DESCRIPTIVE ANALYSIS OF PECAN CULTIVARS, A COMPARISON OF RAW AND ROASTED PECANS, AND HOW PECAN FLAVOR CHANGES OVER TIME

by

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Abstract

Pecan [*Carya illinoinensis(Wangenh.)* K. Koch] is a native North American nut tree that has progressed into a significant agricultural crop. Flavor characteristics were evaluated for sixteen pecan cultivars: ‘Giles’, ‘Hirschi’, ‘Maramec’, ‘Oswego’, ‘Lakota’, ‘Chetopa’, ‘Colby’, ‘Witte’, ‘Dooley’, ‘Kanza’, ‘Pawnee’, ‘Stuart’, ‘Chickasaw’, ‘Peruque’, ‘Major’, and ‘Henning’ using descriptive sensory analysis. A trained panel consisting of six panelists first developed a vocabulary for the raw pecans and scored the intensities of the samples for 20 flavor attributes. Results showed that the sixteen samples differed significantly ($P \leq 0.05$) on 10 of the attributes. ‘Giles’, ‘Lakota’, and ‘Pawnee’ differed from the other 13 cultivars for the majority of the attributes. The remaining thirteen cultivars showed few differences in individual attribute ratings, but did show differences when mapped using multivariate techniques indicating as many as two clusters of pecan cultivars based on flavor. The same sixteen cultivars were then roasted and evaluated using descriptive sensory analysis by the same trained panel using the same 20 flavor attributes. Three texture attributes were also evaluated. These results were compared to the results from the raw pecans. Results showed that 4 attributes differed significantly across all cultivars when raw and roasted flavor was compared. Ten of the flavor attributes had higher intensities for the roasted pecans than for the raw pecans. Most of these attributes fell within the categories of ‘nutty’ and ‘sweet’. When pecans were roasted many flavor attributes were intensified, as compared to when they were raw. How the flavor of the sixteen cultivars changed over a 12 month period was then evaluated. Raw pecans were evaluated when fresh, at 3 months, 6 months, 9 months, and 12 months by descriptive sensory analysis. A trained six member panel evaluated four flavor attributes at all five time points. Results showed that bitter had the highest intensity scores for all 16 cultivars at all 5 time points. Rancidity increased over time and

sweetness decreased over time for all attributes. The results from these studies can be used as a baseline for future pecan research.

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Pecan Production

Pecan [*Carya illinoinensis* (Wangenh.) K. Koch] is a temperate zone nut tree crop that thrives in a warm continental climate (Reid 2012) and for this reason, the majority of pecans are produced in the southern portion of the United States (Reid *et al.* 2000). On the northern edge of the pecan tree's native range, trees in this zone have adapted to colder winter weather and a shorter growing season (Reid *et al.* 2000).

Native Range of Pecans

Pecan is a major component of riparian hardwood forests found growing along major river systems in south central United States and northern Mexico (Rutler *et al.* 1999). Commercial production in the United States can be categorized into four different regions: southwestern, south central, northern, and southeastern (Wood 2001). South central is the smallest region including Oklahoma and Texas. The southwestern region includes California, Nevada, Utah, Arizona, and New Mexico. The southeastern region includes Louisiana, Arkansas, Mississippi, Alabama, Georgia, Florida, North and South Carolina, and Virginia. Tennessee, Kentucky, Indiana, Illinois, Iowa, Missouri, Nebraska, and Kansas make up the northern region (Wood 2001). The northern region has the largest amount of genetic diversity within the native population of pecan trees (Ruter *et al.* 1999).

The majority of northern pecans are produced in the floodplains of Midwestern rivers. In Kansas that includes Neosho, Verdigris, Walnut, Caney, Osage, and Marais des Cygnes rivers (Kadir *et al.* 2001). More than 95% of pecans produced in the northern region are harvested from natural stands (Reid *et al.* 1991). Deep alluvial soils are necessary for ideal pecan tree growth (Kadir *et al.* 2001). Most soils in the northern region vary from clay loams to loam soils. Good internal drainage is necessary to produce as large quantities of high quality pecans (Kadir *et al.*

2001). Twenty-eight inches or more of rainfall per year is required for pecan trees to thrive (Kadir *et al.* 2001).

Pecan Grove Maintenance

The creation of a native pecan grove is a five-step process (Reid *et al.*1985). The first step is thinning the trees. When trees are properly spaced adequate light is able to reach the trees which enhance fruit formation (Hinrichs 1958). Having appropriate space between trees promotes air circulation reducing the conditions that favor the spread of pecan pathogens. When selecting trees for thinning, trees that are a susceptible to systemic pests, prone to severe alternate bearing, or produce very small nuts should be removed. This process enhances stimulates the growth of remaining trees, increases nuts nut production and improves nuts quality (Reid *et al.* 2000). The second step in native grove establishment is to improve the surface drainage within the tree stand. Although pecan trees are resistant to flooding, pools of standing water can led to soil denitrification and the development of non-infectious leaf scorch (Reid 1999). By ensuring all surface water drains freely from the grove, these issues can be resolved. Fertilizing is the third step of the process. Annual applications of nitrogen fertilizers are necessary to stimulate nut production. In Southern states, where pecan are produced on sandy or high pH soils zinc deficiency can present a problem (Sparks 1976), However, in northern states zinc deficiency is extremely rare (Reid *et al.* 2000). The fourth step is related to controlling key pests that can limit pecan production. Many technologies developed for pest control in southern states can be adapted for use in northern states (Reid 2000). Primary nut feeding pests include pecan nut casebearer [*Acrobasis nuxvorella* Neunzig] and pecan weevil [*Curculio caryae* (Horn)]. Pecan scab [*Cladosporium caryigenum* (Ell. et Land.) Gottwald] is the most serious disease affecting pecan fruit. In Kansas, only three to four pesticide applications per year are neede to control all major pests (Reid *et al.* 1991). The fifth and final step is managing the groundcover. Soil erosion is prevented by planting grasses and forbs (Reid *et al.* 2000). It is common for livestock, such as beef cattle to graze in these areas (Reid *et al.* 2000). The livestock is removed before harvest season and the groundcover is mowed. Sticks, manure, and debris are raked from the orchard floor before harvest. This aids in the use of mechanical nut harvesting equipment which is designed to pick up nuts on a groundcover that is neat and well maintained (Reid *et al.* 2000).

