explain intervarietal differences. They found five independent aroma factors that accounted for >69% of intervarietal variation: earthy-organic, basic raw carrot, fruity-perfumey, nonearthy, and piney. Martens et al. (1979) used a trained sensory profile panel of seven people to generate 46 terms to characterize raw carrots. Factor analysis was then used to determine those sensory terms (Table 1) that would best describe quality. Simon and colleagues (1980) used QDA scales and intensity of difference scales to evaluate samples of carrot varieties

grown at different locations. Flavor-profiling methods were used to select "carrot varieties cultivated at different sites that are most suitable for carrot chip production with reference to sensory properties of fresh carrots" (Baardseth et al., 1996).

Simon et al. (1980) used 25 to 30 trained panelists who evaluated identical cultivars grown in Florida, Texas, and California for sweetness, harsh flavor, overall carrot flavor, and overall preference using QDA scales for intensity. In a later study, Simon et al. (1982) planted carrots under optimal conditions in Florida, Wisconsin, and California. They found that the flavor of raw carrots was largely influenced by genetic variation, with domi-

nance for desirable flavor attributes (high sweetness, low harsh flavor). Differences in sweetness could not be detected by a sensory panel, but flavor was harsher in carrots grown in Florida (warmer, higher relative humidity, lower light intensity) than in those grown in California, indicating that climate also has an effect.

Scheerens and Hosfield (1976), using QDA techniques, reported that as total solids increased, the perception of sweetness also generally increased. However, this perception was not true in several instances where the perception of sweetness may have been masked by bitter and harsh sensations. Their recommendation to breeders was to select not only for high total soluble solids, but also for nonbitterness and balanced flavor.

The objective of this study was to determine differences in sensory characteristics of Georgia-grown carrots. Specific objectives were to: 1) characterize and compare attribute intensities of cultivars of carrots; and 2) determine relationships between intensity perception of sweetness and harsh carrot flavor vs. percentage of total sugars and °Brix in these carrots.

Materials and Methods

Experimental design

Carrots were harvested at two maturity dates, 27 Mar. and 8 May 1997, and at two different locations, Pelham Sandy loam in Jefferson Davis County and Lake Sound soil in Wayne County, respectively. Five cultivars were grown at each location. Two varieties, Choctan and Vitasweet 711, were common to the two locations, for a total of eight varieties in all. Two replicate samples representing two different locations in each field were obtained for Study 1 and Study 2, respectively.

Study 1. Testing took place over 2 d. On Day 1, panelists evaluated replication 1 of carrots harvested 22 Apr. 1997. After evaluating five samples, panelists took a break and

Table 1. Sensory attributes used in various studies to characterize carrots.

Color	Taste	Flavor	Texture
Whiteness ^z	Sweet ^{z, y, x, w, v}	Cardboardy ^y	Juiciness ^{z, w}
Color hue ^z	Sickly sweet ^z	Woody ^{y, x}	Crisp ^{z, w}
Color strength ^z	Bitter ^{z, y, w}	Hay-like ^x	Resistance to chewing ^w
	Salty ^y	Earthy ^{z, x}	Hard ^w
	Acid ^z	Piney ^x	Firmness ^z
		Green grass ^{y, w}	
		Turpentine ^y	
		Harsh flavor ^v	
		Carrot ^x	
		Overall carrot flavor ^v	
		Fruity ^{z, x, w}	
		Perfumey ^x	
		Musty ^{y, x}	
		Cloves ^y	
		MSG ^y	
		Waxy ^y	
		Sharp ^w	
		Aftertaste ^{w, v}	

^zBaardseth et al., 1996.

^yCiville and Lyon, 1996.

^xMcLellan et al., 1983.

^wMartens et al., 1997.

^vSimon et al., 1980.

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then evaluated five more samples, which were duplicates of the previous set. On Day 2, the procedures were repeated for replication 2. Twelve panelists evaluated 10 samples each day for 2 d for a total of 240 responses.

Study 2. Testing followed the same procedures as in Study 1. Eight panelists evaluated 10 samples each day for 2 d for a total of 160 responses.

Sample description

Study 1. Carrot cultivars Six Pack F1, Asgrow XPH3973, Choctaw, Vitasweet 711, and Ireland were planted in Pelham sandy loam in Jefferson Davis County, Ga., on 1 Oct. 1996. Carrots were harvested on 27 Mar. 1997, transported to Athens, Ga., on ice, and then stored at 2 °C and 85% relative humidity (RH) for ≈3 weeks. On 21 Apr. 1997, carrots were transported to Griffin, Ga., on ice and were stored at 0 °C and 80% RH for 1 to 2 d. All carrots were stored for 4 weeks after harvest.

