Variety Trials

Yield and Consumer Acceptability of 'Evangeline' Sweetpotato for Production in North Carolina

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SUMMARY. Studies were conducted in 2012 and 2013 to compare Evangeline to various sweetpotato (*Ipomoea batatas*) varieties (Bayou Belle, Beauregard, Bonita, Covington, NC05-198, and Orleans) for commercial production in North Carolina. In another study, microwaved and oven-baked 'Evangeline' and 'Covington' sweetpotato roots were subjected to analysis of chemical and physical properties [color, dry matter (DM), texture, and sugar] and to sensory evaluation for determining consumer acceptance. 'NC05-198' produced the highest no. 1 grade sweetpotato 600 bushels [bu (50 lb)] per acre and total marketable storage root yield was similar to 'Bayou Belle' and 'Beauregard' (841, 775, and 759 bu/acre, respectively). No. 1 and marketable root yields were similar between 'Orleans' and 'Beauregard'. However, 'Orleans' produced more uniform roots than 'Beauregard', in which the latter had higher cull production. 'Evangeline' was comparable to no. 1 yield of 'Bayou Belle', 'Orleans', and 'Covington', which indicates the ability of this variety to produce acceptable yields in North Carolina conditions. 'Covington' had slightly higher DM than 'Evangeline', but instrumental texture analysis showed that these varieties did not differ significantly in firmness after cooking. However, microwaved roots were measurably firmer than oven-baked roots for both varieties. In this study, 'Evangeline' had higher levels of fructose and glucose, with similar levels of sucrose and maltose to 'Covington'. Consumers (n = 100) indicated no difference between varieties in their "just about right" moisture level, texture, and flavor ratings, but showed a preference for Evangeline flesh color over Covington. Consumers in this study preferred oven-baked over microwaved sweetpotato (regardless of variety) and indicated that Evangeline is as acceptable as the standard variety Covington when grown in the North Carolina environment.

North Carolina ranks number one in sweetpotato production in the United States. In 2014, ≈73,000 acres of sweetpotato ($354 million in gross farm value) were harvested in North Carolina [U.S. Department of Agriculture (USDA), 2015a], which is more than half the value of all sweetpotatoes produced in the United States (USDA, 2015b). 'Covington' sweetpotato was released by the North Carolina Agricultural Research Service in 2005 (Yencho et al., 2008), and accounts for 88% of the certified seed root acreage in North Carolina (North Carolina Crop Improvement Association, 2014). Although 'Covington' is the primary variety grown and has been widely successful, new varieties are continuing to be evaluated to improve yields and quality, with the goal of maintaining and expanding domestic and international markets. Varieties may develop problems or mutate over time, so there is a continual need for development of new varieties (Bryan et al., 2003; Clark et al., 2002; Villordon and La Bonte, 1996).

'Covington' has been shown to have storage root issues such as internal necrosis, which has been found in varying degrees of incidence and severity in facilities across North Carolina (Jiang, 2013). Causes of internal necrosis have yet to be determined and continue to be investigated. The economic risk due to internal necrosis to the North Carolina sweetpotato industry is very high, considering this variety is so widely grown. Seven of the 12 certified seed root producers in North Carolina grew only 'Covington' seed in 2014 (North Carolina Crop Improvement Association, 2014). High dependence on a single variety can lead to genetic vulnerability and can lead to substantial yield and market losses to growers.

Therefore, the primary objective of this study was to evaluate seven experimental and recently released varieties grown under North Carolina conditions to investigate their commercial potential. 'LA 07-146', which was recently named 'Bayou Belle', is a red-skinned, high-yielding variety with a deep orange flesh and variation in root shapes that has been developed primarily for the french fry processing industry (D. La Bonte, personal communication; North Carolina Crop Improvement Association, 2015). 'NC05-198' is a rose-skinned, orange-fleshed variety being considered for release by the North Carolina Sweetpotato Breeding and Genetics Program, probably in 2016 (K. Pecota and G. Yencho, personal communication). 'Bonita' is a white-skinned, white-fleshed variety considered to be superior to 'O'Henry' (white-flesh variety), and also has smoother root surface and a drier, sweeter flesh (La Bonte et al., 2011; North Carolina Crop Improvement Association, 2015). 'Orleans' is similar to 'Beauregard' in yield, skin color, flesh color, and sugar content but tends to have an elliptic and more consistent root shape than 'Beauregard' (La Bonte et al., 2012). 'Beauregard' was the standard variety that dominated the U.S. market since the 1990s, soon after its release in 1987 (Rolston et al., 1987), and continues to be an important orange-fleshed variety grown internationally. The North Carolina sweetpotato industry has shown interest in the variety Evangeline, a rose-skinned, deep orange-fleshed variety that has greater sugar content and similar yields to Beauregard (La Bonte et al., 2008).

A second objective of this research was to compare chemical and physical properties (color, texture, DM, and sugar content) and consumer acceptability of 'Evangeline' and 'Covington' prepared by microwave or conventional oven baking. Previous researchers have suggested that due to high sucrose content in 'Evangeline', it may be more suitable to market as a microwavable sweetpotato (La Bonte et al., 2008). Convenience as a microwavable product coupled with high sensory quality and darker orange flesh could lead to expanded markets for 'Evangeline'.