Pecan Pests and Diseases

Pecan trees are attacked by several pests and diseases. Two of the most serious insect pests are the pecan nut casebearer and the pecan weevil (Reid *et al.* 2000). The pecan nut casebearer (*Acrobasis nuxvorella*) has three generations per year in Kansas, although only the first summer generation causes economic damage. Larvae of the first summer generation bore into the base of young nuts and feed on nut's interior. One larvae has the potential to destroy 2 to 3 nuts during its life cycle. The pecan weevil (*Curculio caryae*) is a nut feeding insect that resides in the soil near pecan trees. Adults emerge from the soil in late July through August and females lay eggs within developing fruit. When the eggs hatch, the larvae feed on the kernel until it is completely destroyed. There are several other minor insect pests that can be a hindrance to pecan trees. Nut feeding pests include hickory shuckworm (*Cydia caryana*) and a complex of kernel feeding hemipterans (including brown stink bug [*Euschistus servus* (Say)], southern green stink bug [*Nezara viridula* (Linnaeus)], leaf footed bug [*Leptoglossus phyllopus* (Linnaeus)]. Foliage feeding insects include walnut caterpillar (*Datana integerrima*), fall webworm (*Hyphantria cunea*), and two species of sawfly (*Periclista marginicollis and Megaxyela major*) (Kadir *et al.* 2001).

Pecan scab, caused by the fungus *Cladosporium caryigenum,* is the most serious disease of pecan. Infections that grow to cover the entire pecan shuck will inhibit kernel fill and prevent normal shuck dehiscence. (Kadir *et al.* 2001). Scab is more likely to occur during growing seasons with frequent rainfall and high humidity. Losses from pecan scab can be prevented by selecting resistant cultivars, or with the judicious use of fungicides. Proper tree spacing helps to reduce the spread of scab (Kadir *et al.* 2001). Downy spot and liver spot are two less important diseases of pecan trees. Downy spot, caused by the fungus *Mycosphaerella caryigena,* attacks pecan leaves, inhibiting photosynthesis and causing early defoliation. Liver spot, caused the fungus *Gnomonia carvae* occurs most frequently during wet summer weather. Severe infections can cause premature defoliation of the trees. (Kadir *et al.* 2001).

Harvesting Pecans

The length of harvest varies by region. Optimal harvest times for southern states such as Georgia range from October to December (Heaton *et al.* 1975). In the western region harvest starts in September and goes through November (Perry *et al.* 1998). Because of unpredictable weather that is usually colder, the northern region has a longer harvest time ranging from the first frost in September all through the winter months, sometimes even into March (Kadir *et al.* 2001). Early harvest of pecans right after the shucks open results in the highest quality nuts (Santerre 1994). Pecans are shaken from the trees during the early harvest season (Santerre 1994). This can be achieved either by hand or mechanically (Santerre 1994). The nuts either fall into catch frames or onto the ground, where they are quickly picked up. It is vital that they not remain on the ground for a long period of time where the warm soil promotes mold development (Santerre 1994). Nuts are harvested from the ground by machine. The machine harvested crop is then cleaned by a series of screens, conveyors, and blowers to separate the nuts from the other materials (Santerre 1994). Nuts then must undergo a drying process before they can be stored (Santerre 1994).

Pecan Processing

Steps for processing pecans include: harvesting, cleaning, size grading, storage and conditioning, cracking, and shelling. After shelling pecan kernels are then split into two groups: halves and pieces (Santerre 1994). The processing steps for pieces are size grading, drying, color sorting, water flotation, manual sorting, and packaging (Santerre 1994). The processing steps for halves consist of drying, color sorting, manual sorting, and packaging (Santerre 1994). The packages of pieces and halves are stored frozen until shipped to end users. (Santerre 1994).

Although pecans have a longer shelf life when stored in shell (Nelson *et al.* 1985), the majority of pecans are shelled before being sold (Powell 1975). In-shell pecans are graded by size before being put into cold storage (Santerre 1994). When nuts are removed from cold storage, several different treatments can be applied to in-shell pecans to condition the nuts to reduce kernel breakage during the shelling process (Santerre 1994).

Pecan Cultivars

A popular generalization of northern cultivars is that they produce small, hard shelled nuts that are slow to bear and low yielding (Sparks 1992). This generalization inaccurately portrays the diversity of northern cultivars. The majority of northern cultivars are selections from the wild. Over the year, trees that produce above average-sized nuts, are productive, and shell well have been propagated and named (Reid *et al.* 2000). Outstanding selections are commonly shared among growers who develop their own informal trials to assess the performance. Selections that perform well for multiple growers are widely propagated and then become known as a cultivar (Reid *et al.* 2000).

With this sharing culture, the choice of cultivars is ever increasing. Cultivars that are gaining popularity in southern Kansas are ‘Chetopa’, ‘Faith’, and ‘Jayhawk’ (Reid *et al.* 2000). ‘Chetopa’ and ‘Jayhawk’ consistently produce high quality, medium sized nuts (Reid *et al.* 2000). ‘Warren 346’ has the special quality of being able to ripen fruits by mid-September in a climate that only has 155 frost free days (Reid *et al.* 2000).

The size and shell thickness vary widely among northern cultivars. Though extremely large fruited pecan cultivars cannot mature in the north, there are several moderate sized cultivars that have potential to perform well in the marketplace (Reid *et al.* 2000). Shell thickness ranges from thick (‘Colby’ and ‘Norton’) to thin/paper (‘Lucas’ and ‘Peruque’).

Early fruit bearing is often associated more with southern pecan production. However, there are several cultivars common in northern states that have equal precocity (Smith et al 1993). These include ‘Colby’, ‘Giles’, ‘Hirschi’, and ‘Peruque’ (Reid *et al.* 2000).

Though the location can have an impact on cultivar preference, two cultivars have gained popularity throughout the northern region (Reid *et al.* 2000). The USDA pecan breeding program has released both ‘Pawnee’ and ‘Kanza’, which have been widely grafted (Reid *et al.* 2000). ‘Pawnee’ produces a large kernel, the largest possible that can reach full maturity in northern states (Reid *et al.* 2000). ‘Kanza’ is a medium sized nut that performs well in the categories of shelling and kernel characteristics, and also is cold hardy (Reid *et al.* 2000). For these reasons ‘Kanza’ is currently the number one cultivar choice in northern states, it is often chosen to plant over ‘Pawnee’ which is prone to cold injury during test winters (Reid *et al.* 2000). Other cultivars that are commonly grown in the northern region are ‘Peruque’, ‘Colby’, and ‘Posey’.

Nut Trends

Economic Trends of Pecans

The United States pecan crop totaled approximately 137.3 million kilograms in 2012 (Geisler *et al.* 2013). Though it was a 12% increase from the previous year, the price value decreased by 27%. This is due to the increased crop size (Perez *et al.* 2015, USDA 2015). The total production price for 2012 was $476.8 million (Geisler *et al.* 2013).