Study 2. Carrot cultivars Choctaw, Cheyenne, Vitasweet 711, Dawn Dee, and Asgrow XPH3918 were planted in Lakeland Sand soil in Wayne County, Ga., on 30 Oct. 1996. Carrots were harvested on 8 May 1997 and transported to Athens, Ga., on ice and stored at 2 °C and 85% RH for ≈2 weeks. On 20 May 1997, carrots were transported to Griffin, Ga., on ice and stored at 0 °C and 80% RH for 1 to 2 d. All carrots were stored for 2 weeks after harvest.

Sample preparation

On the day of the descriptive analysis test all materials and equipment were sanitized as prescribed by Clorox Co. (Oakland, Calif). Less than 3 h before each test, 14 carrots of each variety were obtained from the cold room, placed in labeled plastic bags, and brought to a kitchen for preparation. Carrots from one bag were immersed for 2 min in cold water, rinsed for 1 min, and peeled using a potato peeler. The middle third section of each carrot was cut into 0.5-cm-thick slices. Three slices, ≈8–10 g, were placed in 59-mL plastic cups with lids coded with a three-digit random number. Filled sample cups were stored in plastic self-sealing bags in a refrigerator until the time of test.

Panel

Study 1. Panelists were recruited from a pool of panelists trained in descriptive analysis and trained employees or students working in sensory evaluation research at the Univ. of Georgia Experiment Station in Griffin. An additional panelist with no previous training in descriptive analysis also participated. A total of 12 panelists, 11 females and 1 male, participated in the study. Panelists' ages ranged from 39 to 62.

To qualify, panelists had to pass a series of tests, including the correct identification of aqueous solutions of sucrose (ICN Biomedicals, Cleveland, Ohio), sodium chloride (Fisher Scientific, Fair Lawn, N.J.), citric acid (Fisher

Scientific), and caffeine (Fisher Scientific), at concentrations of 2.0%, 0.2%, 0.05%, and 0.05%, respectively, prepared in double deionized water. In addition, prospective panelists had to identify at least five of seven different odors, including banana, anise, peppermint, vanilla, orange, lemon, and pineapple [American Society for Testing and Materials (ASTM), 1992]. A total of 15 panelists were screened to obtain five qualified panelists; the remaining seven were previously screened and qualified for participation. Panelists selected were not allergic to any foods, consumed raw carrots at least once a month, and were available for all training and testing sessions. Before the test each panelist signed a consent form approved by the Univ. Institutional Review Board.

Study 2. Panelists from Study 1 who were available for an additional 3 d in May were asked to return for 1 d of calibration and 2 d of testing. Nine of the 12 original panelists participated in Study 2.

Training

Panelists were trained for 2 h each day for 4 d on intensity scaling. During training panelists individually developed a list of descriptors while evaluating samples of raw carrots, and after discussion, collectively agreed upon a list of attributes (Table 2). These included orange color; harsh carrotty, sweet, green, fruity, bitter, astringent, earthy, and sour flavors; and hard, crunchy, and wet/moist textures. A lexicon of descriptive terms for carrot flavors and aromas (Civille and Lyon, 1996) was used as a basis to establish references for attributes.

Each term was defined by panelists (Table 2). Standard references for each attribute (Table 3) were agreed upon by all panelists (ASTM, 1992) during the second and third day of training. The reference for the harsh carrotty flavor was a market sample of carrots from Florida, chosen by panelists because it best represented this flavor. Each panelist rated the

Table 2. Definition of terms used for descriptive analysis of carrots.

Attribute ^z	Definition
<i>Appearance</i>	
Orange color	Intensity or strength of orange color from light to dark orange
<i>Flavor</i>	
Harsh carrotty	Harsh flavor associated with raw carrots
Sweet	Taste associated with sucrose solutions
Green	Aromatic characteristic of freshly cut grass or green vegetables
Fruity	Aromatic characteristic associated with freshly harvested fruit
Bitter	Taste associated with caffeine solutions
Astringent	Puckering or drying sensation of the tongue surface due to substances such as tannins
Earthy	Aromatic characteristic of damp soil
Sour	Taste associated with solutions of acids such as citric
<i>Texture</i>	
Hard	Force necessary to bite through sample between molars
Crunchy	Force needed and amount of sound generated from chewing a sample with the molar teeth
Wet/moist	Amount of wetness or moisture on the surface

^zAttributes are listed in the order they were perceived by panelists.

