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Pecan Flavor Changes during Storage

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Abstract

Sixteen pecan [*Carya illinoinensis (Wangenh.)* K. Koch] cultivars, 'Giles', 'Hirschi', 'Maramec', 'Oswego', 'Lakota', 'Chetopa', 'Colby', 'Witte', 'Dooley', 'Kanza', 'Pawnee', 'Stuart', 'Chickasaw', 'Peruque', 'Major', and 'Henning', were evaluated by descriptive sensory analysis to assess changes in their flavor profiles as kernels aged at room temperature. Six trained panelists evaluated four flavor attributes at five time points (0, 3, 6, 9, and 12 months) to determine how the flavor of cultivars changed. There was an interaction between time and cultivar for rancidity, bitterness, and sweetness; for example 'Kanza' changed less in its sensory properties than 'Henning' over storage time. The rancidity, bitterness, and sourness increased over time for all 16 cultivars while sweetness decreased for all cultivars Future studies should evaluate consumer acceptance of these cultivars at every time point to determine when the pecans are no longer acceptable. This information can be used by pecan growers who are selecting cultivars for commercial production and by consumers who are selecting cultivars for different applications.

Pecan is a native North American crop that contributes to the agricultural economy in 24 of the 50 United States (Wood, 2001). These states can be divided into four production regions: south central (Texas and Oklahoma), southwestern (New Mexico, Nevada, Arizona, California, and Utah), southeastern (Georgia, Florida, South Carolina, North Carolina, Virginia, Alabama, Mississippi, Louisiana, and Arkansas), and northern (Tennessee, Kentucky, Indiana, Illinois, Iowa, Nebraska, Missouri, and Kansas) (Wood, 2001).

More than 95% of nuts produced in northern pecan states are harvested from natural stands (Reid and Eikenbary, 1991). The harvest of nuts from native trees and from short-season, cold-hardy pecan cultivars has created a pecan industry in northern states that is ever increasing (Reid and Hunt, 2000). Most pecan production in northern states is from cultivars that originated from the wild (Reid and Hunt, 2000). Pecan farmers assess naturally occurring seedlings, choosing the most productive, thin shelled, and large fruited to be propagated and named (Reid and Hunt, 2000). Though cultivar preferences vary with location for northern growers, two cultivars ('Pawnee' and 'Kanza') bred by the USDA-ARS and evaluated cooperatively at several locations, have been widely grafted (Reid and Hunt, 2000). In this study, these two cultivars plus an additional fourteen cultivars commonly grown in northern states were evaluated.

Pecan consumption has increased because of an awareness of the pecan kernel's desirable nutritional properties. This is mainly due to the high quantities of unsaturated fatty acids that are part of the pecan kernel composition. These fatty acids are subject to oxidative cleavage that deteriorates the quality of the pecans (Baldwin and Wood, 2006).

Limited past research focused on how pecan sensory properties change over time. Only two previous studies focused on how storage can impact pecan quality. Baldwin and Wood (2006) evaluated the sensory properties of pecans that had different edible coating treatments and how they changed

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over a 9-month period. Eighteen to twenty panelists were given three kernels from each treatment. They rated appearance and overall flavor on a 9-point hedonic scale to assess preference. They rated texture (crispness) and off-flavor (intensity) on a 9-point category scale (1 = low and 9 = high). After 5 months there was no significant difference from the control sample (no coating) and the three coated samples. A slight off-flavor was detected. After 9 months the intensity of off-flavors increased in the control sample, but did not increase for the coated samples.

Erickson et al. (1994) assessed the oxidative stability of both raw and roasted pecans. Those authors evaluated both categories of pecans for crunchiness, internal lightness, and rancid aroma and flavor. The attribute intensities were recorded on a 150 mm line scale with appropriate anchor words. The samples were evaluated at five different time points (0, 136, 157, 199, and 241 days). Significant differences were found in the intensity of all four sensory attributes.