Georgia, New Mexico, and Texas were responsible for 75% of commercial pecan production in the United States. Eighty percent of pecan production in the world takes place in the United States (Geisler *et al.* 2013). Pecans are commonly exported and imported to and from the United States. Pecans produced in the United States are exported both in-shell and shelled. Most in-shell exportation goes to Asian countries. Hong Kong is the top destination, with sales hitting $165.4 million in 2012 (Geisler *et al.* 2013). The top destination for shelled pecans is Canada, with sales reaching $58.5 million. Though the United States is a top producer of pecans, shelled, in-shell, and pecan products are commonly imported from Mexico, with sales reaching $200.8 million in 2012 (Geisler *et al.* 2013).

Consumption Trends of Nuts

The majority of consumers in the United States know that pecans contain heart healthy fats and proteins (Lombardini *et al.* 2008). Even though this information is widely known, some consumers, primarily women, are still concerned about the high fat content of nuts (Mintel 2012). Many studies have disproved this perception (Vadivel *et al.* 2012, Bes-Rastrollo *et al.* 2007, 2009, and Sabaté 2003), but it still impacts nut consumption trends for some consumer groups (Mintel 2012).

Nuts are a food category that continues to increase in popularity. The category had an increase in sales of 36.1% between the years of 2007 and 2012. The category is projected to grow by another 27.7% from 2012 to 2017 (Mintel 2012). The segmentation of consumers is important to this product category. Nut consumption of households with children tends to be higher than households without children, but the amount of households with children has been on the decline (Mintel 2012). Diversity of multicultural groups continues to increase, which is promising for the nut market. The Hispanic population is projected to increase by 15.8% between 2011 and 2016, the Asian population by 14.4% (Mintel 2012). Both of these groups have higher rates of nut consumption than other cultural groups.

The type of nut also has an impact on consumption. Peanuts, almonds, and cashews have a high monthly household usage, but there is opportunity to introduce other nut types into the consumer diet (Mintel 2012).

Health Benefits of Nuts

All Nuts

Though eating nuts and weight gain were once believed to be linked, several studies have found that increased consumption of nuts does not lead to weight gain and can even lead to weight loss in some individuals (Vadivel *et al.* 2012; Bes-Rastrollo *et al.* 2007, 2009; and Sabaté 2003). One major benefit of incorporating nuts into one's diet would be their impact on decreasing risk factors for coronary heart disease (Hu *et al.* 1998, 1999; Fraser 1999). Studies have shown that eating nuts on a regular basis can decrease the risk for coronary heart disease by 30-50% (Hu *et al.* 1998, 1999 and Fraser 1999). Though most nut health related research has been done on heart disease, there are other components of nuts that are beneficial.

The unique macronutrient and micronutrient profiles of nuts may aid in controlling blood glucose levels (Kendall *et al.* 2010). Though little research has been done in this area, acute feeding studies have been conducted to determine if nuts impact blood glucose. Future studies may be able to prove that inclusion of nuts in a diet may prevent diabetes and micro and macro vascular complications associated with it (Kendall *et al.* 2010).

The composition of nuts provides sources of vitamins, minerals, and phytochemicals that are beneficial to one's health. Nuts provide vitamin E and magnesium. They also aid in the absorption of folate, beta-carotene, vitamin K, lutein and zeaxanthin, phosphorus, copper, selenium, potassium, and zinc. Nuts also contain several phytochemicals including: phyosterols, phenolic acids, flavonoids, stilbenes (a type of phenol), and carotenoids (King *et al.* 2008). Boron is also found in nuts. Boron is bioactive and research reports that it may decrease risk for arthritis, improve bone growth and maintenance, improve central nervous system function, reduce risk of cancer, improve hormone facilitation and immune responses, decrease inflammation and oxidative stress modulation. Nuts are a food category high in boron, other boron rich diets included fruits, vegetables, and pulses (Nielson *et al.* 2001). Nuts are also high in antioxidants. In particular, walnuts, pecans, and chestnuts have the highest contents of antioxidants. Having a diet high in antioxidants can decrease risks for chronic degenerative diseases (Blomhoff *et al.* 2006).

Pecans

Though health benefits of nuts as a whole also apply to pecans, some studies have focused specifically on the nutritional benefits of increasing pecan consumption. Pecans are rich in monounsaturated fatty acids. They can help improve blood lipid levels, lowering cholesterol levels (Rajaram *et al.* 2001). One study was conducted where two diets were assessed. One group was given a pecan rich diet, the other was a control group that did not consume nuts (Morgan *et al.* 2000). Results found that low density lipoprotein cholesterol (LDL-C), high density lipoprotein cholesterol (HDL-C) and total cholesterol levels were all significantly lower in the group who ate the pecan treatment. Findings also showed that the pecan group had significantly higher levels of dietary fiber, monounsaturated fat, polyunsaturated fat, insoluble fiber, magnesium, and energy (Morgan *et al.* 2000).

Impact of Roasting

Studies that assess roasting effects have been conducted on a variety of nuts including cashews, hazelnuts, pistachios, pecans, and peanuts (Chandrasekara *et al.* 2011, Saklar *et al.* 1999, Nikzaedh *et al.* 2008, Özdemir *et al.* 1999, Buckholz Jr. *et al.* 1980, Escher *et al.* 1973, Alasalvar *et al.* 2003, and Erickson *et al.* 1994). Nuts are heat treated for different reasons. Heat treatments can reduce decontamination in nuts. During the roasting process *Aspergillus flavus* and *Aspergillus parasiticus* spores were destroyed on pecan halves (Escher *et al.* 1973). Phenolic content and antioxidant activities are also impacted. During roasting of cashew nuts, the Maillard reaction occurs which forms by products, intermediates, and melanoidins (brown pigments). This change impacts the total phenolic content, flavor, antioxidant activity, and color (Chandrasekara *et al.* 2011). The most popular reason for roasting is how it changes the sensory characteristics of nuts.

Texture of roasted nuts has been the attribute most commonly assessed. The drying process which occurs during roasting causes textural changes to the roasted nuts (Özdemir *et al.* 1999). Several studies assessed changes of texture in nuts both through sensory and instrumental means (Saklar *et al.* 1999, Nikzadeh *et al.* 2008). Saklar *et al.* (1999) evaluated the crispness and crunchiness of roasted hazelnuts when the air temperature, air velocity, and roasting time were altered. Eleven panelists were trained for three months in Quantitative Descriptive Analysis. Descriptive terms, references, and scores were determined via consensus during this training period. Raw hazelnuts were scored as “zero” for both crispness and crunchiness. A 15 cm line was used for scoring with anchors at 1.25cm from both ends for “slight” and “very strong”. A score from 0 to 15 was assigned to each panelist’s evaluation by measuring the mark from the references. Crispness was evaluated when the hazelnut was placed between the incisors and bitten through. Crunchiness has also been evaluated when the hazelnut was placed between the molars and chewed with the molar teeth. Another study defined crunchiness as the degree of low pitched noise with respect to crisp noise (Seymour *et al.* 1988).

