Variety Trials

Bitterness and Composition of Lettuce Varieties Grown in the Southeastern United States

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ADDITIONAL INDEX WORDS. bitterness, β -carotene, lutein, tocopherols, folate, ascorbic acid, production, culture, *Lactuca sativa*

SUMMARY. Lettuce (*Lactuca sativa*) production historically has been limited in the southeastern United States because of the risk of early bolting and unacceptable bitterness. Small-scale vegetable growers may be able to include lettuce in their production through selection of bolt tolerant and nonbitter varieties. The objectives of this research were to evaluate

earliness, bitterness, vitamin E, ascorbic acid, folate, β -carotene, and lutein content in 17 lettuce varieties. Significant differences were found among varieties for days to harvest (DTH) (47 DTH for 'Epic' to 37 DTH for 'Big Curly'). Observed DTH in this study was consistently 7 to 10 days less than commercial descriptions of the lettuce varieties, due to the use of transplants. Only 'Slobolt' and 'Greengo' bolted before reaching marketable size. Panelists found that the bitterness was acceptable for most varieties, but not for 'Nancy,' 'Big Curly,' and 'Slobolt'. Significant differences among varieties were also found in vitamin E, ascorbic acid, folate, β -carotene, and lutein. 'Redprize' and 'Nevada' were the best varieties overall, while 'Salinas 88 Supreme,' 'Epic,' 'Legacy,' 'Big Curly,' 'Slobolt,' and 'Greengo' were unacceptable.

Lettuce is a cool-season, leafy vegetable grown commercially mainly in California, and Arizona. Estimated value for domestic production of head, leaf, and romaine lettuce in 1997 were \$1,324,119,000, \$299,250,000, and \$190,944,000, respectively, and U.S. planted acreage was 102,000, 24,390, and 34,600 acres (41,310, 9,878, and 14,013 ha), respectively (USDA, 2000). The average annual per capita consumption of head lettuce in 1998 was 24 lb (10.9 kg), and that of leaf lettuce/romaine was 14 lb (6.4 kg) (The Leafy Greens Council, 2000). Domestic consumption is on the rise because of the recent expansion of the fresh-cut industry (E. Garrett, personal communication). Fresh-cut retail sales in the United States in 1994 were \$5.8 billion (Hodge, 1995) and are projected to increase to \$19 billion by 2003 (Greenleaf, 1999), representing 228% increase in one decade.

While demand for lettuce has been increasing, spring lettuce production in the southeastern U.S. has been limited mainly for two climate-related reasons. First, some lettuce varieties often bolt before sufficient head or rosette growth occurs. Bolting occurs when the lettuce plant enters its reproductive stage resulting in the elongation of internodes. The onset of bolting is accelerated by high air and root temperature (Nothmann, 1977; Poh et al., 1998; Ryder and Waycott, 1994), nitrogen fertilization (Soundy and Smith, 1992), and gibberellin levels (Waycott and Ryder, 1993). Once lettuce has bolted, undesirable physical and chemical changes that affect consumer acceptability and

marketability occur. Bolting is controlled by several genes (Kahn and Magnello, 1986; Silva et al., 1999; Waycott and Ryder, 1993) that are the basis for the development of varieties more resistant to bolting. Second, spring lettuce can be unpleasantly bitter due to the presence of sesquiterpene lactones. Bitterness is also affected by variety and growing conditions.

Despite these challenges, lettuce production in the southeastern U.S. is currently conducted by a relatively large number of growers, each with a small acreage. This lettuce is often sold locally, at roadside stands. Marketing tools for these direct sales are head freshness, attractiveness (created by the display of several leaf shapes and colors), and potential health benefits to the consumers. Currently, more than 300 varieties of lettuce are available (Simonne et al., 2000), making variety selection a difficult task for small growers. Staggered plantings are necessary to ensure a continuous supply to the roadside stand. However, information on growth characteristics supplied with the seeds are seldom relevant for the production conditions found in the southeastern U.S. Growers typically produce a quick, early lettuce crop using plasticulture and transplants, and then reuse the plastic for one (spring) or two (spring and fall) subsequent vegetable crops.