Though there has been research on quality changes in pecans over time, it has been somewhat limited in characterizing how the flavor changes. Additional information about how the flavor changes in different pecan cultivars could be used by pecan growers in choosing cultivars for new pecan orchards. Therefore, the objectives of this paper were to assess pecan flavor changes over a 12 month period and to determine differences in flavor among northern pecan cultivars using descriptive sensory analysis.

Materials and Methods

Samples. Sixteen pecan cultivars were harvested (~18 kg per cultivar, in shell) from Kansas State University's Pecan Experimental Field orchard in Chetopa, KS, USA. The cultivars included: 'Dooley', 'Pawnee', 'Witte', 'Hirschi', 'Chickasaw', 'Kanza', 'Oswego', 'Major', 'Henning', 'Stuart', 'Lakota', 'Giles', 'Maramec', 'Peruque', 'Chetopa', and 'Colby'. The pecans were transported to the Sensory Analysis Center (Manhattan, KS, USA) on January 24, 2014. The pecans were dried in their shells for 7 days at ambient temperature (23°C ± 1°C). The pecan shelling was completed over a two-month period using a Duke Pecan Walnut Cracker (Duke Pecan Company, West Point, MS, USA) and 15.24 cm cutting pliers (Model No. 436, Channel Lock Inc., Meadville, PA, USA) to remove the nutmeat from the shells. Samples were transferred to 3.79 L Food Saver vacuum seal bags and were vacuum-sealed using a FoodSaver Heat-Seal Vacuum Sealing System (Sunbeam Products Inc., Boca Raton, FL, USA). They were then kept under frozen conditions (-26°C ± 1°C) to maintain freshness and to delay oil oxidation in the nuts.

Sample preparation. The pecans were removed from the freezer the afternoon prior to starting the shelf life test and allowed to thaw at room temperature (23°C ± 1°C) prior to placing into sealed mason jars in the environmental chamber. Five time points (fresh (0), 3, 6, 9, and 12 months) were used to evaluate the shelf-life of 16 raw pecan cultivars. The samples for 3 months through 12 months were stored in sealed mason jars (Ball, Jarden Corporation, Daleville, IN, USA) in an environmental chamber (Forma Environmental Chamber, ThermoFisher Scientific, Ashville, NC, USA) at ambient conditions (22°C ± 1°C and 50% ± 1% relative humidity). This was to model storage conditions where pecans are sold in retail shops and in consumers' homes (Erickson et al., 1994). There were three mason jars for each cultivar at each time point, each containing 100 g of pecan sample. The pecans for the 0 month time point were removed from the freezer the afternoon prior to testing and allowed to thaw at room temperature (23°C ± 1°C) prior to evaluation. The pecans for the other four time points were removed from the sealed mason jars in the environmental chamber the day of testing.

Descriptive analysis. Six panelists (five female, one male) from the Sensory Analysis Center at Kansas State University in Man-

Table 1. Flavor attributes, definitions, and references for descriptive analysis of pecans.*

Attribute	Definition	Reference
Rancid	An aromatic commonly associated with oxidized fat and oils.	Wesson vegetable oil = 2.5 Preparation: microwave 1/3 cup of oil on high power for 2.5 min. Let cool and serve in individual covered cups.
Bitter	A fundamental taste factor of which caffeine is typical.	0.010% caffeine solution = 2.0 0.020% caffeine solution = 3.5 0.035% caffeine solution = 5.0
Sour	A fundamental taste factor of which citric acid is typical.	0.015% citric acid solution = 1.5 0.025% citric acid solution = 2.5
Sweet	A fundamental taste factor of which sucrose is typical.	1% sucrose solution = 1.0

* 0-15-point numeric scale with 0.5 increments was used to rate the intensities of the attributes and references.

hattan, KS, USA were chosen for descriptive evaluation of the raw pecans. All panelists completed 120 h of general training in descriptive analysis methodology, and each panelist had over 2,000 h of testing experience with a wide variety of food items. Five of the panelists had prior experience evaluating nut-related samples. Four flavor attributes were evaluated (Table 1).

Test design and sample evaluation. A series of modified William's Latin Square designs (Hunter 1996) were used to construct the test designs of this study. Computation of the Latin Squares for descriptive evaluation was completed with SAS® statistical software, version 9.3 (SAS Institute Inc., Cary, NC, USA).

