Minnie Finger Lime: A New Novelty Citrus Cultivar

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‘Minnie Finger Lime’ is a new citrus cultivar released 15 Feb. 2018 (Bowman, 2018) by the Agricultural Research Service (ARS) of the U.S. Department of Agriculture (USDA). The major positive attributes of this new citrus scion are the combination of healthy growth in both a pot and the field, abundant production of fruit on very compact trees, and fruit traits that are good and similar to the finger lime (*Microcitrus australasica*) used as a garnish and accent for gourmet food and beverages. The cultivar can be propagated easily by grafting clean budwood of ‘Minnie Finger Lime’ onto a standard citrus rootstock cultivar.

Origin

This citrus scion cultivar originated from a 1997 cross of *Microcitrus australasica* × *Microcitrus inodora* (clone 80-527A) made at the USDA A. H. Whitmore Foundation Farm (Groveland, FL) by Dr. Kim D. Bowman of the USDA, ARS, U.S. Horticultural Research Laboratory (USHRL), FL. Hybrid seed from the cross was planted at the Whitmore Foundation Farm in 1997 and grown until the hybrid that became ‘Minnie Finger Lime’ was selected for further study. Evaluation of ‘Minnie Finger Lime’ was planned and conducted by Kim Bowman under code no. BS97-R4-15, and later US-1936. Fruit quality traits of the cultivar were also evaluated by Greg McCollum, Anne Plotto, and Jinhe Bai of the USHRL.

Description

Trees of ‘Minnie Finger Lime’ are small, compact, and attractive in overall appearance (Fig. 1A). The cultivar has dimorphic leaves, as described for the type species *Microcitrus australasica* (F. Muell.) Swingle. Most other morphological features for ‘Minnie Finger Lime’ are also similar to that described for that species. Mature leaves are 43 to 75 × 18 to 40 mm, more or less coriaceous, and

strongly veined, with small slightly winged and articulated petioles 4 to 6 mm long. Leaf shape is more or less elliptical to slightly oblanceolate, with an acute or acuminate base, and a tip that varies from acute to slightly acuminate. Sometimes the leaf apex is irregularly retuse to emarginate. Leaves are faintly toothed in the basal half, and are irregularly crenate or toothed on the apical half. Young shoots and leaves are a prominent reddish purple, but then become green or dark green when they mature. Most nodes have single slender spines, highly variable in length, and ranging from 3 to 25 mm long. Flowers and fruit are borne singly in leaf axils on short, stout pedicels 1 to 5 mm long. Fruit shape is cylindrical, elongated ellipsoid to slightly fusiform and shows a blunt protuberance on both ends, with the blossom-end protuberance becoming more obtuse to acuminate as fruit matures and after harvest (Fig. 1B and C). The fruit is sometimes slightly curved. The peel shows numerous visible oil glands and has a thickness of 0.95 to 1.5 mm. Immature fruit is dark green with smooth skin, changing to light green and then yellow with semismooth skin at maturity. Mature fruit is 50 to 100 × 15 to 30 mm. The number of locules per fruit ranges from six to seven. Pulp vesicles are pale yellow to pale green, long-stalked, ovoid to pyriform, averaging 7 × 3 mm and loosely cohering, and end in a very blunt or rounded tip (Fig. 1D). Less than one developed seed is found per 50 fruit, and seeds are 4 × 4 mm and 16 mg each.

Fruit Quality, Sensory Traits, and Volatile Constituents

‘Minnie Finger Lime’ is intended for use of the fruit as a garnish and flavoring, as has been described previously (Hawkeswood, 2017; Karp, 2009) for the closely related Australian finger lime (*Microcitrus australasica*). This includes using the sliced fruit for food decoration, and the pulp vesicles as a garnish or flavoring with seafood, avocado, desserts, or beverages. The finger lime is sometimes described as citrus caviar because of the agreeable flavor and firm popping texture of the pulp vesicles when applied to food. Fruit of the ‘Minnie Finger Lime’ appear to fit this description and were subjected to fruit quality and sensory evaluation as follows.

Fruit sample collection. About 50 fruit were collected for each of four harvest dates

(25 June, 16 July, 6 Aug., and 4 Sept. 2018) and divided by external color as green, mottle green and yellow, or yellow. No fully yellow fruit was found during the first two harvests, and no fully green fruit was found during the last two harvest dates.