In this type of marketing system, consumers are responsive to nutrition information. USDA Nutrient Database currently provides nutritional information on iceberg, butterhead, looseleaf, and cos or romaine without information on variety (USDA, 2002). Yet, these categories do not closely represent the varieties currently available, and chemical composition of lettuce may be affected by varieties, as was observed with bell pepper (*Capsicum annuum*) (Simonne et al., 1997a). Testing a wide array of lettuce varieties with different colors and leaf shapes, under the warm spring conditions of the southeastern U.S. will help identify commercially acceptable varieties for lettuce growers. The objectives of this research were to 1) evaluate earliness and bolting of selected lettuce varieties, 2) assess the effect of variety on bitterness using sensory evaluation, and 3) determine the antioxidant content of these varieties.

Materials and methods

FIELD PRODUCTION. Spring lettuce variety trials were conducted in 1996, at the Wiregrass Research and Extension Center (WREC) near Dothan, Ala., the

Journal paper R-08740 of the Florida Agricultural Experiment Station. We gratefully thank farm crews of the Extension centers, the seed companies, Lewis Taylor Farm, Inc. Tifton, GA. for transplant production, and W.B. Rogers, Department of Food Science and Technology, University of Georgia, Athens, for her technical assistance.

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Panelist gender: _____

Age group: 10-20 21-30 31-40 41-50 51-60 61+

Evaluation of bitterness in lettuce

1. Salinas 88 Supreme	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2. Epic	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
3. Optima	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4. Legacy	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
5. Red Salad Bowl	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
6. Nancy	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
7. Greengo	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8. Cabernet Red	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
9. Parris Island	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10. Redprize	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
11. Slobolt M.I.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Comments:

Fig. 1. Data collection form used in 1996 lettuce sensory evaluation for bitterness.

Piedmont Research Center (PRS) near Camp Hill, Ala. and the Sand Mountain Research and Extension Center (SMREC), Crossville, Ala., and in 1997 at the North Alabama Horticulture Station (NAHS), Cullman, Ala. (Table 1). Both trials were conducted using plasticulture and 4-week-old transplants. Plot size was 40 plants per plot. Detailed cultural practices and yield information can be found in Simonne et al. (1996, 1997b). In each trial, lettuce was harvested when they reached commercial size. Days to harvest (DTH) from transplanting for each variety was recorded and compared to information available in seed catalogs. Bolting occurrence was also recorded.

BITTERNESS. Evaluation of bitterness was conducted in 1996 using trained panelists following the guidelines of the American Society for Testing and Materials (ASTM, 1981) on samples from WREC and PSR (Fig. 1). For each growing location, harvested lettuce were immediately placed on ice, shipped to the main campus, washed, cut into bite-size pieces, and refrigerated overnight for sensory evaluation the next day between 1000 and 1100 HR. The same set of panelists were used for all bitterness evaluation. Caffeine solutions with increasing bitterness and their corresponding bitterness rating (0% = 0, 0.05% = 2, 0.08% = 5, 0.15% = 10, and 0.20% = 15) were given to each panelist in small color-coded cups. Panelists were trained using these caffeine solutions and were instructed to calibrate their taste using the caffeine solutions before the test, and also between each sample as needed. Lettuce samples were served one by one and in a predetermined, random order.

CHEMICAL COMPOSITION. Lettuce grown at WREC and PRS in 1996 were used for chemical composition assays. After harvest, lettuce heads were ice-packed and shipped to the site of analysis (Univ. of Georgia, Athens) on the same day. Heads were washed in water and centrifugally dried. For each variety, two independent composites of edible portions were prepared from six heads by cutting the heads into four quarters. The opposite quarters were taken for analyses of moisture, ascorbic acid, folate, vitamin E and carotenoid levels. Sample preparation and analyses for carotenoids, vitamin E, ascorbic acid and folate were completed under a yellow light (Sylvania Gold F40/GO, 40W; General Electric, Sunnyvale, Calif.) to minimize photooxidation.