The morning of evaluation each panelist was served 10 g of each cultivar in a plastic 92.14 g cup with plastic lid (Solo Cup Company, Lake Forest, IL, USA). The cups were labeled with a three-digit blinding code. Panelists sat at a round table under ambient lighting and temperature conditions. Panelists scored the samples individually and evaluated attribute intensities by scoring a ballot containing a 0-15-point numerical scale with 0.5 increments, where 0.0 = none/not present and 15.0 = highest possible intensity. This evaluation procedure has been used in other recently published research (Cherdchu and Chambers, 2014; Miller and Chambers, 2013). A tray with references for the flavor attributes was provided for each panelist along with definition/reference sheets. Panelists took a one-quarter piece of pecan (as determined during orientation to ensure approximately equal sampling amounts) into their mouths and chewed until well masticated before scoring the intensities of attributes. Panelists were encouraged to expectorate. Reverse osmosis, de-ionized water (at room temperature and hot), 0.5 cm peeled carrot slices, 1.27 cm Mozzarella cheese cubes (low moisture, part skim; Kroger Company, Cincinnati, OH, USA), and 0.32 cm skinless cucumber slices were used as palate cleansers. Sample evaluation took approximately 10 min, and a 5 min rest period was used in addition to rinse agents to reduce flavor carryover. Panelists evaluated the sixteen raw pecan samples in triple replicate for each cultivar. For each time point, one replication of the pecan samples was completed over a two-day period. Each evaluation session was one hour. There was a total of four days of testing for each time point.

Statistical analysis. Analysis of vari-

ance (ANOVA) was performed to test the significance of each flavor attribute across cultivars at the 5% level of significance. Cultivar, panelist, time, and replication were used as sources of variation with panelist and replication as random effects to determine significant changes over storage time. Cultivar, panelist, and replication were used as sources of variation with panelist and replication as random effects to determine significant changes among cultivars within a time point. Using Fisher's protected Least Significant Difference (LSD) at the 5% level of significance, post-hoc means separation was analyzed to determine which cultivars were significantly different. Statistical analyses were performed with SAS® statistical software (SAS® version 9.3, SAS Institute Inc., Cary, NC, USA) using PROC MIXED.

Results and Discussion

Four flavor attributes were evaluated for pecan kernels stored at room temperature for five periods of time: 0 (fresh), 3, 6, 9, and 12 months. The attributes evaluated were rancid, bitter, sour, and sweet.

Rancid flavor. Since pecans have high oil content, it was important to evaluate how rancidity changed over time (Baldwin and Wood, 2006). The rancid attribute was not present in fresh samples for any of the 16 cultivars (Table 2). This attribute increased in intensity for every cultivar over 12 months, but the rate at which the intensity increased differed for each cultivar (Fig. 1). The rancid attribute was significantly different ($P \leq 0.05$) among cultivars for the 3 month through 12 month time points. At 3 months the rancid attribute was significantly different ($P \leq 0.05$) across cultivars. Rancid flavor had not developed in 'Colby', 'Witte', and 'Pawnee' after 3 months of storage. 'Maramec' had the highest rancid intensity in comparison to the other cultivars. At 6 months the rancid attribute was highest for 'Maramec' and lowest for 'Colby', 'Witte', 'Kanza', 'Pawnee', 'Chickasaw', 'Peruque', and 'Major'. At 9 months 'Henning' and 'Maramec' had the

Table 2. Mean intensity scores and separation of rancid flavor for sixteen pecan cultivars at five time points*.