Materials and methods

VARIETY EXPERIMENT. A study was conducted in 2012 on a commercial farm in Sims, NC [Wilson County (lat. 35.63°N, long. 78.05°W)] and in 2013 on a commercial farm in Middlesex, NC [Johnston County (lat. 35.72°N, long. 78.20°W)]. In 2012, soil was a Wedowee coarse sandy loam (fine, kaolinitic, thermic Typic Kanhapludults) with 6% to 10% slopes. In 2013, the soil was a Norfolk loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults) with 0% to 2% slopes. The crop husbandry and pesticide handling was done in compliance with recommendation for sweetpotatoes grown in the southeastern United States (Kemble, 2013). No supplemental irrigation was supplied in either year; however, during both years rainfall occurred at regular intervals and in amounts that facilitated adequate crop growth and yields.

Non-rooted 7- to 12-inch-long transplants of 'Evangeline', 'Covington', 'Beauregard' (mericlone B-14), 'Orleans', 'Bonita', 'Bayou Belle', and 'NC05-198' were cut by hand from field propagation beds and then transplanted to 12-inch-tall beds on 14 June 2012 and 6 June 2013 using a mechanical transplanter. Each plot was one 25-ft-long row (12-inch-tall bed) on 3.5-ft centers with 5-ft borders (front, back) between plots. The experimental design was a randomized complete block with four replicates. Sweetpotato storage roots were harvested on 13 Sept. 2012 [91 d after transplanting (DAT)] and 27 Sept. 2013 (113 DAT) using a single-row mechanical chain harvester. Roots were graded according to U.S. and North Carolina standards into no. 1 (diameter of 1.75 to 3.5 inches and length of 3 to 9 inches), canner (diameter 1 to 1.75 inches), jumbo (diameter >3.5 inches), and cull (malformed, distorted or diseased) (USDA, 2005) and weighed. Total marketable yield was calculated as the sum of jumbo, no. 1, and canner grades.

CHEMICAL, PHYSICAL, AND SENSORY QUALITY OF 'COVINGTON' AND 'EVANGELINE'. A study was conducted in 2013 to compare the sensory attributes of 'Evangeline' and 'Covington' using two cooking methods (microwave and oven-baked). Sweetpotatoes were grown at a commercial farm in Bailey, NC [Nash County (lat. 35.87°N, long. 78.14°W)]. All harvested roots were cured under conditions typically used by North Carolina growers (85 °F, 80% to 90% relative humidity for 7 d) and then stored at 55 to 60 °F and 80% to 90% relative humidity (Edmunds et al., 2008) for ≈5 weeks before samples were removed from storage for the experiment. The quality comparison study was conducted only 5 weeks after harvest because the presumed advantage of higher sucrose content in 'Evangeline' vs. 'Covington' could be realized earlier after curing than if stored for a longer period of time when sugar content increases. No. 1 sweetpotato roots of uniform shape and size (7 to 14 oz) were selected, hand washed, and air-dried.

CONVENTIONAL OVEN PREPARATION. Sweetpotato roots were pricked with a fork six times and wrapped in aluminum foil. About 13 wrapped roots of each variety were placed on a baking pan such that a pan had either Covington or Evangeline. Each pan was placed on its own rack and

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
29.5735	fl oz	mL	0.0338
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
0.4536	lb	kg	2.2046
1.1209	lb/acre	$kg \cdot ha^{-1}$	0.8922
47.8803	lb/ft^2	Pa	0.0209
28.3495	oz	g	0.0353
0.001	ppm	$mg \cdot g^{-1}$	1000
(°F – 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

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cooked simultaneously in a conventional oven. Walter (1987) reported that sweetpotato roots should be baked at 400 °F for 90 min (Walter, 1987); however, in preliminary research for this study, the roots that were baked for 90 min were overcooked and therefore much too soft to be cut into portions once cooled. Consequently, bake time was reduced to 75 min at 400 °F to correct the level of doneness. Pans placed at each level within the oven were switched halfway through the bake time to promote even baking. After baking, roots were cooled and stored at 41 °F overnight to become firm. Cooked roots, once cooled, were firm enough to cut into sections to prepare individual samples for chemical, physical, and sensory evaluation.

Microwave oven preparation. Sweetpotato roots (12–13 per variety) were pricked with a fork six times and then placed individually into microwave cookers (GMMC-48 Microwave Potato Cooker with Lid; Progressive International, Kent, WA). Microwave cookers with lids were chosen to replicate the sealed nature of the oven-baked sweetpotato roots, which were individually wrapped in foil, with the intention of preserving both moisture level and texture between cooking methods. Sweetpotato roots were cooked in a 900-W microwave on high power for 4 min and 15 s and then held inside the cooker for 5 min. Referenced microwave cook times for sweetpotatoes have large variability. Picha (1985) suggested cooking roots for 15 min with a 1500-W microwave. Purcell and Walter (1988) microwaved sweetpotatoes for 3 min in a 6000-W oven. Allen et al. (2012) microwaved peeled and sliced sweetpotato samples for 5 min in a 1000-W oven. Microwave cooking time in this study was determined by a preliminary trial (Barkley and Johanningsmeier, unpublished data). Cooked samples were then wrapped in aluminum foil and placed on a baking sheet and stored overnight at 41 °F.

Sample preparation for chemical, physical, and sensory evaluation. The day after cooking, the chilled roots were peeled and cut in half horizontally from tip to end. The root tip was sliced off and thrown away. Each half of the root was divided into four pieces. One quarter from one half was placed in a 4-oz portion cup with lid, designated for texture analysis. One quarter from the other half of the root was designated for color, DM, and sugar analysis. The remaining pieces were then cut in half. Two sections, ≈1 × 1 inch each, were placed into 4-oz lidded portion cups coded with three-digit random numbers. Coded samples were placed into a 122 °F incubator to equilibrate to the proper serving temperature for the consumer panel.