MOISTURE ANALYSES. Moisture was analyzed by an Association of Official Analytical Chemists (AOAC) method 920.151 (AOAC International, 1995).

WATER SOLUBLE VITAMINS. Folate was analyzed following the tri-enzyme method described by De Souza and Eitenmiller (1990). Ascorbic acid was analyzed by the AOAC method (967.22) (AOAC International, 1995). The composite samples were blended in metaphosphoric-acetic acid extractant.

VITAMIN E AND CAROTENOID ANALYSIS. Vitamin E was analyzed by a normal phase high-performance liquid chromatography (HPLC) while β -carotene and lutein were analyzed by reverse phase HPLC, following saponification and extraction.

SAPONIFICATION AND EXTRACTION OF VITAMIN E AND CAROTENOIDS. Vitamin E and carotenoids were extracted simultaneously from the sample composites. Three, 3-g samples from each composite were placed into three extraction tubes, two for duplicate analy-

ses, and the third for a recovery study. Twenty milliliters of 6% pyrogallol (in isopropanol) were added to each tube and the contents were mixed thoroughly, then 30 mL of deionized water was added to the mixture. The mixture were then blended with a homogenizer (Polytron 3100; Brinkmann Instruments, Inc., Westbury, N.Y.) for 2 min on a speed setting at four. After blending, the samples were flushed with nitrogen (N_2) for 1 min, and sonicated in an ultrasonicator (B8510-DTK; Branson, Danbury, Conn.) at 70 °C (158 °F) for 10 min. Then, 5 mL of 60% potassium hydroxide were added to the each tube and mixed. A known spike standard was added at this step for recovery studies. Extraction tubes were flushed with N_2 for 1 min and the contents saponified at 70 °C for 30 min (Thompson and Hatina, 1979).

After saponification, the tubes were sonicated for 5 min and placed in an ice bath for 10 min. To each tube, 10 mL of 2% sodium chloride (NaCl) or about 3 g of NaCl was added and mixed well to minimize emulsification. The mixture was extracted five times with 20 mL of hexane containing 0.1% butylated hydroxytoluene (BHT). After extraction, the hexane layer was transferred to a tube with about 5 g of magnesium sulfate, mixed well, and allowed to stand for a few minutes to remove water. The hexane phase was then filtered through Whatman #1 filter paper and collected in a 100-mL volumetric flask. Volume was brought to 100 mL with hexane.

VITAMIN E ANALYSES. Analyses of vitamin E were done following the procedures of Håkansson et al., (1987) and Yao et al., (1992). The normal phase liquid chromatography (LC) system consisted of an injector (model 7125; Rheodyne, Cotati, Calif.), a solvent delivery system (model LC-6A; Shimadzu

Scientific Instruments Inc., Norcross, Ga.), a column (25 cm × 4 mm, 5 µm Lichrosorb Si60; Hibar Fertigsäule RT, Darmstadt, Germany), a fluorescence detector (Perkin-Elmer 650-15; Hitachi, Norwalk, Conn.). The excitation and emission wavelengths were 290 and 330 nm, respectively. Data were collected using an integrator (CR501 Chromatopac; Shimadzu). Flow rate of the mobile phase (0.9% isopropanol in hexane) was 1 mL·min⁻¹. Immediately before use, the mobile phase was filtered through a 0.2-µm membrane filter (Nylon 66; MSI Inc., Westboro, Mass.) and degassed by stirring under vacuum. Vitamin E standards (α-, β-, γ-, and δ-tocopherols) were obtained from Henkel Corp. (La Grange, Ill.). Purity, concentration and stability of the standards were monitored with a diode array spectrophotometer (Hewlett-Packard Co., Palo Alto, Calif.). Standard curve preparation, detection limits, and identification of tocopherols were completed following Yao et al. (1992). The hexane extracts (20 µL) were directly injected.