Nikzadeh and Sedaghat (2008) determined how roasting temperature and storage time affected the moisture, texture, and sensory attributes of pistachio nuts. Moisture and texture properties of ‘hardness’, ‘fracture force’, and ‘firmness’ were evaluated over a 3-month storage period both instrumentally and by sensory evaluation. Results found that as storage time increased the moisture content increased, but the texture properties all decreased. This was caused by increasing the roasting temperature. The sensory measurements were in correlation with the texture measurements.

Buckholz Jr. *et al.* (1980) assessed two varieties of roasted peanuts at 163°C for three different time periods (7, 8, 9 minutes). A trained panel used a 9-point hedonic scale to rate the strength and desirability of the odor and flavor of the peanuts. The peanut samples were presented in capped jars that were warmed to 43.3C before evaluation. The samples were served in randomized order, with random numbers assigned to each sample. Triangle tests were performed before the panelist’s evaluated the products. If the panelist incorrectly chose which was the odd sample, his hedonic rating was eliminated for that session. The 9-point scale had anchors for strength at 1(weakest), 5(moderate), and 9(strongest). For desirability the anchors were 1(least liked), 5(neutral), and 9(most liked). Results showed that panelists could agree on the strength of aroma and flavor for the different peanut samples, but not on the desirability. This was not a surprising finding as consumers, even trained consumers, differ in their preferences for different flavor combinations. It was found that the amount of time for roasting significantly influenced the strength of the odor and flavor of the roasted peanuts.

How flavor attributes change when hazelnuts are roasted was studied by Alasalvar *et al.* 2003. Sixteen flavor attributes were assessed by a trained descriptive panel on an 80 mm line scale. The anchors were 0 = none and 80 = very. The panelists participated in 3 orientation sessions prior to evaluation. The samples were coded with a three digit code. Total of 10 g of each sample was served in a randomized order, with two replicates. Significant differences were found for the burnt, coffee/chocolate-like, and roasty attributes. These were significantly higher in the roasted hazelnut samples. Rancid and painty attributes were not detected due to the freshness of the hazelnut samples.

Sensory Evaluation

Other Nuts

A variety of sensory testing methods have been used on different nuts in the past to describe flavor, aroma, appearance, and texture attributes. Nut varieties evaluated have included almonds, walnuts, hazelnuts, pistachios, and peanuts (Alasalvar *et al.* 2003; Buckholz Jr. *et al.* 1980; Ingels *et al.* 1990; Miller *et al.* 2013a; Nikzadeh *et al.* 2008; Saklar *et al.* 1999; Tsantili *et al.* 2010; Warmund *et al.* 2009a, 2009b). The evaluations conducted ranged from established descriptive methods to informal testing with untrained panelists. A plant variety occurs naturally and is true to type, a cultivar is derived from a variety, but selected and cultivated by humans (Haynes 2008).

The purpose of the majority of these studies was to evaluate differences between nut cultivars. Tsantili *et al.* (2010) studied 8 different pistachio nut cultivars. An 8 person panel with minimum training was used to individually evaluate the samples. There were two categories evaluated, the nut as a whole and the nut kernel. The attributes related to the whole nut were the size, shape, shell color, and overall visual acceptance (OVA). The attributes related to the kernel were size, shape, color, OVA, and overall flavor (OF). The attributes were evaluated on a five point scale (1: unacceptable, 2: poor, 3: fair, 4: good, 5: excellent). Results indicated that the panelists preferred pistachio nuts that were larger in size and had a yellow tint in color. ‘Kerman’ had the highest scores, but it was not significantly higher than ‘Mumtaz’. Ng *et al.* (2009) looked at characteristics of different peanut cultivars. A trained descriptive panel evaluated flavor and aroma attributes for dry roasted peanuts. The Spectrum® method (Meilgaard *et al.* 1987) was used to evaluate 18 attributes. These included roast peanutty, sweet aromatic, dark roast, raw beany, earthy, and painty. Only small differences were found for the cultivars studied. Warmund *et al.* (2009a) used descriptive analysis to assess differences in black walnut cultivars based on the kernel color. Dark, medium, and light kernels were assessed for three different cultivars and one wild variety of black walnuts. Six highly trained descriptive panelists evaluated the walnuts on a 0-15 point intensity scale with 0.5 increments. Eighteen flavor attributes were used to assess the walnuts. Results showed that kernel color did have an impact the intensities of attributes. Dark kernels had higher intensities of musty/dusty, burnt, woody, oily, astringent, and sour flavors. Cultivars with darker kernels used for this study were ‘Emma K’ and ‘Sparks 127’. Differences in Persian walnut cultivar flavor were studied by Ingels *et al.* (1990). Instead of using a descriptive method, they opted to conduct a discrimination test. The duo-trio method was used to detect differences in 8 walnut cultivars. There were 21 judges selected for the study. One cultivar (Hartley) was compared to the other 7 cultivars, with four replications. The judges were given two samples plus the reference cultivar and asked to select which sample was different from the reference. These pair tests were also conducted for specific attributes including firmness, astringency, sweetness, and overall walnut flavor. For this second round of testing with specific attributes 11 judges were used. Results showed that significant differences were found for four of the cultivars ('Chico', 'Sunland', 'Howard', and 'Chandler') when compared to Hartley. Guerrero *et al.* (2000) used trained and untrained panelists to evaluate the differences that existed in walnut varieties. The walnuts were from different growing regions and different drying temperatures. Both trained and untrained panelists were asked to brainstorm descriptors that could be used to characterize the walnuts based on a questionnaire. Untrained panelists were important to give a consumer perspective and provide words that would be commonly used by consumers. A trained panel was then used to classify the walnut samples into groups based on the descriptors. Some of the descriptors used were: sweetness, skin color, kernel veins, color uniformity, roughness, brightness, astringency, sourness of skin, and flour flavor.

Some studies had objectives other than evaluating differences in nut cultivars. Isleib *et al.* (2006) wanted to describe sensory difference between two types of peanuts that had a known difference in composition. The comparison was between normal peanuts and high-oleic acid peanuts. The reasoning for conducting this research was that high oleic acid content has the capability of improving oxidative stability in nuts. How the flavor differed, especially off flavors, was studied in comparison to normal peanuts. Flavor databases were compared and used to describe flavor and off flavor in peanuts. The high-oleic peanuts were higher in the intensities of roasted peanut, over-roast, astringent and nutty. The off flavors assessed included: fruity, painty, stale, moldy, and petroleum. No significant differences were found in the off flavor of the two different types of peanuts. It was concluded that a high-oleic acid content did not impact the overall sensory characteristics of peanuts.