Flesh color. Cooked sweetpotato samples from six roots within each treatment were pureed together using a food processor and aliquoted into one petri dish. This process was repeated with another six roots, for a total of two distinct pooled samples per treatment, which were designated for analysis. Air bubbles were removed by tapping the filled dish several times on the laboratory bench and the surface of the sweetpotato was smoothed. Color of the samples was measured with a colorimeter (Hunterlab DP 9000; Hunter Associates Laboratory, Reston, VA). Results were expressed as tristimulus values, L^* (lightness, 0 for black, 100 for white), a^* ($-a$ = greenness, + a = redness), and b^* ($-b$ = blueness, + b = yellowness) (Leksrisompong et al., 2012). The instrument (45°/0° geometry, D25 optical sensor) was calibrated against a standard white reference tile (L^* = 92.75, a^* = –0.73, b^* = –0.08). Two measurements for each tristimulus value were taken with the sample turned 180° between measurements and then averaged.

DM content. Cooked sweetpotato samples were mashed and samples from six roots within treatment were combined to make one pooled sample. This process was repeated with another six roots, for a total of two distinct pooled samples per treatment designated for analysis. The DM content was determined by drying a representative 0.5-oz sweetpotato sample at 212 °F for 24 h in a laboratory radiant heat oven (Imperial III; Laboratory-Line Instruments, Dubuque, IA). The DM content (percent) was calculated by using the dry weight and the fresh weight according to the following formula: DM (percent) = (dry weight of sample/total weight of sample) × 100.

Sugar composition. Raw sweetpotato samples were peeled and then pureed by a food processor (RSI 241; Robot Coupe U.S.A., Ridgeland, MS). Cooked samples were mashed, and samples from six roots within treatment were pooled, with a total of two distinct pooled samples per treatment designated for analysis. Samples of 15 g were weighed into flasks. Ethanol heated to 80 °C was added to each sample, which was then pureed with a tissuemizer (SDT-1810; Tekmar Co., Cincinnati, OH) to homogenize the samples. A vacuum filtration system was used during sugar extraction with a total of three extractions per sample. The residue and original container were washed with additional ethanol solution during the filtration and brought to a final volume of 100 mL. High-performance liquid chromatography was used for quantification of glucose, fructose, sucrose, and maltose in both raw and cooked sweetpotato samples (Truong et al., 2014).

Texture properties. Instrumental texture measurement was conducted for 20 sweetpotato samples from each treatment. Cooked sweetpotato samples were cut into a cylindrical shape (1.35 cm diameter × 2.2 cm length) using a size 10 cork borer and manually trimmed to the desired length (Truong et al., 1997). The cylinders (incubated at 55 °C) were compressed uniaxially along the longitudinal axis using a texture analyzer (TA.XT Plus; Texture Technologies Corp., Hamilton, MA) equipped with 5-kg load cell and a 5-cm-diameter compression plate (TA-25; Texture Technologies Corp.) traveling with a crosshead speed of 10 cm·min^{-1}. Data collection and calculations were completed using Texture Expert Exceed software (Texture Technologies Corp.) to measure fracture force, height at fracture, fracture stress, and percent compression at fracture.

Sensory evaluation and consumer acceptance. Consumer acceptance testing was conducted in accordance with the North Carolina State University Institutional Review Board for Human Subject guidelines (Institutional Review Board, 2013) and procedure followed as described by Leksrisompong et al. (2012). Sweetpotato consumers (n = 100) were recruited to evaluate ‘Covington’ and ‘Evangeline’ cooked (conventional oven or microwave) sweetpotato roots. Panelists completed a demographic questionnaire to determine gender and age distribution, frequency of consumption, and preferred cooking method of sweetpotato. Coded samples were served one at a time, in a randomized order to each consumer. Consumers recorded responses on paper ballots that had samples identified by a unique three-digit sample number. Participants were asked to evaluate overall, color, texture, and flavor liking on a 9-point hedonic scale, where 9 was anchored with the term, "like extremely" and 1 was anchored with the term, "dislike extremely." Participants were also asked to evaluate moistness, texture, sweetpotato flavor, and sweetness using a 7-point just-about-right scale, where 4 was anchored with the term "just about right" and 1 and 7 were anchored with the opposite extremes of each trait, i.e., "not at all sweet" and "much too sweet," respectively.

STATISTICAL ANALYSIS. All data were checked for homogeneity of variance and normality. Data from variety experiment were subjected to analysis of variance (ANOVA) using the PROC GLM procedure of SAS (version 9.4; SAS Institute, Cary, NC) to test for treatment effects and interactions. Year and variety were considered fixed effect in the analysis. There was no variety × year interaction; therefore, data from 2012 and 2013 variety experiment were pooled. Consumer liking scores, flesh color values, DM content, sugar composition, and texture data were subjected to ANOVA using PROC GLM procedure of SAS and means were separated with Fisher's protected least significant differences at $P \leq 0.05$.