	Storage (months)				
Cultivar	0	3	6	9	12
Chetopa	0.00^{c}	0.53^{cBC}	1.42^{bBC}	1.76^{bBC}	2.78^{aA}
Chickasaw	0.00	0.08^{DE}	0.11^{F}	0.26^{H}	0.41^{E}
Colby	0.00^{b}	0.00^{bE}	0.22^{bF}	0.29^{bH}	1.19^{aCD}
Dooley	0.00	0.11^{DE}	0.47^{EF}	0.74^{FGH}	0.75^{DE}
Giles	0.00^{c}	0.06^{cDE}	1.22^{bCD}	1.00^{bEFG}	2.31^{aAB}
Henning	0.00^{d}	0.75^{cB}	2.00^{bB}	2.58^{abA}	2.94^{aA}
Hirschi	0.00^{c}	0.19^{cCDE}	0.94^{bCDE}	1.59^{bCDE}	2.47^{aA}
Kanza	0.00	0.14^{DE}	0.19^{F}	0.22^{H}	0.53^{DE}
Lakota	0.00	0.11^{DE}	0.58^{DEF}	0.44^{GH}	0.47^{E}
Major	0.00^{b}	0.08^{bDE}	0.00^{bF}	0.24^{abH}	0.61^{aDE}
Maramec	0.00^{c}	1.42^{bA}	2.81^{aA}	2.38^{aAB}	2.92^{aA}
Oswego	0.00^{c}	0.39^{cCD}	1.44^{bBC}	1.17^{bCDEF}	2.67^{aA}
Pawnee	0.00^{b}	0.00^{abE}	0.19^{abF}	0.53^{abGH}	1.75^{aBC}
Peruque	0.00^{c}	0.11^{cDE}	0.06^{cF}	1.03^{bDEFG}	2.64^{aA}
Stuart	0.00^{c}	0.19^{cCDE}	1.36^{bBC}	1.65^{bCD}	2.56^{aA}
Witte	0.00^{b}	0.00^{bE}	0.14^{bF}	0.24^{abH}	0.53^{aDE}

* Means with different superscripts in lower case within a row (time points) are significantly different ($P<0.05$) according to Fisher's protected least significant difference (LSD) test; means with different superscripts in upper case within a column (cultivars) are significantly different ($P<0.05$) according to Fisher's protected least significant difference (LSD) test.

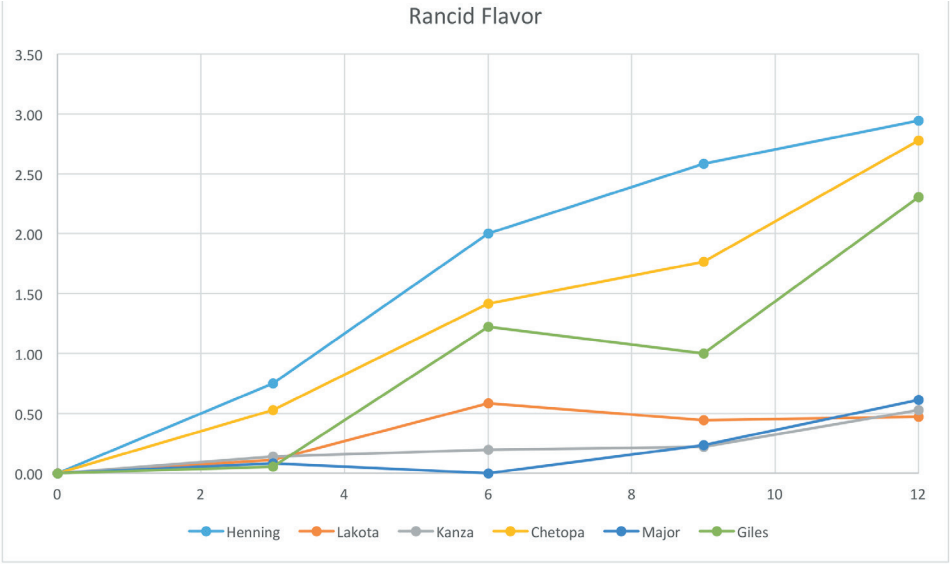

Fig. 1: Rancid flavor intensity at 0, 3, 6, 9, an 12 months for 'Henning', 'Lakota', 'Kanza', 'Chetopa', 'Major', and 'Giles' (scale from 0 to 15 with 0.5 increments).

highest intensity and 'Major', 'Chickasaw', 'Kanza', 'Witte', and 'Colby' had the lowest. At 12 months the rancid flavor greatly increased for many cultivars. 'Lakota' had the lowest intensity while 'Maramec', 'Henning', 'Hirschi', 'Oswego', 'Chetopa' and 'Stuart' all had higher intensities of rancid flavor.