β-CAROTENE AND LUTEIN ANALYSES. β-Carotene and lutein were quantified following the procedure of Bushway (1986) with minor modifications. The hexane extract (1 to 10 mL depending on the concentration of the

β-carotene and lutein) was evaporated to dryness with continuous flow of nitrogen. The residue was dissolved in the mobile phase containing 20 acetonitrile : 28 methanol : 2 tetrahydrofuran (by volume). LC system instrumental configuration are given in the section of vitamin E analysis with addition of a UV-VIS detector (model SPD-10AV; Shimadzu) and a photodiode array detector (PDA) with SPD-M6A software (model SPD-M6A; Shimadzu) connected in series. A column packed with polymerized carbon with a length of 18-C (C₁₈, 5 µm, 4.6 × 25 cm, model 218TP54; Vydac, Hesperia, Calif.) was used in the carotenoid analysis. The flow rate was set at 1 mL·min⁻¹. For quantitation, the ultraviolet and visible (UV-VIS) detector was set at 450 nm. The PDA scan wavelengths were between 390 and 800 nm. The concentration of individual carotenoid in lettuce extracts was determined using peak areas relative to the corresponding standards. β-Carotene and lutein standards were obtained from Sigma Chemical Co. (St. Louis, Mo.). Purity, concentration and stability of the carotenoid standards were monitored spectrophotometrically using a diode array spectrophotometer (Hewlett-Packard Co.); wavelengths were 445 nm for lutein and

450 nm for β-carotene with absorptivities of 2550 for lutein (in ethanol) and 2480 for β-carotene (in methylene chloride) (Davies, 1976).

Statistical analyses. Days to harvest, bitterness scores, and compositional data were analyzed separately using analysis of variance and Duncan's multiple range test at α = 0.05 (SAS, 2000). A global comparison of varieties for yield, bitterness scores, and composition was made by rating each category (field performance, bitterness, and nutritional quality) on a 1 to 3 potential scale (where 1 = potential; 2 = moderate; and, 3 = low). Based on the sum of individual ratings, varieties were classified as unacceptable, acceptable, or very acceptable.

Results and discussion

Earliness. Days to harvest ranged from 37 DTH for 'Big Curly' to 47 DTH for 'Epic' (Table 1). When varieties were grouped by type, DTH was significantly greater for crisphead (53 DTH), than for looseleaf (42 DTH), romaine (42 DTH), and butterhead (41 DTH). Though numerically small, these differences are of practical importance for scheduling plantings and harvests. Moreover, since fertilization and irrigation were scheduled on a weekly

Table 1. Type, seed source, and observed days to harvest for selected lettuce varieties grown in the spring at the Wiregrass Research and Extension Center, Headland, Ala. (WREC), Piedmont Research Station, Camp Hill, Ala. (PRS), North Alabama Horticulture Station, Cullman, Ala. (NAHS), and Sand Mountain Research and Extension Center, Crossville, Ala. (SMREC).