Results and discussion

Variety experiment

'NC05-198' produced the greatest marketable yield (841 bu/acre), which was comparable to 'Beauregard' and 'Bayou Belle' (Table 1). 'NC05-198' also produced the greatest yield of no. 1 roots (600 bu/acre). 'Beauregard' and 'Orleans' had similar total marketable root yield, 759 and 709 bu/acre, respectively (Table 1). However, 'Beauregard' produced the most culls (63 bu/acre), which reduced the percentage of marketable roots to 92%, less than 'NC05-198' and 'Evangeline' (Table 1). 'Bayou Belle' yielded the most canners (118 bu/acre), but was only different from 'Covington' and 'Evangeline' (76 and 49 bu/acre, respectively). No difference in production of jumbo roots was observed among varieties. 'Bonita', 'Evangeline', and 'Covington' were the lowest yielding varieties for both no. 1 and total marketable yield (Table 1). However, all varieties tested were similar in percentage of no. 1 roots [59% to 71% (Table 1)]. Although yields were lower than several of the varieties we tested, Covington has consistently "packed out" (percentage of stored roots shipped to market) better than Beauregard, with the latter being the primary variety grown before the release of Covington (Yencho and Pecota, 2008). Beyond yields, flesh quality, particularly internal necrosis (IN) in 'Covington', continues to be of concern (Clark et al., 2013). It is important to note that the 'Covington' and 'Evangeline' yields measured in the present experiment were higher than reported yields from commercial growers in North Carolina during these growing seasons (USDA, 2015a). At the start of this experiment, 'Evangeline' had recently been introduced for commercial production (La Bonte et al., 2008) and much interest was expressed by the North Carolina industry in its production and quality. It was reported in National Sweetpotato Collaborator Group trials in Charleston, SC, that 'Evangeline' was among the top four producers in total marketable yield alongside 'Orleans', 'Covington', and 'Beauregard' (Jackson, 2011). In this study, 'Evangeline' marketable root yield was comparable to 'Orleans' and 'Covington', but less than 'Beauregard'. Varieties can perform differently depending on climatic differences between growing season and location that influence the number of growing degree days within a growing season (Villordon et al., 2009).

Chemical, physical, and sensory evaluation of 'Evangeline' and 'Covington'

FLESH COLOR. Sweetpotato flesh color was significantly affected by cooking method ($P < 0.001$) and different between varieties ($P < 0.001$). Cooked 'Evangeline' flesh had higher redness (a^*) values than 'Covington'. In contrast, 'Covington' had higher yellow (b^*) and lightness (L^*) values than 'Evangeline' (Table 2) as illustrated by the deeper orange color of 'Evangeline' compared with 'Covington' (Fig. 1). This observation agrees with the deeper orange flesh color of 'Evangeline' reported by La Bonte et al. (2008). Microwaved sweetpotato had higher

Table 1. Sweetpotato varieties yield and percent by grade at Wilson and Johnston Counties, NC, in 2012 and 2013, respectively (data combined over years).

	Yield					Percent by grade				
	No. 1	Canner	Jumbo	Cull	Marketable	No. 1	Canner	Jumbo	Cull	Marketable
Variety	(bushels/acre)[z]					(%)[y]				
NC05-198	600 a[x]	110 ab	130	6 b	841 a	71	13 ab	15	1 b	99 a
Beauregard	502 b	89 ab	168	63 a	759 ab	61	11 bc	20	8 a	92 b
Bayou Belle	477 bc	118 a	179	31 ab	775 ab	59	15 ab	22	4 ab	96 ab
Orleans	468 bc	96 ab	145	14 b	709 bc	65	13 ab	20	2 ab	98 ab
Bonita	393 cd	107 ab	123	14 b	623 cd	62	17 a	19	2 ab	98 ab
Evangeline	393 cd	49 c	157	7 b	600 cd	65	8 c	26	1 b	99 a
Covington	338 d	76 bc	105	16 ab	520 d	63	14 ab	20	3 ab	97 ab
LSD	90	36	97	48	119	NS[x]	5	NS	5	5

LSD = least significant difference.
[z]Marketable yield = no. 1 + canner + jumbo; no. 1 roots are 1.75 to 3.5 inch diameter and 3 to 9 inch length; canner roots are 1 to 1.75 inch diameter; jumbo roots are > 3.5 inch diameter; and cull roots are malformed or distorted; 1 inch = 2.54 cm, 1 [50 lb (22.68 kg)] bushel/acre = 56.0426 $kg \cdot ha^{-1}$.
[y]Percent by grade = (yield root grade/total yield) × 100.
[x]Means within columns followed by same letters are not significantly different according to Fisher's protected LSD test at $P \leq 0.05$; NS = nonsignificant at $P \leq 0.05$.

lightness (L^*) values and lower yellow (b^*) and redness (a^*) values, which indicates a slightly lighter, muted color in comparison with oven-baked roots (Fig. 1). Color is an important trait when considering selection of a variety for commercial production because color is known to alter consumer perception of flavor (Delwiche, 2012). In this study, consumers showed higher liking for the flesh color of the 'Evangeline' ($P < 0.05$).

DM CONTENT. The cooking method by variety interaction was not significant for DM content (Table 3). However, DM content was significantly different between varieties ($P = 0.005$) and affected by cooking method ($P = 0.004$). 'Covington' had slightly higher DM than 'Evangeline' (Table 3). Microwaved samples had the highest DM (30.3%), followed by oven-baked, then raw (27.4% and 25.8%, respectively). According to the USDA Agricultural Research Center, the range of DM for sweetpotato is 12% to 44%, with the average being 29% (USDA, 1998). From an eating quality perspective, higher DM of sweetpotato has been positively correlated with consumer acceptability along with sweet taste and maltose content (Laurie et al., 2013). Laurie et al. (2013) reported that varieties with lower DM (15.6% to 24.6%) were associated with higher ratings for the sensory attribute of wateriness, which resulted in reduced consumer acceptance. On the other hand, cooked sweetpotato of high-DM varieties (DM content of 30.0% and 30.6%) were perceived as mealy by a descriptive sensory analysis panel, and the mealiness scores for baked sweetpotato with a wide range in DM were highly correlated with fracturability, hardness, and shear stress measured by instrumental methods (Truong et al., 1997). Therefore, the seemingly small differences in DM may be detected by consumers. In fact, the 3% difference in DM content for microwave vs. oven-baked sweetpotato in this study coincides with the differences in firmness and moistness noted by consumers using just-about-right scales.