Sample preparation. Samples were prepared by hand-squeezing vesicles and juice out of each half fruit, with four to six fruit per replication for instrumental analysis (soluble solids content, titratable acidity, and peel oil volatiles). For sensory evaluation, whole vesicles from the other half of all ≈20 fruit were mixed and distributed among 20 cups (10 panelists, two replications).

Instrumental analysis of fruit quality. Fruit dimensions, and stem and blossom end necks were measured on 20 fruit per sample time. External color, soluble solids, and titratable acidity were measured on four juice samples (four replications of five fruit) per time, and fruit color by methods as described previously (McCollum and Bowman, 2017).

Fruit quality results. Overall fruit size was 5.2 × 1.8 cm and weighed ≈8.4 g (Table 1). Total soluble solids increased from 8.2% to 9.5% over the four harvests, whereas percent acid increased from 4.5% at the first harvest (25 June) to 7.2% at the last harvest (4 Sept.).

Sensory evaluation. Ten panelists trained and experienced at tasting citrus products (Plotto et al., 2010, 2017) gathered in two 1-h sessions to define descriptors that could characterize finger lime and to choose reference standards for three taste and five flavor attributes that matched those descriptors (Table 2). Each reference standard was assigned a value that would correspond to a level that could be found in the finger lime samples. Four texture attributes were also chosen without associated reference standard. Two samples were evaluated in duplicate at each harvest, either green and mottled, or mottled and yellow, because green and yellow fruit were never available at the same time on the tree. Samples, 4.0 to 6.0 g in 30-mL cups with lids (Solo® Cups Company, Urbana, IL), were served at room temperature in an alternate order across panelists and sessions. Panelists were asked to taste all the reference standards to review descriptor characteristics before rating the samples using a 10-cm linear scale with anchors (0 = none and 10 = high). Data were recorded using Compusense Cloud (Compusense®, Guelph, Ontario, Canada). All taste panels took place in isolated booths equipped with computers, and under positive air pressure and red lighting. Water and salted crackers were provided to rinse the mouth between samples as necessary. Sensory data were analyzed for each harvest and for all harvests combined by analysis of variance using a mixed model for which “panelists” was random and the main effect was tested against the interaction (Panelist × Sample), and by principal components analysis using SenPAQ (version 5.01; Qi Statistics Ltd., Berkshire, UK). Differences between means were performed using the least significant difference test, with probability error $\alpha = 0.05$.

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Sensory results. Panelists could not perceive any difference between samples within each harvest—when comparing mottled fruit with green fruit for harvests 1 and 2, and when comparing mottled fruit and yellow

fruit for harvests 3 and 4, except for harvest 2 when the mottled sample was slightly sweeter than the green sample (2.1 vs. 1.8, respectively; $P < 0.05$). When comparing across harvests, samples from the first harvest

were perceived to be drier than samples from the later harvests, and samples from the August harvest (harvest 3) were perceived as more sour (Table 3). A principal component analysis explained 78% of the variation, with descriptors “crunchy” and “dry” explaining mostly harvest 1, and samples with greater aromatics (“minty/fresh”) and sweetness being from harvest 4 (Fig. 2). Samples from the third harvest were mostly described as “sour” with a “pop-in-the mouth” texture.

Volatile constituents. Peel from 20 fruit at each harvest date and color was collected and immediately frozen to -20°C , and stored at the same temperature for up to 6 weeks. After storage, peel tissue (four replications of five fruit) was immersed in liquid N_2 and powdered using a blender (Waring Commercial, Torrington, CT). Five grams of the powder was dissolved with methylene chloride:pentane (5:3) solvents, 20 mL was extracted using a sonicator (Omni Sonic Ruptor 250; Omni International, Kennesaw, GA) at pulse 70 and power 6.5 for 10 min in an ice bath. After filtering through Whatman #1 filter paper and drying over Na_2SO_4 , the extraction was concentrated to 1.5 mL in a 25°C bath under a stream of nitrogen gas at less than 1.87 kPa. A gas chromatograph–mass spectrometer (model 6890N/5975; Agilent, Santa Clara, CA) equipped with a DB-5 column (length, 60 m; i.d., 0.25 mm; film thickness, 1.00 μm ; J&W Scientific, Folsom, CA) was used for volatile determination. An extraction sample of 2 μL was injected, and the injector split ratio was 2:1 (injector temperature, 250°C). The column oven was programmed to increase at $4^{\circ}\text{C}\cdot\text{min}^{-1}$ from the initial 40°C to 250°C , then ramped at $100^{\circ}\text{C}\cdot\text{min}^{-1}$ to 260°C and held for 4 min for a total run time of 63 min. Helium was used as carrier gas at a flow rate of $1.5\text{ mL}\cdot\text{min}^{-1}$. Inlet, ionizing source, and transfer line were kept at 250, 230, and 280°C , respectively. Mass units were monitored from 40 to 300 m/z and ionized at 70 eV. Data were collected using a data system (ChemStation G1701 AA; Hewlett-Packard, Palo Alto, CA). A mixture of C-5 to C-18 n-alkanes was run at the beginning of each day to calculate retention indices (Bai et al., 2014). Volatile components were identified by comparing their mass spectra with the mass spectra from mass spectrometry libraries (NIST 06) and were confirmed using retention indices, and the value was compared with those reported in the literature.