Table 3. Standard references and intensities used in descriptive analysis of carrots.

Attribute	Reference or source	Intensity ^z (mm)
Orange color	Orange folder (20th Century Plastics, Brea, Calif.)	124
Harsh carrotty	Florida 2 market sample (Apopka, Fla.)	55
Sweet	2.0% sucrose in double deionized water	20
	5.0% sucrose in double deionized water	50
	10.0% sucrose in double deionized water (ICN Biomedicals, Cleveland, Ohio)	100
	Fresh parsley stems (Kroger, Griffin, Ga.)	55
Green	Red Delicious apples (Wenatchee, Wash.)	50
Fruity	0.15% caffeine in double deionized water	100
	0.08% caffeine in double deionized water	50
	0.05% caffeine in double deionized water (Fisher Scientific, Fair Lawn, N.J.)	20
	Grape juice (Welch's Grape Juice, Welch's, Concord, Mass.)	70
Astringent	Potting soil (Schultz, St. Louis)	80
Earthy	0.15% citric acid in double deionized water	100
	0.08% citric acid in double deionized water	50
	0.05% citric acid in double deionized water (Fisher Scientific, Fair Lawn, N.J.)	20
	American cheese slices (Kraft Deluxe, Kraft, Glenview, Ill.)	40
Hard	Almonds (Blue Diamond, Sacramento, Calif.)	110
Crunchy	Dry roasted peanuts (Planters, Winston-Salem, N.C.)	85
Wet/moist	Red Delicious apples (Wenatchee, Wash.)	70

^zRated on a 150-mm scale.

attribute intensity of each reference standard by first evaluating the reference and giving it an intensity rating from 0 to 150 using flashcards. Panelists who did not rate the intensity within 10 points of intensity score of the majority of the panelists were asked to evaluate the sample again and to adjust their ratings until consensus was obtained. Intensity scores for each reference (Table 3) were established by the panel and based upon consensus. During the remaining 3 d of training, panelists practiced evaluating samples of raw carrots using a computerized scoresheet. Reference standards and a list of reference standard intensities were provided in each booth. Panelists evaluated each carrot sample in a balanced sequential monadic order (one at a time). A scoresheet for each sample presented during the test appeared on the computer screen with each attribute listed vertically (Compusense, version 2.2; Compusense, Guelph, Ont., Canada). In the order of attributes listed, a panelist pointed to each attribute using a light pen to view a pop-up screen with a 150-mm unstructured line scale with anchors at 12.7 and 137.5 mm. Using the light pen, panelists marked the intensity of that attribute on the line scale until all attributes were rated. Scores were analyzed each day.

At the beginning of the next session all panelists received a copy of their test results from the previous sessions, which included their scores and the panel mean for each attribute of each sample evaluated. Panelists scoring within 10 points of the panel mean for a particular attribute were considered to be calibrated for that attribute. Panelists continuously calibrated themselves on the reference standards and samples of raw carrots during the remaining training sessions.

Descriptive analysis

All tests were performed in a sensory laboratory in environmentally controlled, partitioned booths under white incandescent lighting. Panelists were instructed to taste two slices of carrots when evaluating flavor attributes and to taste the remaining slice when evaluating textural properties. Five samples were evaluated in each session, for a total of 10 samples and two sessions each day. All samples were expectorated. Panelists rinsed their mouths with tap water at room temperature between samples and were given a compulsory 20-min break between sessions.

Carrots were evaluated using a hybrid descriptive analysis procedure (Einstein, 1991) to determine and quantify color, and flavor and texture characteristics and intensities. Evaluation procedures for testing were the same as outlined in the last 3 d of training.

Instrumental procedures

Brix. About 2.5 cm of each end of every carrot was cut off and the middle portion was blended into a purée using a retail juicer (Juiceman Jr. Co., Mt. Prospect, Ill.). The purée was then filtered using Whatman #1 filter paper to obtain a clear carrot juice ex-

tract. Soluble solids were measured using a hand-held refractometer (NSG Precision Cells, Farmingdale, N.Y.). Three to four drops of the extract were placed on the refractometer stage for °Brix measurements.