Table 2. Effect of cooking methods on flesh color values of 'Covington' and 'Evangeline' sweetpotato.

Main effect	Treatments	Color[z]		
		L^*	a^*	b^*
Cooking method (CM)	Conventional oven	55.6 b[y]	26.6 a	62.0 a
	Microwave	59.1 a	24.4 b	54.7 b
Variety (V)	Covington	59.0 a	22.7 b	59.8 a
	Evangeline	55.8 b	28.3 a	56.8 b
CM		<0.001	<0.001	<0.001
V		<0.001	<0.001	<0.001
CM × V		0.002	NS[y]	NS

[z]Color measurement: L^* (lightness, 0 for black, 100 for white), a^* ($-a^*$ = greenness, $+a^*$ = redness), and b^* ($-b^*$ = blueness, $+b^*$ = yellowness).
[y]Means within columns for main effects (cooking method or variety) followed by the same letter are not significantly different according to Fisher's protected least significant difference test at $P \le 0.05$; NS = nonsignificant at $P \le 0.05$.

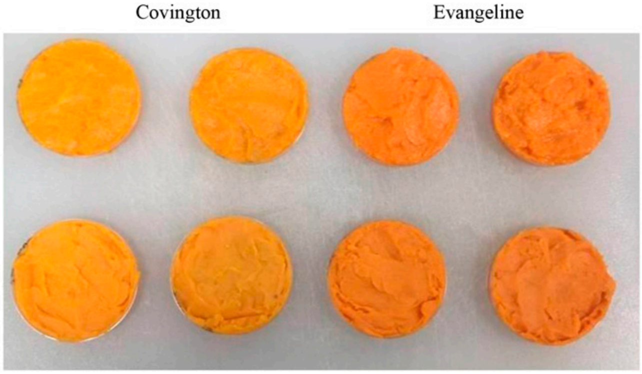

Fig. 1. Sweetpotato samples microwaved and oven-baked for color measurement. Note the darker orange flesh in 'Evangeline' vs. 'Covington'.

Table 3. Effect of cooking method on dry matter content and sugar composition of 'Covington' and 'Evangeline' sweetpotato.

Main effect	Treatment	Dry matter (%)[z]	Sugar composition			
			Glucose	Fructose	Sucrose	Maltose
			(mg·g^{-1} fresh wt)[y]			
Cooking method (CM)	Conventional oven	27.4 b[x]	6.9 a	4.8 a	41.8 a	64.2 a
	Microwave	30.3 a	7.7 a	5.8 a	42.5 a	41.9 b
	Raw	25.8 c	7.0 a	5.2 a	37.5 a	0 c
Variety (V)	Covington	28.7 a	6.2 b	4.3 b	41.3 a	35.2 a
	Evangeline	27.0 b	8.3 a	6.2 a	40.0 a	35.3 a
CM		0.004	NS[x]	NS	NS	0.002
V		0.005	0.021	0.006	NS	NS
CM × V		NS	NS	NS	NS	NS

[z]Dry matter (%) = (dry weight of sample/total weight of sample) × 100.
[y]1 mg·g^{-1} = 1000 ppm.
[x]Means within columns for main effects (cooking method or variety) followed by the same letter are not significantly different according to Fisher's protected least significant difference test at $P \le 0.05$; NS = nonsignificant at $P \le 0.05$.

Table 4. Effect of cooking methods on instrumental texture properties of 'Covington' and 'Evangeline' sweetpotato.

Main effect	Treatment	Fracture force (N)[z]	Fracture distance (mm)	Fracture stress (Pa)	Compression fracture (%)
Cooking method (CM)	Conventional oven	1.26 b[y]	4.13 a	8,797 b	19.47 a
	Microwave	2.69 a	3.38 b	18,789 a	15.78 b
Variety (V)	Covington	1.63 a	3.68 a	11,403 a	17.24 a
	Evangeline	2.34 a	3.83 a	16,373 a	17.99 a
CM		0.005	0.001	0.005	0.001
V		NS[y]	NS	NS	NS
CM × V		NS	NS	NS	NS

[z]1 N = 0.2248 lb; 1 mm = 0.0394 inch; 1 Pa = 0.0209 lb/ft^2.
[y]Means within columns for main effects (cooking method or variety) followed by the same letter are not significantly different according to Fisher's protected least significant difference test at $P \leq 0.05$; NS = nonsignificant at $P \leq 0.05$.