Some studies have aimed at not only determining differences, but also similarities. This was true of the study conducted by Warmund *et al.* (2009b) whose objective was to define the relationship between Persian and black walnuts based on aroma, flavor, and texture attributes. Descriptive analysis with 8 highly trained panelists was used. The Spectrum® method (Sensory Spectrum, Chatham, NJ, USA) was used. Panelists evaluated 1 aroma, 11 flavor, and 10 texture attributes for the Persian and black walnuts on a 15 point intensity scale. Results showed that all but 20 of the 22 attributes were appropriate to describe both black walnuts and Persian walnuts. Black walnuts had higher intensities of fruity and musty flavors. Persian had higher intensity ratings of nutty, woody, and astringent flavors. The conclusion drawn was that both the black and Persian walnuts had shared attributes that can be considered characteristic of walnuts as a whole, but both have unique attributes that differentiate them.

Walnuts have also been used to assess if different trained panels can produce similar results. Sinesio *et al.* (2001) searched for key attributes that could describe the sensory quality of walnuts. Three trained panels in three different locations (France, Spain, and Italy) were used. All three panels were similar in training background, experience, and composition. Each panel consisted of 8 panelists. They started by creating a lexicon via consensus. The French panel created a lexicon with 26 descriptors. The Italian and Spanish panels both had 18 descriptors. All three used continuous line scales to assess the intensity of these attributes. The Spanish panel's scale spanned from 0 to 10, 0 to 9 for the Italian scale, and 1 to 10 for the French scale. Though the three panels created different lexicons with varying terms, they all had a similar separation of the samples. The importance of certain attributes varied depending on the country.

Other lexicons have also been created to gain a better understanding of flavor attributes that encompass different nuts. Lexicons have been developed for nuts including almonds, black walnuts, and peanuts (Civille *et al.* 2010; Johnsen *et al.* 1988; Miller *et al.* 2013a). A lexicon to describe the appearance, aroma, flavor, and texture of almonds was developed by Civille *et al.* (2010). A trained 9 member panel assessed 20 almond samples using the Spectrum™ descriptive method (Meilgaard *et al.* 1987). The panel first discussed appropriate attributes and created a lexicon that also listed the order of which attributes should be listed on a ballot. The scale used was from 0 to 15, which is sensitive to tenths with 150 points of discrimination possible. After the lexicon was created variability was assessed. Raw almonds were assessed and cultivars were compared. Although significant differences were not determined among cultivars, the authors found that the lexicon could appropriately discriminate for appearance, aroma, flavor, and texture attributes for almonds. Johnsen *et al.* (1988) developed a lexicon for describing peanut flavor. This study created a 13 member panel of industry professionals. The panelists evaluated 18 samples with different roasts. The purpose was to compile terms to describe the aromatics, basic tastes, and feeling factors that are present in peanuts. The intensity of the attributes was rated on a ten-point scale. Off flavors were also assessed. After the lexicon was created, it was also validated. The lexicon was determined to be valid, but the data obtained was not used to characterize flavor differences of the samples used. Though these studies have characterized flavors of specific nuts, the “nutty” characteristic itself had not been defined until Miller *et al.* (2013b).

The purpose of the study conducted by Miller *et al.* (2013b) was to characterize the nutty attribute not only to be used to describe nuts, but also many other food items. Two trained panels were used to describe nuttiness. The first developed the terms; the second validated the terms created by evaluating different products that possessed nutty characteristics. Over 200 products were used to understand the different facets of the nutty attribute. The end result was the creation of five nutty attributes. Four of these attributes were subsets of the fifth (overall nutty). The other four attributes were: nutty-grain-like, nutty-beany, nutty-woody, and nutty-buttery. This study was used as a base line to create a lexicon of black walnut cultivars (Miller *et al.* 2013b).

Miller *et al.* (2013a) used descriptive sensory analysis to create a lexicon for black walnuts. Seven trained panelists assessed 7 black walnut cultivars and developed a lexicon containing 22 flavor attributes. This study was two-fold, first the lexicon for black walnuts was created and then the seven black walnut cultivars were assessed to describe differences between them by using the lexicon. The 7 cultivars were significantly different for 13 of the 22 flavor attributes. For most of the attributes, only Emma K was different from the others. The methodology and lexicon from this study aided in the creation of the design of the current study about pecans. Table 1-1 is a compilation of attributes and definitions that have been used to describe nuts in previous research.

Table 1-1. Sensory attributes and definitions from selected literature

Attribute	Definition	Nut Type	Source
Acrid	Sharp/acrid, charred flavor associated with a food over baked or excessively browned in oil.	Black walnut	Warmund *et al.* (2009a) Lee *et al.* (2011) Miller *et al.* (2013)
Almond nut meat	Aromatics associated with the meat of almonds.	Almond	Civille *et al.* (2010)
Aftertaste	Remaining desirable and delicate flavor/taste after swallowing	Hazelnut	Alasalvar *et al.* (2003)
Astringent	Feeling of puckering or tingling sensation on the surface and/or edge of the tongue and mouth.	Black walnut	Miller *et al.* (2013)
Astringency	N/A	English walnut	Ingels *et al*. (1990) Sinesio and Moneta (1997)
Bitter	Taste associated with caffeine	Hazelnut	Alasalvar *et al.* (2003)
Bitter	Fundamental taste factor of which caffeine is typical.	Black walnut	Miller *et al.* (2013)
Bitter	Fundamental taste described as harsh. Taste is simulated by	English and black walnut	Warmund *et al.* (2009a) Warmund *et al*. (2009b)

	solutions of caffeine or quinine.		Lee *et al.* (2011)
Bitter taste	N/A	English walnut	Guerrero *et al*. (2000) Sinesio *et al*. (2001)
Bitterness	N/A	English walnut	Sinesio and Moneta (1997)
Black walnut	Intensity of sweet, musty/earthy, oily, brown, buttery, woody, piney, astringent, bitter, and slightly acrid flavors.	Black walnut	Warmund *et al.* (2009a) Lee *et al.* (2011)
Black Walnut ID	An overarching attribute. Aromatics associated with black walnuts including musty/earthy, piney, woody, brown, sweet, buttery, oily, astringent, and slightly acrid aromatics; other aromatics may include musty/dusty, floral/fruity, and/or fruity dark.	Black walnut	Miller *et al.* (2013)
Brown	Rich, full aromatic with a degree of darkness generally associated with canned pinto beans.	Black walnut	Warmund *et al.* (2009a) Lee *et al.* (2011) Miller *et al.* (2013)