Twelve of the 16 cultivars had significant differences ($P \leq 0.05$) in rancid intensity over the 12 months (Table 2). 'Maramec' and 'Henning' had a significant ($P \leq 0.05$) increase in intensity after 3 months had passed. 'Giles', 'Hirschi', 'Oswego', 'Chetopa', and 'Stuart' had a significant ($P \leq 0.05$) increase in intensity after 6 months had passed. 'Peruque' had a significant ($P \leq 0.05$) increase in intensity after 9 months while 'Witte', 'Colby', 'Pawnee', and 'Major' had a significant ($P \leq 0.05$) increase in intensity after 12 months. Previous studies have affirmed this finding that the intensity of rancidity increases over time (Heaton et al., 1975; Erickson et al., 1994). However, rancidity remained low and did not change with time in 'Lakota', 'Dooley', 'Kanza', and 'Chickasaw'. It would be beneficial to conduct consumer research at these time points to see if consumers find pecan cultivars with varying levels of rancidity acceptable. This research could be done on selected cultivars such as 'Major', 'Kanza','Chickasaw', and 'Dooley' which had low levels of rancidity after 1 year had passed, but also on 'Maramec' and 'Henning', that indicated relatively higher levels of rancidity.

*Bitter taste***.** All pecan cultivars had high bitter intensities in comparison to the other three attributes. Bitterness was significantly different ($P \leq 0.05$) across all cultivars at every time point (Table 3). 'Henning' had a high intensity of bitterness at every time point. At 0 months (or "fresh") in addition to 'Henning', 'Lakota' also had a relatively high intensity of bitterness, while 'Pawnee' had the lowest intensity. At 3 months 'Witte' had the lowest intensity, while 'Henning' and 'Maramec' had the highest bitterness among the cultivars studied. 'Dooley' had the lowest bitter intensity at 9 months and 12 months.

Table 3. Mean intensity scores and separation of bitter taste for sixteen pecan cultivars at five time points*.

Cultivar	Storage (months)				
	0	3	6	9	12
Chetopa	2.97^{BCD}	3.22^{BCD}	3.25^{CDEF}	3.38^{ABC}	3.58^{ABCD}
Chickasaw	2.94^{BCD}	3.11^{CDE}	3.19^{DEFG}	3.26^{BCD}	3.06^{E}
Colby	3.06^{ABC}	2.92^{DE}	3.19^{DEFG}	3.15^{CD}	3.31^{CDE}
Dooley	2.81^{CD}	3.08^{CDE}	2.86^{G}	3.09^{D}	3.11^{E}
Giles	3.25^{AB}	3.19^{BCD}	3.36^{BCDE}	3.44^{AB}	3.69^{ABC}
Henning	3.31^{A}	3.56^{A}	3.72^{A}	3.69^{A}	3.92^{A}
Hirschi	3.06b^{ABC}	3.14^{bBCDE}	3.44^{abABCD}	3.62^{aA}	3.78^{aAB}
Kanza	2.89^{CD}	3.06^{CDE}	3.08^{EFG}	3.14^{CD}	3.14^{E}
Lakota	3.33^{A}	3.14^{BCDE}	3.39^{ABCDE}	3.18^{BCD}	3.31^{CDE}
Major	2.81^{CD}	3.22^{BCD}	2.94^{FG}	3.21^{BCD}	3.36^{CDE}
Maramec	2.81^{bCD}	3.44^{aAB}	3.64^{aAB}	3.59^{aA}	3.81^{aAB}
Oswego	2.89^{cCD}	3.03^{bcCDE}	3.06^{bcEFG}	3.42^{abABC}	3.83^{aA}
Pawnee	2.69^{bD}	3.06^{abCDE}	3.06^{abEFG}	3.06^{abD}	3.42^{aBCDE}
Peruque	2.86^{cCD}	3.14^{bcBCDE}	3.00^{bcFG}	3.31^{bBCD}	3.86^{aA}
Stuart	2.92^{cCD}	3.28^{bcABC}	3.58^{abABC}	3.44^{bAB}	3.94^{aA}
Witte	3.03^{ABC}	2.86^{E}	3.08^{EFG}	3.21^{BCD}	3.22^{DE}

* Means with different superscripts in lower case within a row (time points) are significantly different (P<0.05) according to Fisher's protected least significant difference (LSD) test; means with different superscripts in upper case within a column (cultivars) are significantly different (P<0.05) according to Fisher's protected least significant difference (LSD) test.