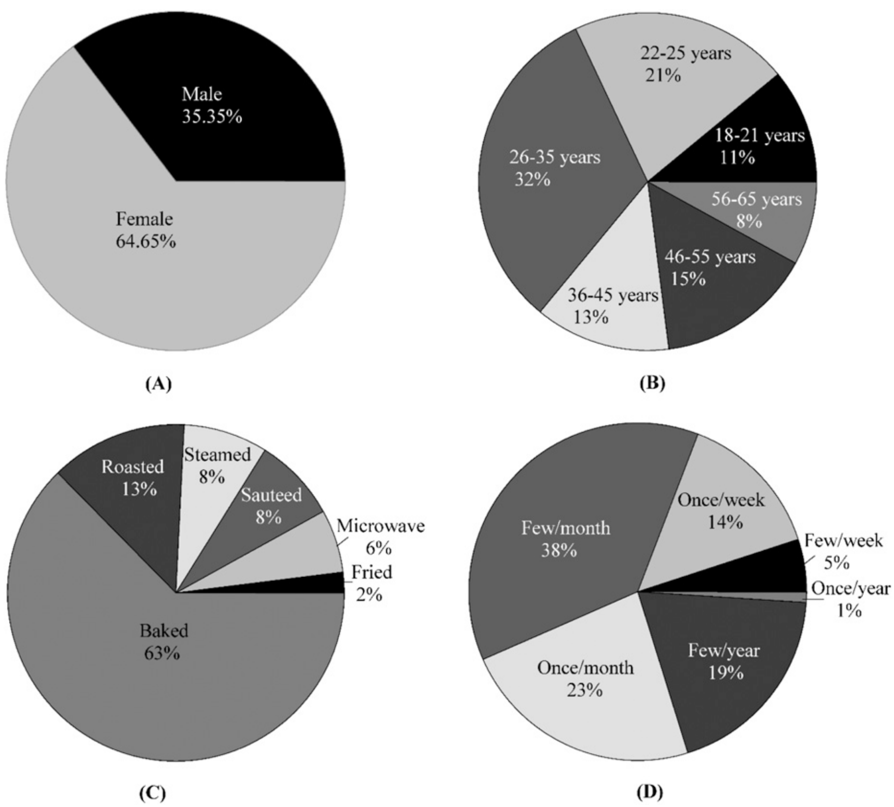

Fig. 2. Proportion of total participants (%) in sweetpotato sensory panel (n = 100): (A) gender distribution, (B) age groups, (C) preferred cooking method, and (D) consumption frequency.

SUGAR COMPOSITION. The cooking method × variety interactions were not significant for sugar composition (Table 3). However, there were significant differences between varieties in glucose (P = 0.021) and fructose (P = 0.006) content. However, there were no differences in sucrose content for either variety or cooking method. 'Evangeline' contained higher levels of glucose in contrast to 'Covington' (8.3 and 6.2 mg·g^{-1}, respectively) (Table 3). Fructose levels were also higher in 'Evangeline' than 'Covington' (6.2 and 4.3 mg·g^{-1}, respectively). The sugar levels in raw 'Covington' were comparable with the content of sucrose (38 mg·g^{-1}), glucose (8.8 mg·g^{-1}), and fructose (5.5 mg·g^{-1}) reported by Yencho et al. (2008). La Bonte et al. (2008) reported that oven-baked 'Evangeline' sucrose content was higher (63 mg·g^{-1}) in contrast with 'Beauregard' (27 mg·g^{-1}). However, we found sucrose content of 'Evangeline' and 'Covington' grown in North Carolina to be 40.0 and 41.3 mg·g^{-1}, respectively, which were in agreement with the results recently reported by Sato et al. (2016). Sugar concentration variations are complex and can easily be influenced by a number of different factors, including annual and environmental differences (Kou et al., 2012), and in some varieties, delaying harvest timing can induce a linear increase in total sugar concentrations (Lewthwaite et al., 2000). Because of the many variables that contribute to sugar content, one can only speculate the environmental effects for the lower than expected sucrose content of 'Evangeline' in the present study as varieties were harvested at the same time and stored for 5 weeks.

The main effect of cooking method was only significant for maltose content (P = 0.002), which was in agreement with a previous report (Truong et al., 2014). The starch–maltose conversion during the heating process is due to hydrolysis of gelatinized starch by endogenous amylases in sweetpotato roots (Ridley et al., 2005; Walter et al., 1975). As expected, oven-baked roots had the highest maltose content (64 mg·g^{-1}) followed by microwaved (42 mg·g^{-1}) and raw (0 mg·g^{-1}) (Table 3). The effect of cooking on maltose content is consistent with previous findings (Lewthwaite et al., 1997; Picha, 1985; Ridley et al., 2005; Walter et al., 1975). Sucrose, fructose, and glucose are present in raw sweetpotato tissue, but maltose is only produced during heating. During the cooking process, starch is converted into dextrins and maltose by α-amylase and β-amylase. The microwaved roots have less maltose than oven-baked roots due to the rapid nature of microwave heating. During oven baking, there is ample time for α-amylase to degrade starch into maltose (Purcell and Walter, 1988).

Texture properties. Texture analysis revealed that the 'Evangeline' and 'Covington' did not differ significantly in texture properties, but cooking method influenced ($P < 0.05$) fracture force, distance at fracture, fracture stress, and percent of compression at fracture (Table 4). Fracture force and stress were higher for microwaved roots than conventional oven-baked. In contrast, distance at fracture and percent of compression at fracture were lower for microwaved roots than conventional oven-baked (Table 4). This indicated that microwaved roots were measurably firmer than oven-baked roots despite efforts in preliminary trials to minimize differences in texture obtained with the two cooking methods.

Consumer acceptance of 'Evangeline' and 'Covington'. Consumer panelists consist of 65% female and 35% male (Fig. 2A), ages 18 to 65 years, with a majority between 26 to 35 years of age (Fig. 2B). Their preferred cooking method for sweetpotato was oven-baked (63%) followed by roasted (13%) then sauteed (8%), steamed (8%), or fried (2%) (Fig. 2C). Frequency of sweetpotato consumption among these consumers ranged from once per year to a few times per week (Fig. 2D). The highest percentage of participants (38%) reported that they consume sweetpotato a few times per month.

The interactions for cooking method and variety were not significant for all consumer liking attributes (overall, color, texture, and flavor). However, the main effect of cooking method was significant for all the attributes and variety was only significant for color (Table 5). Overall, consumers preferred oven-baked sweetpotato to microwaved with no difference in overall liking between varieties (Table 5). 'Evangeline' sweetpotato roots were more highly liked for color than 'Covington', and panelists showed a preference for the color of oven-baked over microwaved roots, which corresponds with the deeper orange color detected in the color measurement analysis. Both texture and flavor liking were higher for oven-baked over microwaved with no differences between varieties (Table 5).