Variety	Seed source ^a	Type	Leaf color	1996 WREC	1996 PRS	1996 SMREC	1997 NAHS	Days to harvest	
								Literature ^b	Observed ^c
Big Curly	Vilmorin	Looseleaf	Green	+	+			68	37 c
Brunia	Vilmorin	Looseleaf	Red	+	+			62	40 bc
Cabernet Red	Asgrow	Looseleaf	Red	+				66	43 abc
Epic	Sakata	Crisphead	Green	+	+			65	47 a
Greengo	Asgrow	Looseleaf	Green	+	+	+		65	39 bc
Legacy	Takii	Crisphead	Green	+	+			70	46 ab
Nancy	SeedWay	Butterhead	Green	+	+	+		66	32 abc
Nevada	Vilmorin	Looseleaf	Green	+	+			58	40 bc
Optima	Vilmorin	Butterhead	Green	+	+	+	+	55	41 abc
Ostinata	Stokes	Butterhead	Green	+				60	41 abc
Parris Island	Stokes	Romaine	Green	+	+			65	44 abc
Red Salad Bowl	Vilmorin	Looseleaf	Red	+				50	43 abc
Redprize	Ferry-Morse	Looseleaf	Red	+	+	+		46	41 abc
Salanca GM	Vilmorin	Looseleaf	Green	+	+			NA	39 bc
Salinas 88 Supreme	Sakata	Crisphead	Green	+	+			75	46 ab
Sierra	Vilmorin	Looseleaf	Green	+	+			74	40 bc
Slobolt	Harris	Looseleaf	Green	+	+	+		48	39 bc
Significance (P)								0.02	

^aAsgrow = Asgrow Vegetable Seeds, Ventura, Calif.; Ferry-Morse = Ferry-Morse Seed Co., Fulton, Ky.; Harris = Harris Seeds, Rochester, N.Y.; Sakata = Sakata Seed America, Morgan Hill, Calif.; SeedWay = SeedWay, Elizabethtown, Pa.; Stokes = Stokes Seeds, Buffalo, N.Y.; Takii = American Takii, Salinas, Calif.; Vilmorin = Vilmorin, Empire, Calif.

^bFor direct-seeded production.

^cUsing 4-week-old transplants in the spring.

^dNA = not available.

Table 2. Mean, most frequent, and highest bitterness scores for selected lettuce varieties grown at the Wiregrass Research and Education Center, Headland, Ala. (WREC), and the Piedmont Research Station, Camp Hill, Ala. (PRS).

Variety	Type	Bitterness score ^z			
		Mean ^y	Mode ^x	Lowest	Highest
WREC, Spring 1996					
Epic	Crisphead	1.6 b	1	0	6
Salinas 88 Supreme	Crisphead	1.6 b	0	0	4
Redprize	Looseleaf	2.2 b	2	0	7
Legacy	Crisphead	2.3 b	1	0	7
Nancy	Butterhead	2.9 ab	3	0	10
Red Salad Bowl	Looseleaf	3.2 ab	0	0	11
Cabernet Red	Looseleaf	3.5 ab	2	1	13
Parris Island	Romaine	3.6 ab	3	0	14
Slobolt	Looseleaf	3.8 ab	2	0	10
Optima	Butterhead	4.1 ab	2	0	12
Greengo	Looseleaf	5.2 a	5	1	15
PRS, Spring 1996					
Nevada	Looseleaf	2.0 b	0	0	9
Sierra	Looseleaf	2.5 b	2	0	7
Brunia	Looseleaf	3.3 b	1	0	10
Optima	Butterhead	4.9 b	0	0	13
Nancy	Butterhead	8.4 a	4	0	15
Big Curly	Looseleaf	9.3 a	13	0	15
Slobolt	Looseleaf	10.1 a	15	1	15

²Scoring done by trained panels on a 0 to 15 scale, where 0 = 0% caffeine solution, 2 = 0.05%, 5 = 0.08%, 10 = 0.15%, and 15 = 0.20%.

^yWithin each location, mean bitterness scores followed by different letters are significantly different according to Duncan's multiple range test at the 5% level.

^xMode = most frequent score.