At 9 months 'Hirschi' and 'Maramec' had higher intensities that were not significantly different (P≤0.05) from 'Henning'. At 12 months 'Oswego', 'Stuart', and 'Peruque' had also increased in bitter intensity.

Though the intensity of the bitter attribute was the most intense for all time points of the attributes evaluated, it had only slight increases in intensity over time. Ten of the 16 cultivars ('Giles', 'Lakota', 'Chetopa', 'Colby', 'Witte', 'Dooley', 'Kanza', 'Chickasaw', 'Major', and 'Henning') did not have a significant (P≤0.05) increase in intensity over 12 months. 'Pawnee' had a significant (P≤0.05) increase in bitter intensity after 12 months had passed. 'Hirschi', 'Oswego', and 'Peruque' had a significant (P≤0.05) increase in intensity after 9 months. 'Stuart' had a significant (P≤0.05) increase after 6 months had passed and 'Maramec' had a significant (P≤0.05) increase in bitter intensity after only 3 months. A study conducted by Grosso and Resurreccion (2002) examined how flavor of different peanut samples changed over time. They also determined that the intensity of bitter increased as time increased. Bitterness is a basic taste that can have an impact on consumer acceptance. It is innate for consumers to dislike the bitter taste due to natural instincts (Clark, 1998). High levels of bitterness can be an indicator of toxicity, which is why many consumers dislike this characteristic (Drewnowski and Gomez-Carneros, 2000). Acquiring a liking of the bitter taste is common due to foods like lager, coffee, and spicy food (Clark, 1998). For this reason it cannot be assumed that every consumer will have the same opinion about acceptable levels of bitterness in pecans.

Sour. The sour attribute was significantly different (P≤0.05) across all 16 cultivars at three of the five time points (3, 9, and 12 months). 'Henning' had the highest sour intensity at 3 months and had one of the highest at 12 months (Table 4). 'Pawnee' had the lowest intensity at 3 months. 'Chetopa' had the highest intensity at 9 months and one of the highest at 12 months, while 'Colby' had

Table 4. Mean intensity scores and separation of sour taste for sixteen pecan cultivars at five time points*.

Cultivar	Storage (months)				
	0	3	6	9	12
Chetopa	1.86^{c}	2.06^{bcABC}	1.89^{bc}	2.21^{abA}	2.50^{aA}
Chickasaw	1.75	1.83^{BCD}	1.92	2.00^{ABC}	2.06^{E}
Colby	1.89	1.75^{CD}	1.75	1.71^{D}	2.14^{DE}
Dooley	1.78	1.81^{BCD}	1.83	1.88^{CD}	2.15^{DE}
Giles	1.75^{b}	1.92^{bABCD}	1.94^{b}	2.00^{bABC}	2.42^{aABC}
Henning	1.67^{c}	2.22^{abA}	2.00^{b}	2.14^{bAB}	2.47^{aA}
Hirschi	1.67^{c}	1.86^{bcBCD}	1.89^{bc}	2.06^{abABC}	2.28^{aABCDE}
Kanza	1.75	1.81^{BCD}	1.81	1.94^{BC}	2.19^{CDE}
Lakota	1.78^{b}	1.69^{bD}	2.03^{ab}	1.85^{bCD}	2.28^{aABCDE}
Major	1.50^{c}	1.83^{bcBCD}	1.97^{ab}	1.91^{abCD}	2.22^{aBCDE}
Maramec	1.58^{b}	2.11^{aAB}	2.14^{a}	2.06^{aABC}	2.33^{aABCD}
Oswego	1.81^{b}	1.92^{bABCD}	1.94^{b}	1.94^{bBC}	2.47^{aA}
Pawnee	1.69^{b}	1.67^{bD}	1.72^{b}	1.97^{bBC}	2.39^{aABC}
Peruque	1.61^{c}	1.78^{bcCD}	1.83^{bc}	2.06^{bABC}	2.44^{aAB}
Stuart	1.67^{b}	1.92^{bABCD}	2.03^{b}	2.00^{bABC}	2.44^{aAB}
Witte	1.83	1.97^{ABCD}	1.75	1.91^{CD}	2.14^{DE}