The cooking method also significantly impacted the consumers' perceptions of sweetpotato moisture level, texture, and flavor (Table 6). Fifty-eight percent of panelists rated moisture levels for microwaved roots to be "slightly too dry" to "much too dry" (Fig. 3A), which corresponds with the higher DM content (30.3 $mg \cdot g^{-1}$). Thirty-six percent of panelists thought that the microwaved roots were "slightly too firm" to "much too firm" in contrast to oven-baked (14%) (Fig. 3B), which corresponds with texture analysis results. However, 41% of panelists rated oven-baked sweetpotato to be "slightly too soft" to "much too soft" (Fig. 3B). Fifty-six percent of panelists rated microwaved sweetpotato flavor as "slightly unflavorful" to "not at all flavorful" and only 39% rated as "just about right," in contrast to oven-baked roots, in which 51% of panelists rated as "just about right" and only 14% as "slightly unflavorful" to "not at all flavorful" (Fig. 3C). Although cooking method clearly influenced the eating quality of the sweetpotato, 'Evangeline' and 'Covington' were not significantly different in consumer acceptability in relation to perceived moisture level, texture, and flavor.

Sweetness ratings of cooked sweetpotato roots were influenced by cooking method and variety (Table 6). Oven-baked 'Covington' roots had the highest percentage of "just about right" scores (53%), followed by oven-baked 'Evangeline', microwaved 'Covington', and microwaved 'Evangeline' (44%, 40%, and 35%, respectively) (Fig. 4A and B). Based on these results, there was little varietal difference in "just about right" scores for sweetness. This corresponds with the similar sucrose levels measured between varieties in this study. Sixty one and 45% of panelists rated 'Evangeline' to be "slightly not sweet enough" to "not at all sweet" for microwaved and oven-baked sweetpotato, respectively (Fig. 4A and B). The slightly higher amounts of glucose and fructose in

Table 5. Effect of cooking method on consumer liking of 'Covington' and 'Evangeline' sweetpotato.

		Consumer liking (1–9 scale)[z]			
Main effect	Treatment	Overall	Color	Texture	Flavor
Cooking method (CM)	Conventional oven	6.8 a[y]	7.1 a	6.5 a	6.9 a
	Microwave	5.7 b	6.3 b	5.6 b	5.6 b
Variety (V)	Covington	6.3 a	6.0 b	6.2 a	6.4 a
	Evangeline	6.2 a	7.3 a	6.0 a	6.3 a
CM		<0.001	<0.001	<0.001	<0.001
V		NS[y]	<0.001	NS	NS
CM × V		NS	NS	NS	NS

[z]Overall, color, texture, and flavor liking were scored on a 9-point hedonic scale where 9 = like extremely and 1 = dislike extremely.
[y]Means within columns for main effects (cooking method or variety) followed by the same letter are not significantly different according to Fisher's protected least significant difference test at $P \leq 0.05$; NS = nonsignificant at $P \leq 0.05$.

Table 6. Effect of cooking method on the consumer perception of sensory attributes for 'Covington' and 'Evangeline' sweetpotato.

		Sensory attribute (1–7 scale)[z]			
Main effect	Treatment	Moistness	Texture	Flavor	Sweetness
Cooking method (CM)	Conventional oven	3.7 b[y]	3.6 a	3.7 a	3.6 a
	Microwave	5.0 a	4.3 b	3.1 b	3.1 b
Variety (V)	Covington	4.3 a	3.8 a	3.4 a	3.5 a
	Evangeline	4.3 a	4.0 a	3.4 a	3.2 b
CM		<0.001	<0.001	<0.001	<0.001
V		NS[y]	NS	NS	0.009
CM × V		NS	NS	NS	NS

[z]Sweetpotato moistness, texture, flavor, and sweetness were rated on 7-point "just about right" scale where 4 was anchored with the term "just about right" and 1 and 7 were anchored with the opposite extremes of each trait, i.e., for sweetness these are "not at all sweet" and "much too sweet," respectively.
[y]Means within columns for main effects (cooking method or variety) followed by the same letter are not significantly different according to Fisher's protected least significant difference test at $P \leq 0.05$; NS = nonsignificant at $P \leq 0.05$.