Volatile results. Volatiles contributing to peel oil were very rich in monoterpenes: 82%

Fig. 1. Tree and fruit traits of ‘Minnie Finger Lime’. (A) Three-year-old tree of ‘Minnie Finger Lime’, growing on Volkamer rootstock in Ft. Pierce, FL. The tree is 2.1 m tall and had 642 fruit (mostly still green) on 18 June 2018. (B) Fruit on field tree. (C) Close-up of two fruit harvested Aug. 2018. (D) Fruit interior in longitudinal orientation and as a cross-section.

Table 1. Physical and analytic fruit quality traits of ‘Minnie Finger Lime’ at four harvests.

Harvest	Wt (g)	Overall (mm)		Blossom end neck (mm)		Stem end neck (mm)		Total soluble solids (%)	Acid (% citric)
		Length	Width	Length	Width	Length	Width		
25 June	8.7	54.2	18.1	8.8	6.8	4.9	6.1	8.2	4.5
16 July	8.5	50.8	18.3	8.0	6.2	4.6	5.9	8.2	5.5
6 Aug.	8.1	49.7	18.1	7.5	6.3	4.4	5.7	8.7	6.1
4 Sept.	9.0	49.3	19.4	6.7	6.4	4.1	5.8	9.5	7.2
Mean	8.6	51.0	18.5	7.8	6.4	4.5	5.9	8.7	5.8
SD	0.4	2.2	0.6	0.9	0.3	0.3	0.2	0.6	1.1

Table 2. Descriptors and reference standards with suggested intensity for finger lime sensory descriptive panel, using a 10-cm line scale (0 = none, 10 = high).

Sensory modality	Descriptor (suggested intensity)	Reference standard
Taste	Sweet (5)	2% Sucrose (pure sugar, Publix, Lakeland, FL) in water
	Sour (5)	0.75% Citric acid ($\geq 99.5\%$, Sigma-Aldrich) in water
	Bitter (7)	11.5 mg·L ⁻¹ Quinine monohydrochloride dihydrate (90% Sigma-Aldrich) in water
Aroma/flavor	Citrus (8)	A mixture of lime and lemon juice (Santa Cruz Organic®; The J.M. Smucker Company, Orrville, OH), each juice diluted to 20% and added together
	Green (8)	A mixture of (Z)-3-hexenal (2 $\mu\text{L}\cdot\text{L}^{-1}$, Sigma-Aldrich) and (Z)-3-hexenol (7 $\mu\text{L}\cdot\text{L}^{-1}$, Sigma-Aldrich) in solution at 0.09% of ethanol
	Minty/fresh (8)	Peppermint oil (Aura Cacia®; Frontier Co-op, Norway, IA): 250 $\mu\text{L}\cdot\text{L}^{-1}$ in a solution of 10% ethanol
	Citronella (8)	Lemongrass oil (Ancient Apothecary, North Palm Beach, FL): 250 $\mu\text{L}\cdot\text{L}^{-1}$ in a solution of 10% ethanol
	Terpiny/piney (8)	Pine oil (100Pure Essential Oils): 2.5 mL·L ⁻¹ in a solution of 10% ethanol

Table 3. Sensory ratings (0–10 line scale) for ‘Minnie Finger Lime’ harvested at 3- to 4-week intervals from June (H1), July (H2), August (H3), and September (H4) at three ripeness stages: green, mottled, and yellow. Data are averages of 10 trained panelists.