Table 3. Chemical composition of selected lettuce varieties.²

Variety	Type	Moisture	Vitamin E (mg/100 g) ^y		Ascorbic acid	Folate	b-carotene	Lutein
		(%)	a-tocopherol	g-tocopherol	(mg/100 g)	(µg/100 g)	(µg/100 g)	(µg/100 g)
Big Curly	Looseleaf	93.1 h	1.23 b	0.09 b	10.8 def	44.7 c	363 cd	1710 bcd
Brunia	Looseleaf	94.3 efg	0.58 de	0.51 a	14.1 cde	74.5 c	802 ab	1599 bcde
Cabernet Red	Looseleaf	94.5 de	0.82 cd	0.17 b	17.5 bcd	36.5 g	633 abc	1413 bcde
Epic	Crisphead	95.1 bc	0.56 def	0.26 ab	15.8 bcde	34.2 gh	627 abc	1436 bcde
Greengo	Looseleaf	93.8 g	0.96 bc	0.19 b	18.6 abcd	55.3 d	900 a	2099 ab
Legacy	Crisphead	96.6 a	0.22 f	0.05 b	4.8 f	17.3 k	124 d	387 f
Nancy	Butterhead	94.7 cde	0.76 cd	0.20 b	17.9 abcd	33.2 h	608 abc	1395 bcde
Nevada	Looseleaf	95.2 b	0.54 def	0.18 b	9.9 def	102.4 a	257 cd	663 ef
Optima	Butterhead	94.4 ef	0.63 cde	0.15 b	17.8 abcd	44.4 e	602 abc	1778 bcd
Ostinata	Butterhead	95.2 b	0.56 def	0.09 b	8.3 fe	57.3 d	285 cd	856 def
Parris Island	Romaine	93.2 h	0.98 bc	0.14 b	23.3 ab	43.6 ef	850 a	1964 abc
Redprize	Looseleaf	95.1 bc	0.72 cde	0.25 ab	14.9 bcde	22.0 j	490 abcd	1183 bcdef
Red Salad Bowl	Looseleaf	94.0 fg	0.98 bc	0.16 b	22.3 abc	41.3 f	829 a	1572 bcde
Salanca GM	Looseleaf	92.4 i	2.27 a	0.08 b	13.3 def	94.3 b	885 a	2709 a
Salinas 88 Supreme	Crisphead	95.0 bcd	0.36 ef	0.11 b	10.6 def	21.3 j	341 cd	872 def
Sierra	Looseleaf	95.1 bc	0.63 cde	0.14 b	12.1 def	56.2 d	676 abc	1443 bcde
Slobolt	Looseleaf	94.3 efg	0.98 bc	0.31 ab	26.2 a	26.2 i	391 bcd	1083 cdef
Mean for each type:								
crisphead (n=3)		95.6 a	0.38 b	0.14 a	10.4 b	24.3 b	364 b	898 b
butterhead (n=3)		94.8 ab	0.65 ab	0.15 a	14.7 b	45.0 ab	498 ab	1343 ab
romaine (n=1)		93.2 c	0.98 a	0.14 a	23.4 a	43.6 ab	850 a	1964 a
looseleaf, green (n=6)		94.0 bc	1.10 a	0.17 a	15.0 b	63.2 a	579 ab	1535 ab
looseleaf, red (n=4)		94.5 ab	0.77 ab	0.27 a	17.2 ab	43.6 ab	676.0 ab	1442 ab
P		0.01	0.02	0.30	0.08	0.02	0.11	0.15

²Numbers in the same column followed by different lower case letters indicate significant differences based on Duncan's multiple range test at 0.05 level of significant.

^y1.0 mg/100 g = 10 ppm; 1.0 µg/100 g = 0.01 ppm.

basis, production costs increase significantly when an additional week is needed to reach marketable size. The DTH observed in this study were an average 7 to 10 d fewer than those reported in seed catalogues.

Bitterness. As bitterness was scored on a 0 to 15 scale, a bitterness score less than 7 was considered acceptable. The varieties Nancy, Optima, and Slobolt were included in both testing sessions. For these three varieties, significant differences were found for sensory sessions ($P < 0.01$) and variety ($P < 0.05$). Combined over both locations, mean bitterness scores were 7.3 a, 6.3 ab, and 4.8 b for 'Slobolt,' 'Nancy,' and 'Optima,' respectively (Table 2).