Brown fruit	Aromatics associated with the general category of brown fruit, such as raisins, prunes, and figs.	Almond	Civille *et al.* (2010)
Burnt	Smell of grilled meat, burnt smell	Hazelnut	Alasalvar *et al.* (2003)
Burnt	Dark, brown, somewhat sharp, overbaked grain aromatic.	Black walnut	Miller *et al.* (2013)
Buttery	Aromatics commonly associated with natural, fresh, slightly salted butter.	Black walnut	Warmund *et al.* (2009a) Lee *et al.* (2011)
Caramelized	Round, full-bodied, medium brown aromatic	Black walnut	Miller *et al.* (2013)
Caramel-like	Flavor or caramel or butter	Hazelnut	Alasalvar *et al.* (2003)
Coconut/lactone	Aromatics associated with shredded or dried coconut and coconut milk, including lactones.	Almond	Civille *et al.* (2010)
Coffee/Chocolate-like	Flavor of coffee, chocolate	Hazelnut	Alasalvar *et al.* (2003)
Cooked (almond)	Aromatics associated with nuts, beans, or legumes that have been gently heated or boiled.	Almond	Civille *et al.* (2010)
Dark roast	N/A	Peanut	Isleib *et al.* (2006)
Dark roast (almond)	Aroma compounds associated with cocoa beans and/or nuts that are dark-roasted but not burnt.	Almond	Civille *et al.* (2010)

Dark roasted peanut	The aromatic associated with dark-roasted peanuts (4+ on USDA color chips) and having very browned or toasted character.	Peanut	Johnsen *et al.* (1988) Ng and Dunford (2009)
Firmness	N/A	English walnut	Ingels *et al*. (1990)
Fishy	The aromatic associated with trimethylamine, cod liver oil, or old fish.	Peanut	Johnsen *et al.* (1988) Ng and Dunford (2009)
Flavor intensity	N/A	English walnut	Sinesio and Moneta (1997) Guerrero *et al*. (2000) Sinesio *et al*. (2001)
Floral flavor	N/A	English walnut	Sinesio and Moneta (1997)
Floral/Fruity	Sweet, light, aromatics impression associated with flowers and fruits.	Black walnut	Miller *et al.* (2013)
Flour flavor	N/A	English walnut	Guerrero *et al*. (2000) Sinesio *et al*. (2001)
Fruity	Delicate, desirable, fruity flavor associated with most fruits	Hazelnut	Alasalvar *et al.* (2003)
Fruity	Aromatic of fermented fruit or non-citrus fruits.	English and black walnut	Warmund *et al.* (2009b)
Fruity-dark	Sweet, brown, honey/caramel-like aromatics commonly associated with dark fruits such	Black walnut	Miller *et al.* (2013)

	as raisins and prunes that have been cooked.		
Green/grassy	Odor of cut leaves of green plants	Hazelnut	Alasalvar *et al.* (2003)
Musty	Aromatic of a damp basement or damp soil (wet) or dust (dry).	English and black walnut	Warmund *et al.* (2009b)
Musty/Dusty	Dry, dirt-like aromatic associated with dry, brown soil.	Black walnut	Miller *et al.* (2013)
Musty/earthy	Humus-like aromatics that may or may not include damp soil, decaying vegetation, or cellar-like characteristics.	Black walnut	Warmund *et al.* (2009a) Lee *et al.* (2011) Miller *et al.* (2013)
Nutty	Delicate, characteristic flavor of tree nut products	Hazelnut	Alasalvar *et al.* (2003)
Nutty	N/A	Peanut	Isleib *et al.* (2006)
Nutty	Intensity of nut flavor, including raw nutty.	English and black walnut	Warmund *et al.* (2009b)
Nutty-buttery	Nutty aromatic characterized by a buttery impression, and/or increased fatty aromatics and musty/earthy character.	Black walnut	Miller *et al.* (2013)

Nutty-grain-like	Nutty aromatic characterized by the presence of a grainy aromatic, increased musty/dustiness, and brown.	Black walnut	Miller *et al.* (2013)
Nutty-Woody	Nutty aromatic characterized by the presence of woodiness, increased musty/dustiness, brown, astringent, and bitter.	Black walnut	Miller *et al.* (2013)
Oily	Oily taste or mouthfeel	Hazelnut	Alasalvar *et al.* (2003)
Oily	Light aromatics associated with vegetable oil (for example, corn, or soybean oil.)	Black walnut	Miller *et al.* (2013)
Overall flavor	N/A	Pistachio	Tsantili *et al.* (2010)
Overall nutty	Intensity of all nutty characteristics including sweet, oily, light brown, slightly musty and/or buttery, earthy, woody, astringent, and bitter flavors.	Black walnut	Warmund *et al.* (2009a) Lee *et al.* (2011) Miller *et al.* (2013)
Overall Sweet	Aromatic associated with the impression of sweet substances.	Black walnut	Miller *et al.* (2013)
Over-roast	N/A	Peanut	Isleib *et al.* (2006)

Painty	Odor associated with linseed oil or oil-based paint	Hazelnut	Alasalvar *et al.* (2003)
Painty/rancid	Aromatic of oxidized oil, linseed oil, oil-based paint.	English and black walnut	Warmund *et al.* (2009b)
Piney	A slight resinous aromatic associated with fresh green pine needles.	Black walnut	Warmund *et al.* (2009a) Lee *et al.* (2011) Miller *et al.* (2013)
Pungent	Burning or stinging sensation	Hazelnut	Alasalvar *et al.* (2003)
Rancid	Associated with old or oxidized fat	Hazelnut	Alasalvar *et al.* (2003)
Rancid	Aromatic commonly associated with oxidized fat and oils.	Black walnut	Warmund *et al.* (2009a) Lee *et al.* (2011) Miller *et al.* (2013)
Rancid flavor	N/A	English walnut	Guerrero *et al*. (2000) Sinesio *et al*. (2001)
Raw (almond)	Aromatics associated with uncooked beans or legumes.	Almond	Civille *et al.* (2010)
Raw bean/peanutty	The aromatic associated with light-roast peanuts (about 1-2 on USDA color chips) and having legume-like character (specify beans or pea if possible).	Peanut	Johnsen *et al.* (1988) Ng and Dunford (2009)
Raw/beany	N/A	Peanut	Isleib *et al.* (2006)