* Means with different superscripts in lower case within a row (time points) are significantly different (P<0.05) according to Fisher's protected least significant difference (LSD) test; means with different superscripts in upper case within a column (cultivars) are significantly different (P<0.05) according to Fisher's protected least significant difference (LSD) test.

the lowest intensity at 9 months. In addition to 'Henning' and 'Chetopa', 'Oswego' had a high intensity at 12 months that was not significantly different (P≤0.05) from the other two. 'Chickasaw' had the lowest intensity in sourness after a year.

The sour attribute had the second highest intensity for all cultivars for the first 3 months of testing. At 12 months, the intensity of the sour attribute had increased for every cultivar. 'Colby', 'Witte', 'Dooley', and 'Kanza' did not have a significant (P≤0.05) change in sour intensity throughout the study. 'Giles', 'Oswego', 'Pawnee', and 'Stuart' all had a significant (P≤0.05) increase in sour intensity after 12 months had passed. 'Hirschi', 'Peruque', 'Lakota', and 'Chetopa' had significant (P≤0.05) increases in intensity after 9 months. 'Major' had a significant (P≤0.05) increase in sour intensity after 6 months and 'Maramec' and 'Henning' had a significant (P≤0.05) increase after just 3 months had passed. Grosso and Resurreccion (2002) studied how bitterness changed in peanuts, and also evaluated the sour taste. They found that the sour attribute increased as time increased, which was confirmed in the current study. The perception of sour is related to bitter in that it has an instinctive negative perception by consumers (Clark, 1998).

Sweet. The sweet attribute had a low intensity even at the first time point (scores ranged from 0.75 to 1.03 on a scale of 0 to 15). Sweetness was significantly different (P≤0.05) across all cultivars at 9 months and 12 months (Table 5). 'Major' had the highest intensity of sweetness at 12 months and one of the highest intensities at 9 months. Seven cultivars were not significantly different (P≤0.05) from 'Major' at 9 months. 'Chetopa' had the lowest intensity of sweetness at 12 months and one of the lowest intensities at 9 months. Seven cultivars were not significantly different (P≤0.05) from 'Chetopa' at 9 months.

The sweetness scores remained fairly constant for the first 6 months of testing. Six cultivars ('Kanza', 'Chickasaw', 'Ma-

Table 5. Mean intensity scores and separation of sweet taste for sixteen pecan cultivars at five time points*.

	Storage (months)				
Cultivar	0	3	6	9	12
Chetopa	1.00^{a}	0.81^{a}	0.86^{a}	0.38^{bD}	0.33^{bF}
Chickasaw	0.83	0.94	1.06	0.74^{A}	0.85^{AB}
Colby	0.81	0.89	0.92	0.65^{ABC}	0.78^{ABC}
Dooley	1.03	0.89	0.94	0.68^{AB}	0.78^{ABC}
Giles	0.78^{a}	0.86^{a}	0.97^{a}	0.38^{bD}	0.69^{abABCD}
Henning	0.75^{a}	0.78^{a}	0.78^{a}	0.28^{bD}	0.39^{bEF}
Hirschi	0.83^{a}	0.86^{a}	0.78^{a}	0.35^{bD}	0.64^{abBCDE}
Kanza	0.92	0.92	0.89	0.81^{A}	0.89^{AB}
Lakota	0.78^{ab}	1.08^{a}	0.89^{ab}	0.74^{bA}	0.83^{abABC}
Major	0.94	0.94	0.94	0.85^{A}	0.97^{A}
Maramec	0.86^{a}	0.69^{ab}	0.69^{ab}	0.21^{cD}	0.56^{bCDEF}
Oswego	0.89^{a}	0.89^{a}	0.86^{a}	0.42^{bCD}	0.67^{abBCDE}
Pawnee	1.00^{a}	1.03^{a}	0.94^{a}	0.76^{abA}	0.56^{bCDEF}
Peruque	0.83^{a}	0.89^{a}	0.92^{a}	0.44^{bBCD}	0.39^{bEF}
Stuart	0.89^{a}	0.97^{a}	0.86^{a}	0.44^{bBCD}	0.42^{bDEF}
Witte	0.86	0.75	0.94	0.65^{ABC}	0.83^{ABC}