Because most varieties differed by location, sensory data were analyzed by location. Bitterness score was significantly different among varieties (Table 2). In the first session, bitterness scores ranged between 1.6 for 'Salinas 88 Supreme,' and 5.2 for 'Greengo,' with an overall average of 3.1. Although the highest bitterness score was below the median value (8.0), varieties with significantly lower mean bitterness scores ($P < 0.02$) were 'Nancy,' 'Legacy,' 'Red Prize,' 'Epic,' and 'Salinas 88 Supreme'. In the second session, mean bitterness ratings ranged between 2.0 for 'Nevada' and 10.1 for 'Slobolt'. Overall mean bitterness score was 5.5. 'Slobolt,' 'Big Curly,' and 'Nancy' had significantly ($P < 0.02$) higher mean bitterness scores than the other varieties. Also, the

mean bitterness scores of these varieties were above the median value of 8.0.

Mean bitterness scores for 'Epic,' 'Salinas 88 Supreme,' 'Red Prize,' 'Legacy,' and 'Sierra' were below 7, suggesting that none of the panelists found these varieties unpleasantly bitter. The ranges in individual bitterness scores for 'Nevada' was 0 to 9, suggesting that this variety could be slightly bitter. In contrast, as for the other varieties when the bitterness scores almost span the entire 0 to 15 scale, suggesting that panelists' bitterness perceptions for these varieties were highly variable. The most frequent bitterness scores given for 'Big Curly' and 'Slobolt' were 13 and 15, respectively. These results, along with comments from several panelists, indicate that both of these varieties had unpleasant levels of bitterness.

Sensory evaluation indicates that different varieties have varying levels of bitterness. Factors in addition to variety (such as location) may affect bitterness. Overall, the varieties that tended to be less bitter were 'Epic,' 'Salinas 88 Supreme,' 'Legacy' (crisphead), 'Paris Island' (romaine), and 'Nevada,' 'Sierra,' and 'Red Prize' (looseleaf).

Compositional properties. All components assayed were significantly affected by variety ($P < 0.01$). Moisture of lettuce varieties ranged from 93% to 96%. 'Big Curly' and 'Paris Island' tended to have higher moisture contents than 'Legacy.'

Only α -tocopherol and γ -toco-

pherol were detected. α -Tocopherol levels ranged from 0.22 mg/100 g in 'Legacy' (crisphead) to 2.27 mg/100 g in 'Salanca' (looseleaf). γ -Tocopherol was present in small amounts, but measurable in all lettuce varieties with levels ranging from 0.09 to 0.51 mg/100 g. According to the USDA Nutrient Database, the vitamin E content in butterhead, iceberg, looseleaf, and romaine are 0.44, 0.28, 0.44, and 0.44 α -tocopherol equivalents, respectively (USDA, 2002). One α -tocopherol equivalent is equal to 1 mg of RRR- α -tocopherol and 0.1 mg of γ -tocopherol (National Research Council, 1989). α -Tocopherol values found in this study for most varieties were higher than the reference values for most varieties. Only mean α -tocopherol contents of crisphead lettuce varieties fell within the range of the USDA values.

Ascorbic acid levels ranged from 4.8 mg/100 g in 'Legacy' to 26.16 mg/100 g in 'Slobolt.' Most leaf lettuces contained higher ascorbic acid levels than the crisphead lettuce; ascorbic acid content [per 100 g basis (3.53 oz)] in the USDA Database are 8, 24, 3.9 and 18 mg/100 g in butterhead, romaine, iceberg and looseleaf lettuce, respectively. Based on the current RDA for ascorbic acid (75 and 90 mg·d⁻¹ for women and men age 19 and older, respectively) and the per capita consumption, lettuce could be a moderate source of the nutrient. Based on these results, the romaine and looseleaf let-

Table 4. Overall rating of field performance, bitterness, and nutritional quality, and overall acceptability of selected lettuce varieties.