Red fruit	Total aromatics associated with red berries, including the synthesized, raw, and cooked notes of berries, such as strawberries, raspberries, and cherries.	Almond	Civille *et al.* (2010)
Roasted (almond)	Aromatics associated with almonds that have been roasted.	Almond	Civille *et al.* (2010)
Roasted peanut	N/A	Peanut	Isleib *et al.* (2006)
Roasted peanut	N/A	Peanut	Isleib *et al.* (2006)
Roasted peanutty	The aromatic associated with medium-roast peanuts (about 3-4 on USDA color chips) and having fragrant character such as methyl pyrazine.	Peanut	Johnsen *et al.* (1988) Ng and Dunford (2009)
Roasty	Flavor of roasted meat	Hazelnut	Alasalvar *et al.* (2003)
Skunky/mercaptan	The aromatic associated with sulfur compounds, such as mercaptan, which exhibit skunk-like character.	Peanut	Johnsen *et al.* (1988) Ng and Dunford (2009)
Sour	Taste associated with citric acid	Hazelnut	Alasalvar *et al.* (2003)
Sour	Fundamental taste factor of which citric acid is typical.	Black walnut	Miller *et al.* (2013)
Stale/cardboardy	Aromatic of wet cardboard and associated with slightly oxidized oils.	English and black walnut	Warmund *et al.* (2009b)
Sweet	Taste associated with sugar or sweetener	Hazelnut	Alasalvar *et al.* (2003)

Sweet	Fundamental taste factor of which sucrose is typical.	Black walnut	Miller *et al.* (2013)
Sweet aromatics	Aromatics associated with products that smell sweet, such as honey, maple syrup, brown sugar, and vanilla	Almond	Civille *et al.* (2010)
Sweet taste	N/A	English walnut	Guerrero *et al*. (2000) Sinesio *et al*. (2001)
Sweetness	N/A	English walnut	Ingels *et al*. (1990) Sinesio and Moneta (1997)
Under-roast	N/A	Peanut	Isleib *et al.* (2006)
Walnut	Aromatics associated with walnuts.	Almond	Civille *et al.* (2010)
Walnut flavor	N/A	English walnut	Ingels *et al*. (1990)
Wood/hull/skins	N/A	Peanut	Isleib *et al.* (2006)
Woody	Odor of hazelnut hard shell or hazelnut tree	Hazelnut	Alasalvar *et al.* (2003)
Woody	Aromatics associated with the general category of wood.	Almond	Civille *et al.* (2010)
Woody	Sweet, brown, musty, dark, dry aromatics associated with the bark of a tree.	Black walnut	Warmund *et al.* (2009a) Miller *et al.* (2013)
Woody odor	N/A	English walnut	Guerrero *et al*. (2000) Sinesio *et al*. (2001)
Woody/hulls/skins	The aromatics associated with base peanut character (absence	Peanut	Johnsen *et al.* (1988)

	of fragrant top notes) and related to dry wood, peanut hulls, and skins.		Ng and Dunford (2009)
Woody/hulls/skins	Aromatic associated with the outer protective coating of the nut, a dry wood note.	English and black walnut	Warmund *et al.* (2009b)

Pecans

Sensory research relating to pecans has been limited. Several studies have focused on the kernel quality relating to different harvest times. Heaton *et al.* (1975) used ten panelists to rate the quality of three different pecan cultivars ('Schley', 'Stuart', and 'Wichita') harvested from six weekly time periods from three successive crop years. The panelists rated the appearance, aroma, color, texture, and flavor of the samples using a ten point scale where 1 was very poor and 10 was excellent. The results indicated that the pecan flavor improved with successive harvests. The earliest time point had a harsh, pungent flavor that disappeared with more drying. Resurreccion *et al.* (1987) continued this study. Early and traditionally harvested pecans were evaluated by a trained panel consisting of eleven people. The flavor of four samples was evaluated using a 150 mm line scale. Three anchors were present: "bland" on the far left, "characteristic pecan flavor" in the middle, and "off flavor" on the far right of the line. Results showed that early harvested pecans were to the left of "characteristic pecan flavor" and traditionally harvest pecans were between halfway between "characteristic pecan flavor" and "off flavor". Herrera (1994) assessed seven samples, six were early harvested and dried at different temperatures (23C to 35c) for varying amounts of time (24 hours to 72 hours). The seventh sample was collected at normal harvest time (control). Seventeen untrained panelists ranked the flavor on a seven-point scale (7 was "best", 1 was "worst"). The samples from the normal harvest time were rated better than the other six samples. Off flavor was associated with early harvested pecans.

Ocón *et al.* (1995) analyzed differences in the texture of four cultivars. The attributes evaluated were hardness, flexibility, and crispness. Ten trained panelists used a 5-point scale with end point anchors “least” to “most” for each attribute. Each judge received four samples per session, and each sample was two nut halves in a plastic coded cup. Each sample was evaluated three times. No significant difference was found in the hardness or flexibility for the cultivars. Wichita was determined to be less crisp than the other three cultivars (‘Barton’, ‘Mahan’, and ‘Western Schley’).

Erickson *et al.* (1994) compared sensory properties of raw and roasted pecans and assessed their oxidative stability. The attributes internal lightness, crunchiness, rancid aroma, and rancid flavor were evaluated. Raw and roasted pecans were stored at two different relative humidities (55 and 65%) for up to 8 months. Eleven trained panelists evaluated the samples. They participated in two 1 hour training sessions to become acclimated with the samples and the attributes. Each sample was evaluated twice, once in the morning and once in the afternoon. Raw and roasted samples were tested on consecutive days. Samples were evaluated in individual testing booths and were coded with a three-digit number. Water and unsalted crackers were provided to clean out between each sample. Evaluation was recorded by placing a vertical line on a 150 mm line scale. There were two anchors for each attribute and references were provided. Results showed that there were no significant differences in the rancid aroma and rancid flavor between the raw and roasted samples. This led the researchers to conclude that the panel may not have been sensitive enough to detect oxidative differences. Panelists also did not differentiate between the color of the raw and roasted pecans. The varying relative humidities during storage did not affect the flavor or aroma scores significantly for raw or roasted samples. The crunchiness was affected by the humidity, samples stored at 65% relative humidity had lower scores for crunchiness than those stored at 55%.

Baldwin *et al.* (2006) evaluated the sensory properties of pecans that had different edible coating treatments. 18 to 20 panelists were given three kernels of each treatment. The panelists 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.

Research Objectives

Although past studies on the sensory characteristics of pecans exist, few have characterized flavor and texture attributes of pecans. Descriptions of pecan flavor, other than rancidity, both when fresh and over time have not been captured so far. Pecans are used in various applications and how their sensory attributes change has also not been described. This project aimed to determine: 1) flavor of pecans and differences in flavor attributes among pecan cultivars using descriptive sensory analysis; 2) differences in flavor and texture attributes between raw and roasted pecan cultivars; and 3) changes in flavor attributes among pecan cultivars over a 12 month period.