Percentage of sugar. Two milliliters of the juice extract was pipetted into centrifuge tubes and 30 mL of 100% ethanol added, followed by the settling agent, Celite 503 (JT Baker, Jackson, Tenn.). Tubes were shaken manually and placed in a 55–80 °C water bath for 10 min. Tubes were centrifuged for 10 min at 17,540 g_n . The solution was decanted and filtered through filter paper into 100-mL volumetric flasks. Thirty milliliters of 60% ethanol were added to the Celite suspension remaining in the centrifuge tubes and the tubes were placed in a water bath at 55–80 °C for 10 min, then centrifuged for 10 min at 17,540 g_n . The extract was filtered through filter paper into the flasks containing the initial filtrate and the flasks filled to volume with 100% ethanol and shaken manually. Two milliliters of the solution were then pipetted into test tubes, and 1 mL of a 5% phenol solution and 5 mL of concentrated sulfuric acid added directly to the liquid surface. The tubes were allowed to stand for 10 min, then shaken manually and placed into a 30 °C water bath for 15 min for color development. Absorbance at 490 nm of 1:4 dilution of the acid/phenol/extract with distilled water was determined using a spectrophotometer (Spectronic, Rochester, N.Y.). To determine percentage of sugar, absorbance readings were compared with a standard curve prepared using 1 mL of 5% phenol, 5 mL of sulfuric acid, and 10, 25, 50, 75, and 100 mg glucose, diluted and made up to volume with distilled water.

Statistical analysis

Analysis of variance was used on balanced data to determine if there were significant differences between treatments. The model included the main effects of replication, panelist, and treatment and the interaction between panelist and treatment. The General Linear Model option (SAS Institute, 1990) was used on unbalanced data for °Brix and percentage of sugar values, and Fisher's least significant difference (LSD) mean comparison tests were performed to determine which treatments differed ($P = 0.05$) from one another. Relations between variables were determined using Pearson product-moment correlations and significance probabilities.

Results

In both Study 1 and Study 2, there were no correlations between any of the attributes, orange color; harsh carrotty, sweet, green, fruity, bitter, astringent, earthy, and sour flavors; and hard, crunchy, and wet/moist textures, which suggests that there was no redundancy in attribute terms and that none of the terms are associated.

In both studies, differences among cultivars were nonsignificant for harsh carrotty flavor, green, fruity, astringent, earthy, and

sour flavors, and hardness (data not shown). Harshness, as defined by Simon et al. (1980), is the strong, burning, turpentine-like flavor most strongly perceived at the back of the throat during or after chewing.

In Study 1, 'Asgrow XPH3973' was significantly highest in sweet taste, whereas differences among the other four cultivars were not significant. In Study 2, 'Dawn Dee' and 'Cheyenne' were rated significantly higher in sweet taste than 'Asgrow XPH3918' or 'Choctaw', but did not differ significantly from 'Vitasweet 711', which was similar to 'Choctaw'.

In Study 2, 'Asgrow XPH3918' was significantly less fruity than the other cultivars, but there were no significant differences among the other four cultivars. 'Asgrow XPH3918' was significantly higher in bitter taste than were 'Choctaw', 'Cheyenne', and 'Dawn Dee', but similar to 'Vitasweet 711'. 'Dawn Dee' was low in bitter taste, but did not differ significantly from 'Choctaw' and 'Cheyenne', while 'Choctaw', 'Cheyenne', and 'Vitasweet 711' were all similar.

In Study 1, 'Vitasweet 711' and 'Ireland' were significantly higher in orange color intensity than were 'Six Pack F1' and 'Asgrow XPH3973' (Table 4). 'Six Pack F1' was significantly lower in orange color intensity than all other cultivars except 'Asgrow XPH3973', which was similar to 'Choctaw'. In Study 2, 'Dawn Dee' was significantly higher in orange color intensity than all other cultivars.

In Study 1, all cultivars were similar in crunchiness, except for 'Ireland', which was significantly different from 'Choctaw' and 'Six Pack F1'. In Study 2, crunchiness did not differ among cultivars.

In Study 1, 'Six Pack F1' was rated higher in the wet/moist attribute than was 'Ireland'. All other cultivars were intermediate in this characteristic. Differences among cultivars were nonsignificant in Study 2.