Type	Variety	Field performance ^a	Bitterness ^a	Nutritional quality ^a	Overall acceptability ^b
Looseleaf, green	Big Curly	2	3	2	—
	Sierra	1	1	2	+
	Slobolt	3	3	2	—
	Greengo	3	3	2	—
	Nevada	1	1	2	++
	Salanca GM	2	NT	1	+
Looseleaf, red	Brunia	2	2	1	+
	Cabernet Red	1	2	2	+
	Red Salad Bowl	1	2	1	+
	Redprize	1	1	1	++
Crisphead	Salinas 88 Supreme	3	1	3	—
	Epic	3	1	3	—
	Legacy	3	1	3	—
Butterhead	Optima	1	2	2	+
	Ostinata	1	NT	2	+
	Nancy	1	2	2	+
Romaine	Parris Island	1	1	2	+

^aBased on bolting and earliness; 1 = high potential; 2 = moderate; 3 = low; NT = not tasted.

^b(-) = unacceptable, (+) = acceptable, (++) = very acceptable.

tudes are better sources of ascorbic acid than the crisphead or butterhead types.

β -Carotene was not present in high amounts [124 to 900 $\mu\text{g}/100\text{ g}$ or 10 to 75 retinol equivalents (RE)/100 g where 1 RE = 12 μg of β -carotene] (Table 3). Although lutein has no vitamin A activity, it may be beneficial to eye health in humans (Fullmer and Shao, 2001; Olmedilla et al., 2001). Although RDA for lutein has not yet been established, lettuce could be an excellent source for lutein in the American diet.

Overall, crisphead (iceberg) lettuces with mostly light-colored leaves, such as 'Salinas 88 Supreme,' 'Legacy,' and 'Epic' were much lower in β -carotene, lutein, vitamin E (α - and γ -tocopherol), total ascorbic acid and folate compared to red oak leaf 'Brunia,' green/red Batavia 'Sierra,' green butterhead 'Nevada,' or green looseleaf 'Greengo,' and 'Slobolt' (Table 3). Despite this fact, based on sales figures, Americans consume more crisphead lettuce than leaf lettuce. A green 'Salanca' was among the top in all nutrients except for ascorbic acid. It contained 2.3 mg α -tocopherol, 94 μg folate, 885 μg β -carotene, and 2,700 μg lutein/100 g edible portion. Oak leaf, romaine, looseleaf, maraichere, and batavia varieties contained 20% or more RDA of ascorbic acid, folate, vitamin E and β -carotene per 100 g. In contrast, most crisphead lettuce commonly consumed in the U.S. contained 10% or less of the RDA of these nutrients per 100 g. These data could be displayed at roadside stands to educate consumers about the different nutritional value of nontraditional lettuce varieties and types.

Although selected lettuce varieties contained moderate amount of folate (18 to 102 $\mu\text{g}/100\text{ g}$), they can be a significant source of folate considering the per capita consumption of lettuce in the U.S. More popular crisphead lettuce provides almost 50% less folate than butterhead, romaine, or looseleaf lettuce.

Overall comparison of lettuce varieties. Because of the broad scope of this evaluation, no single variety stood out in all categories. Some varieties were below acceptable levels for one or more attributes (Table 4). 'Slobolt' and 'Greengo' tended to bolt before they reach marketable size. Mean bitterness score of 'Nancy,' 'Big Curly,' and 'Slobolt' were above the median bitterness range, implying that these varieties may not do well in the southeastern

U.S. From bitterness and nutritional standpoints, 'Redprize' was the only variety having high nutritive values with low bitterness level. 'Redprize' and 'Nevada' were the overall best varieties, while 'Salinas 88 Supreme,' 'Epic,' 'Legacy,' 'Big Curly,' 'Slobolt,' and 'Greengo' were unacceptable. Within the list of acceptable lettuce varieties, small-scale lettuce growers should select and plant several varieties that cover a broad range of characteristics.

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