Descriptors	H1 green	H1 mottled	H2 green	H2 mottled	H3 mottled	H3 yellow	H4 mottled	H4 yellow
Dry	4.1 ab	4.7 a	3.0 cd	2.6 cd	2.3 d	2.8 cd	3.3 bc	3.1 cd
Juicy	5.9 a	5.7 a	5.7 a	6.1 a	6.4 a	6.1 a	6.3 a	6.3 a
Crunchy	7.4 a	7.3 ab	6.7 ab	6.5 b	7.0 ab	6.8 ab	6.7 ab	6.5 b
Pops in mouth	6.4 a	6.3 a	6.2 a	6.0 a	6.7 a	6.5 a	6.0 a	6.2 a
Sweet	1.9 a	1.6 a	1.6 a	2.0 a	1.8 a	1.6 a	2.1 a	2.0 a
Sour	5.7 d	5.9 cd	7.0 ab	6.7 abc	7.5 a	7.5 a	6.6 bcd	7.1 ab
Bitter	0.8 ab	0.8 ab	0.5 ab	0.5 b	0.7 ab	0.5 b	1.0 a	0.8 ab
Citrus	3.8 b	3.4 b	4.0 b	4.5 ab	4.0 b	3.8 b	5.2 a	5.5 a
Green	2.3 a	2.2 a	1.9 a	2.1 a	1.6 a	1.4 a	2.0 a	2.1 a
Minty/fresh	0.8 a	0.7 a	1.0 a	1.1 a	1.0 a	0.7 a	1.0 a	1.0 a
Citronella	2.1 d	2.0 d	2.1 d	2.5 cd	3.2 abc	2.9 bcd	3.7 ab	3.9 a
Terpiny/piney	1.3 a	1.0 a	1.4 a	1.2 a	1.5 a	1.4 a	1.7 a	1.5 a

Values followed by the same letter are not statistically different by the least significant difference test ($P < 0.05$).

Fig. 2. Principal components (PC) analysis of sensory data rating ‘Minnie Finger Lime’ over four harvests (H1, 25 June; H2, 16 July; H3, 6 Aug.; H4, 4 Sept.) and at three ripeness stages: green, mottled, and yellow. Circles around the means (10 panelists) represent 95% confidence intervals.

limonene followed by 6.52% β -myrcene, 2.08% α -pinene, 1.59% elemene isomer, and 0.94% γ -elemene (Table 4). The results agreed with previous reports (Delort and

Jaquier, 2009; Delort et al., 2015; Lota et al., 2002) that limonene is the dominant component in all cultivars of *M. australasica*, but each cultivar differed in other specific

components. However, Ruberto et al. (2000) reported that limonene was found only at a concentration of 1.2% in the peel oil of *M. australasica* var. *sanguinea* Swingle, whereas bicyclogermacrene was the most abundant component. Limonene was also reported previously as the primary component in the peel oil of *M. inodora* (Shaw et al., 2000), which is the other parent of ‘Minnie Finger Lime’.

Cultivation

‘Minnie Finger Lime’ has been evaluated primarily as a scion grafted on a good citrus rootstock, and it is recommended that trees of this cultivar be propagated by grafting certified clean budwood onto a suitable rootstock. ‘Minnie Finger Lime’ has grown well and appears compatible with all citrus rootstocks tested so far, including Volkamer, rough lemon, Cleopatra, US-812, US-897, US-942, and US-1516. Pollination requirements were not studied systematically, but based on observation of trees in isolated greenhouse culture over several years, it is thought that neither pollinator nor pollinizer is required for good fruit set and quality. Based on observations in the field, trees of ‘Minnie Finger Lime’ appear more sensitive to damage from freezing temperatures than sweet orange. Field trees of ‘Minnie Finger Lime’ have appeared healthy and less affected by huanglongbing disease than adjacent sweet orange trees in Ft. Pierce, FL, but the tolerance of ‘Minnie Finger Lime’ to huanglongbing will take several more years to evaluate fully. This cultivar is being released for small-scale or dooryard use in Florida and

Table 4. Volatile components of ‘Minnie Finger Lime’ solvent peel extracts at three harvest dates (June to August).