°Brix and percentage of sugar

In Study 1, 'Asgrow XPH3973', 'Choctaw', and 'Ireland' were similar in °Brix, although all were significantly higher than 'Six Pack F1' and 'Vitasweet 711' (Table 5). In Study 2, 'Dawn Dee' was significantly higher than all other cultivars, and 'Cheyenne' and 'Asgrow XPH3918' were significantly lower. In Study 1, all cultivars except 'Ireland' were significantly different from each other in percentage of sugar. 'Ireland' was similar to 'Six Pack F1' and 'Asgrow XPH3973'. In Study 2 'Choctaw' and 'Vitasweet 711' were higher in percentage of sugar than 'Cheyenne' and 'Dawn Dee', which were not significantly different from each other, and 'Asgrow XPH3918' was lowest.

Discussion

In both studies, harsh flavor did not differ among any of the cultivars of carrots. The intensity ratings of the harsh carrotty flavor evaluated in Study 1 ranged from 37.52 to 39.74 on a 150-mm unstructured line scale,

Table 4. Mean intensity ratings² of sensory attributes of carrot cultivars.

Cultivar	Sensory attribute					
	Sweet	Fruity	Bitter	Orange color	Crunchy	Wet/moist
<i>Study 1</i>						
Six Pack F1	28.8 b ^y	27.4	19.2	73.1 c	33.0 b	52.2 a
Asgrow XPH3973	31.0 a	27.9	18.2	74.1 bc	45.2 ab	43.5 abc
Choctaw	28.2 b	27.7	19.6	75.6 ab	37.5 b	47.8 ab
Vitasweet 711	27.6 b	26.7	19.2	76.6 a	43.9 ab	38.5 bc
Ireland	28.1 b	26.3	20.3	76.9 a	57.2 a	33.7 c
<i>Study 2</i>						
Choctaw	26.3 bc	28.2 a	18.5 bc	74.3 b	38.6	58.0
Cheyenne	28.2 a	28.7 a	18.7 bc	73.9 b	46.0	54.6
Vitasweet 711	27.1 ab	28.1 a	19.5 ab	74.4 b	49.6	50.5
Dawn Dee	27.9 a	28.7 a	18.0 c	76.1 a	48.9	53.5
Asgrow XPH3918	25.2 c	26.5 b	20.6 a	73.8 b	53.9	53.9

²Based on a 150-mm scale.^yMean separation within columns and studies by LSD_{0.05}.

Table 5. Mean °Brix and percentage of sugar values of carrot cultivars.

Cultivar	°Brix	Sugar (%)
<i>Study 1</i>		
Six Pack F1	8.7 b ^z	6.8 c
Asgrow XPH3973	9.3 a	6.0 d
Choctaw	9.2 a	7.6 b
Vitasweet 711	8.6 b	8.4 a
Ireland	9.5 a	6.3 cd
<i>Study 2</i>		
Choctaw	9.0 b	9.7 a
Cheyenne	8.1 d	7.9 b
Vitasweet 711	8.6 c	9.5 a
Dawn Dee	10.0 a	8.7 b
Asgrow XPH3918	7.8 d	7.0 c

^zMean separation within columns and studies by LSD_{0.05}.

indicating that the harsh carrot flavor was slight. Little difference existed between the cultivars of carrots in sweetness, except for 'Asgrow XPH3973' in Study 1, which was significantly higher in sweetness. In a study of soil and climatic effects on sensory components of carrot flavor in California and Florida carrots, Simon and colleagues (1982) found that those carrots with high sweetness were lower in harsh flavor and vice versa. This contrasts with our observation that harsh

carrot flavor and sweetness were independent of each other in the five cultivars of carrots studied. Further, Simon et al. (1980) found that harshness was important in determining lack of preference, and in some cases was 24 times as important as sweetness. Harshness was more important in determining preference for Florida-grown carrots, while sweetness was more important in California-grown carrots. The authors also indicated that location played an important role in the determination of preference and overall carrot flavor.

Differences in ratings for perceived hardness were nonsignificant in both studies; however, ratings in Study 2 were, in general, much lower than those in Study 1. All intensity ratings were based on a 150-mm line scale, with 0 as not hard.

°Brix is a scale of densities often used for sugar solutions and fruit juices. It measures the percentage of soluble solids in, and the sugar content of, a given weight of juice (Peckham and Freeland-Graves, 1996). There was no general trend in the relation of perceived intensity of sweetness vs. the level of °Brix and percentage of sugar found in the carrots. Although 'Asgrow XPH3973' was higher in perception of sweet taste and in °Brix, it was among the lowest in percentage of sugar.

Scheerens and Hosfield (1976) attributed this to the harsh flavor masking the perception of sweetness. Differences in sensory profiles existed between all cultivars of carrots studied, but no general trend was found in the relation of sweetness to harsh flavor.

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