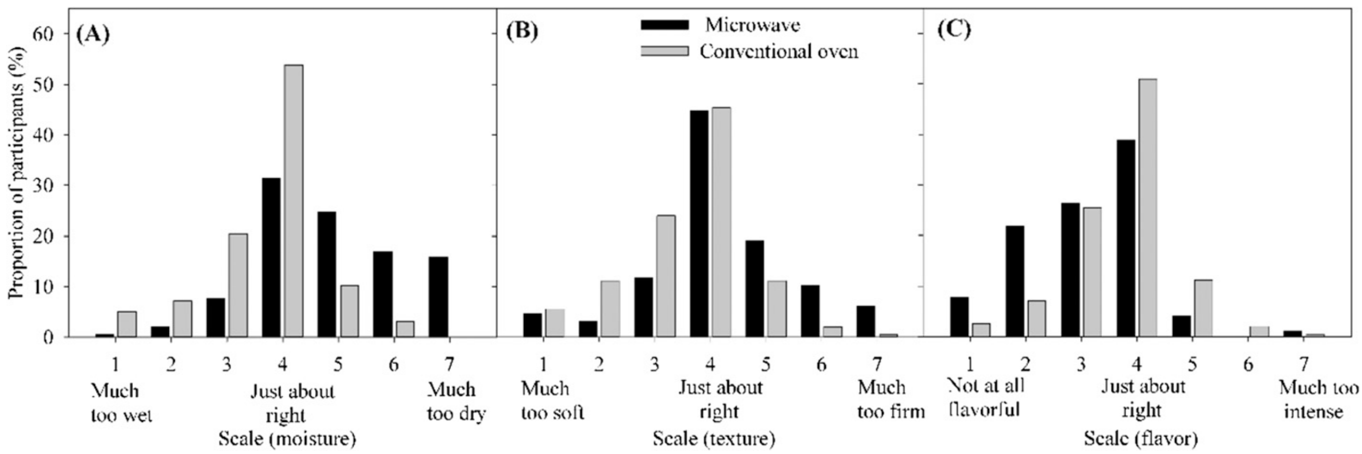

Fig. 3. Histograms of moistness (A), texture (B), and flavor (C) ratings for microwave vs. oven-baked sweetpotato (combined across 'Covington' and 'Evangeline'). Participants rated sweetpotato samples on a 7-point scale that had 4 anchored with "just about right" and 1 and 7 anchored with extremes.

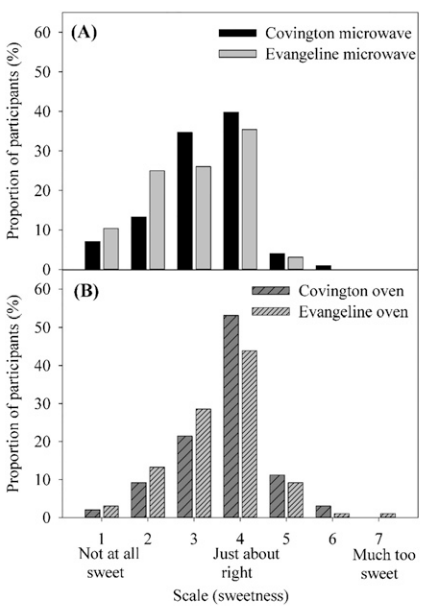

Fig. 4. Histograms of consumer opinion for 'Covington' and 'Evangeline' sweetpotato sweetness. Participants rated microwaved (A) and oven-baked (B) samples for sweetpotato sweetness on a 7-point scale that had the number 4 anchored with "just about right" and 1 and 7 anchored with "extremes."

'Evangeline' compared with 'Covington' were apparently not detected by these consumers. A sensory study on perceived sweetness of tomatoes (*Solanum lycopersicum*) with equal amounts of added glucose, fructose, and sucrose reported that samples with added sucrose and fructose were rated sweeter than samples with added glucose (Baldwin and Thompson, 2000). However, it seems that sweetness perception of fructose is dependent on other factors such as temperature and pH (Fricker et al., 1973; Harris et al., 1978; Hyvonen et al., 1977). Fontvieille et al. (1989) reported that perceived fructose sweetness decreased as temperature increased from 77 to 122 °F. They also reported that the perceived sweetness of fructose increases with increasing acidity. Different sugar types at similar concentrations have a different perceived sweetness. Biester et al. (1925) reported that fructose was five times, sucrose three times, and glucose two times sweeter than maltose. However, the type of sugar also has an effect on flavor in addition to sweetness. In a sensory study with equal sweetness of different sugars in sweetpotato puree, panelists preferred maltose > sucrose > fructose (Koehler and Kays, 1991). Therefore, when considering sugar concentrations for sweetpotato, maltose levels may be more important than sucrose, fructose, or glucose due to its relation to perceived sweetpotato sweetness. It is also known that sensory responses are not solely dependent on perceived sweetness, but also on texture, moisture, color, and flavor (Delwiche, 2012; Laurie et al., 2013).

Microwaved roots of both varieties were rated drier and firmer than oven-baked roots, which directly affected the overall appeal of the sweetpotato. Moisture levels of microwaved sweetpotatoes have been reported to be significantly lower than convection oven (Purcell and Walter, 1988). Perhaps if the sweetpotato were shrink-wrapped, as some commercially marketed microwavable sweetpotato are, then moisture levels would have been closer to oven-baked roots. Fresh market sweetpotato lose ≈2.5% of their weight after 3 weeks at room temperature in contrast to shrink-wrapped of 0.5% (Picha, 2009). Moisture levels and even slight differences in texture may have affected panelist perception of other characteristics, such as overall liking and sweetpotato flavor.

In summary, 'NC05-198' and 'Bayou Belle' performed consistently well in North Carolina conditions. Both yielded better than several of the currently commercialized varieties in no. 1 and total marketable root production. 'Beauregard' produced greater culls, which agrees with previously reported findings (La Bonte et al., 2012). 'Covington' had the lowest yields in this study, and provides reason to be vigilant in searching for new and more promising varieties. 'Evangeline' had comparable yields of no. 1 roots to 'Bayou Belle', 'Orleans', and 'Covington', which indicates the ability of this variety to produce acceptable yield in North Carolina conditions. Consumers in this study also indicate that 'Evangeline' is as well-liked as the current, commercial variety Covington, and even preferred Evangeline flesh color over Covington. However, due to similarities in sucrose content of the 'Evangeline' and 'Covington' grown in North Carolina, the previously hypothesized value of marketing 'Evangeline' preferentially to ‘Covington’ as a microwavable sweetpotato was not realized when grown in the North Carolina environment. Perhaps ‘Evangeline’ roots grown in the hotter Gulf south region where higher sucrose levels were reported (Labonte et al., 2008) would be better suited for microwaving. In addition, the consumer preference of oven-baked over microwaved sweetpotato is not surprising considering the drying nature and rapid heating associated with microwave cooking, resulting in higher DM content and limited starch conversion into maltose and therefore lower moistness and sweetness ratings in comparison with conventional baking.

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