* Means with different superscripts in lower case within a row (time points) are significantly different (P<0.05) according to Fisher's protected least significant difference (LSD) test; means with different superscripts in upper case within a column (cultivars) are significantly different (P<0.05) according to Fisher's protected least significant difference (LSD) test.

jor', 'Colby', 'Witte', and 'Dooley') did not have any significant (P≤0.05) differences in intensity scores throughout the 12 months. The scores started to decrease at the 9-month mark, with eight cultivars showing significant (P≤0.05) decreases at this time ('Giles', 'Hirschi', 'Maramec', 'Oswego', 'Chetopa', 'Stuart', 'Peruque', and 'Henning'). The intensity continued to decrease at 12 months. 'Pawnee' had a significant (P≤0.05) decrease at the final time point. Grosso and Resurreccion (2002) also identified that the intensity of sweetness decreased in samples of peanuts, as time increases. The acceptability of the sweet taste is an instinctual reaction that is even found in infants. When babies were exposed to the sweet taste it elicited a positive facial expression in a study conducted by Steiner (1977). This positive perception of sweetness continues through adulthood for a myriad of consumers (Clark, 1998). This indicates that as the sweetness decreases over time, the cultivars may be less desirable to consumers.

The pecan cultivars used in this study were grown in the northern region of the United States. The use of a wider selection of pecans from other regions could potentially lead to other findings for how flavor changes during storage. The growing season could also have an effect on this understanding. The samples used for this study were from the 2013 growing season, so any impact that seasonal variation has on attribute intensities cannot be shown. One type of storage condition was used for this study. Other conditions and packaging may produce different results. Though the oxidation process is slowed when pecans are refrigerated and frozen, this is not common knowledge for consumers or not how pecans are sold commercially (Erickson et al., 1994). When modified atmosphere packaging was compared with ambient conditions for pistachios, oxidation was more rapid for the nuts stored at ambient conditions (Maskan and Karatas, 1999).

Future research could focus on comparing these different methods, which may have

an impact on flavor intensity. Other areas of potential research could focus on consumer acceptance. Consumers could evaluate the pecan cultivars at different time points to determine the acceptable level of these flavors. This could help determine the appropriate shelf-life for these pecan cultivars. Other sensory aspects such as texture, aroma, and appearance could also be evaluated for the pecans as those attributes change over a period of time. The information from this study plus future studies can aid consumers and pecan product manufacturers in selecting cultivars for different applications and to help encourage pecan storage to move to a freezer instead of a shelf.

Conclusions

The interaction effect between cultivar and time point was significantly different for the rancid, bitter, and sweet attributes. The intensity of rancidity increased over time for all 16 cultivars. Bitterness had the highest intensity for every cultivar at every time point and sweetness had the lowest. 'Witte', 'Dooley', 'Colby', 'Kanza', and 'Chickasaw' did not have any significant changes in the four flavor attributes that were evaluated. Future research should focus on consumer acceptance evaluation for these cultivars at every time point. This could help determine what the acceptable levels of rancidity, bitterness, sourness, and sweetness are which can affirm the shelf life of these cultivars. This information can be used by pecan product manufacturers to determine which cultivars are higher in quality and can resist oxidation longer. Pecan farmers can also use this information to determine which cultivars should be grown for commercial sale.

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