Compound	CAS no.	RI	Abundance (Total ion current × 10 ⁷)						Avg %
			Harvest 1		Harvest 2		Harvest 3		
			Green	Mot	Green	Mot	Mot	Yellow	
α-Pinene	000080-56-8	950	11.5	11.1	14.8	17.2	13.9	13.0	2.08
Sabinene	003387-41-5	989	3.0	2.8	3.9	4.5	3.7	3.6	0.55
β-Myrcene	000123-35-3	998	36.7	35.9	46.2	53.0	43.4	39.9	6.52
α-Phellandrene	000099-83-2	1,021	2.2	2.0	2.0	2.4	1.3	1.3	0.28
3-Carene	000498-15-7	1,028	4.9	5.0	6.1	6.6	5.8	5.6	0.86
D-limonene	005989-27-5	1,052	494.3	491.0	559.7	602.0	534.5	509.7	82.41
β-Phellandrene	000555-10-2	1,055	1.9	3.6	0.0	1.0	4.5	3.8	0.36
Terpinolene	000586-62-9	1,104	1.2	1.2	0.9	2.2	1.4	2.2	0.23
Linalool	000078-70-6	1,106	2.1	1.8	3.4	1.2	1.1	3.4	0.33
(E)-Alloocimene	007216-56-0	1,134	3.0	3.1	4.8	5.0	3.6	3.1	0.57
(E)-p-2,8-menthadien-1-ol	007212-40-0	1,136	1.9	1.7	1.4	2.1	3.0	5.9	0.42
(Z)-p-menth-2,8-dien-1-ol	003886-78-0	1,149	0.7	0.6	0.8	1.0	1.0	1.3	0.14
Citronellal	000106-23-0	1,157	2.7	2.0	4.2	3.4	3.4	2.4	0.46
(E)-p-menth-1(7),8-dien-2-ol	1000374-16-7	1,202	0.6	0.5	0.6	0.9	0.8	1.2	0.12
Citronellol	000106-22-9	1,226	1.1	0.8	1.2	0.9	1.2	1.6	0.18
Carvyl acetate	001197-06-4	1,230	0.1	0.2	0.1	0.8	0.4	0.9	0.07
(Z)-p-Mentha-1(7),8-diene-2-ol	1000374-16-8	1,240	0.4	0.2	0.3	0.5	0.7	0.9	0.08
Elemene isomer	1000414-93-6	1,352	8.3	8.3	13.8	13.8	9.7	8.2	1.59
β-Elemene	000515-13-9	1,406	0.9	0.9	1.6	1.7	1.1	1.3	0.19
β-Gurjunene	017334-55-3	1,439	0.4	0.3	0.5	0.2	0.2	0.14	0.09
Alloaromadendrene	025246-27-9	1,447	0.9	0.9	1.4	1.3	1.1	1.2	0.17
α-Farnesene	000502-61-4	1,500	0.5	0.7	3.0	1.9	0.4	2.2	0.23
Germacrene D	023986-74-5	1,508	2.5	2.3	3.4	3.1	1.7	2.8	0.40
γ-Elemene	030824-67-0	1,523	5.4	4.8	7.7	8.3	5.1	5.4	0.94
Citronellyl propionate	000141-14-0	1,564	0.7	1.8	2.1	2.0	1.3	2.0	0.25
Spathulenol	006750-60-3	1,612	1.6	1.8	2.6	3.4	2.4	1.8	0.34

CAS = Chemical Abstracts Service; RI = retention index; Mot = mottled.

other areas within USDA plant hardiness zones 9b through 11, or when used as a potted plant when protection can be provided against freezing. ‘Minnie Finger Lime’ was selected and evaluated as a novelty or specialty cultivar, and its tolerance of common biotic and abiotic conditions is considered acceptable, but were not studied thoroughly.

‘Minnie Finger Lime’ appears to be suitable for use of the fruit as a standard finger lime in the culinary market because it has acceptable physical appearance, flavor characteristics, and volatile components, and excellent cropping under Floridian conditions. It should also be noted that ‘Minnie Finger Lime’ typically grows as an attractive and very compact tree, suitable for pot culture and the dooryard. Under suitable conditions, even very small trees may bear heavy crops of fruit.

Availability

Source plant material for ‘Minnie Finger Lime’ is available from the Florida Bureau of Citrus Budwood Registration clean budwood program (3027 Lake Alfred Road, Highway 17, Winter Haven, FL 33881) and will be distributed according to Florida Department of Agriculture and Consumer Services regulations. Plant tissue for research, as well as additional information on ‘Minnie Finger Lime’ may be obtained from Kim D.

Bowman, USDA, ARS, USHRL, 2001 South Rock Road, Ft. Pierce, FL 34945 (kim.bowman@ars.usda.gov). Genetic material of this release will be deposited in the National Plant Germplasm System, where it will be available for research purposes, including development and commercialization of new cultivars. Appropriate recognition should be made if this germplasm contributes to the development of a new breeding line or cultivar.

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