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Chapter 2 - Descriptive Analysis of Flavor Characteristics among Raw Pecan Cultivars

Abstract

Sixteen pecan cultivars, ‘Dooley’, ‘Pawnee’, ‘Witte’, ‘Hirschi’, ‘Chickasaw’, ‘Kanza’, ‘Oswego’, ‘Major’, ‘Henning’, ‘Stuart’, ‘Lakota’, ‘Giles’, ‘Maramec’, ‘Peruque’, ‘Chetopa’, and ‘Colby’, were evaluated by descriptive sensory analysis. Six trained panelists the intensities of 20 flavor attributes of the samples. Of the 20 flavor attributes defined by this study, significant differences ($P \leq 0.05$) were found among cultivars for 10 attributes. ‘Giles’, ‘Lakota’, and ‘Pawnee’ differed from the other 13 cultivars for the majority of these attributes.

‘Lakota’ was characterized by having the highest scores for woody, astringent, and bitter attributes. ‘Giles’ was characterized by having the lowest scores for overall nutty, nutty-buttery, musty/earthy, overall sweet, oily, and caramelized attributes. ‘Pawnee’ was characterized by having the highest scores for nutty-buttery, overall sweet, and oily, and for having the lowest scores for astringent, bitter, and acrid attributes. The remaining thirteen cultivars showed few differences in individual attribute ratings, but did show differences when mapped using multivariate techniques indicating as many as two clusters of pecan cultivars based on flavor. Future studies should include descriptive analysis of other pecan cultivars, both wild and commercial, that could be grown and harvested for production.

Introduction

Pecan [*Carya illinoinensis(Wangenh.)* K. Koch] is a native North American nut tree that has evolved into a significant agricultural crop (Santerre 1994). Though more than 93% of the United States’ commercial pecan crop is grown in southeastern and southwestern states, a small but expanding pecan industry exists in the northern states of Kansas, Missouri, Iowa, Illinois, and Indiana (Reid *et al.* 2000). Pecans are a high value crop with its timber and pecan kernels having applications in industry. Pecan nut kernels are used in baking, confections, and ice cream. The nut kernels are sold as gift-packs, retail cello packs, and in bulk boxes to wholesale outlets or various food service outlets (Wood 2001).

When consumers were surveyed on purchase intent of pecans, their top reason was the taste, followed by the health benefits of pecans (Lombardini *et al.* 2008). Sensory research of flavor has primarily focused on rancid or off flavors associated with poor quality pecan kernels. These flavor defects are linked to the high quantities of unsaturated fatty acids found in pecan kernels. These fatty acids are subject to oxidative cleavage that degrades the quality of the pecans (Baldwin *et al.* 2006).

Baldwin *et al.* (2006) assessed the sensory properties of pecans that had different edible coating treatments. The coatings included hydroxypropyl cellulose (HPC) and carboxymethyl cellulose (CMC), plus various additives. Eighteen to twenty panelists were given three kernels of 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.

Previous research has also focused on how harvest time impacts pecan flavor. Heaton *et al.* (1975) used ten panelists to score flavor on a ten-point scale (1 = very poor and 10 = excellent) for pecans harvested at different times. Results showed that flavor improved with successive harvests. Early harvested pecans had harsh, pungent flavors that diminished as they dried in the grove. As a continuation of the 1975 study, Resurreccion *et al.* (1987) evaluated the flavor of early-harvested versus traditionally harvested pecans. Eleven panelists who had previous experience evaluation pecans underwent on day of training prior to evaluation. Sessions were conducted in individual booths. A 150mm line scale was used with three anchor points to evaluate if off flavors were present. The results showed that early-harvested pecans were closer to the “characteristic pecan flavor” anchor and traditionally harvested pecans were halfway between the “characteristic pecan flavor” anchor and the “off-flavor” anchor. Herrera (1994) conducted a study to determine if oven drying temperatures had an effect on early-harvested pecans. A 17 person untrained sensory panel was asked to rank the seven samples from 7 (best) to 1 (worst). The treatments consisted of different oven drying times and temperatures, with the addition of one sample that was not dried, and one that was harvested at the normal time. The results found that the sample collected at the normal harvest time (control) was consistently rated better than the other samples.

Since research on evaluation the flavor of pecans has been somewhat limited in the past, primarily focusing on the quality and presence of flavors, additional information about flavor could prove useful to pecan growers seek to establish new pecan orchards and to retailers who sell pecans for various applications. This study was undertaken to develop a vocabulary to describe various pecan cultivars and to determine differences in flavor attributes among pecan cultivars using descriptive sensory analysis.

Materials and Methods

Samples

Sixteen pecan cultivars (~18 kg per cultivar, in shell) were collected from the Kansas State University Experimental Field pecan 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 (23C ± 1C). The pecan shelling was completed over a two-month period using a Duke Pecan Walnut Cracker (Duke Pecan Company, West Point, MS, USA) and Channel Lock model number 436, 15.24 cm cutting pliers (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) and were kept under frozen conditions (-26C ± 1C) to maintain freshness and delay oil oxidation in the nuts (Reid 2011).

Descriptive Analysis

Six panelists (five female, one male) from the Sensory Analysis Center at Kansas State University in Manhattan, KS 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.

Orientation and Vocabulary Development

Two, 2-hour sessions were used to expose the panelists to fourteen of the sixteen samples and to develop the ballot and attribute list for evaluation. The panelists were given an initial lexicon, which was adapted from two previous black walnut studies (Matta *et al.* 2005 and Miller *et al.* 2013). Panelists were instructed to taste the samples one at a time and compare with the initial lexicon given if those attributes were appropriate. The panelists then engaged in an open discussion to determine if any attributes should be added or deleted. The attributes were then grouped and ordered by dominance, with the most dominant attributes appearing first on the definition sheet. The same grouping style was applied to the ballot as well. The panelists also discussed the appropriate serving size for the samples and the proper evaluation technique. They practiced these techniques with several samples to ensure consistent results. An open discussion took place to clarify any confusion about the attributes related to intensity scoring. All samples were evaluated at room temperature (23C ± 1C). Suwonsichon *et al.* (2012), Adhikari *et al.* (2011), Elía (2011), Koppel *et al.* (2010), and Limpawattana and Shewfelt (2010) used similar vocabulary development procedures. Orientation sessions were used to clarify definitions and references for the attributes. All references in the attribute list were provided for the panelists. The panelists were asked to taste them to ensure that they were suitable for evaluation of pecans. The final ballot included 20 flavor attributes including astringent and three basic tastes bitter, sour, and sweet. Table 2-1 lists the attributes, definitions, and references used for testing.

Table 2-1. Flavor attributes, definitions, and references for descriptive analysis of pecans*

Attribute	Definition	Reference
Pecan ID	The aromatics commonly associated with pecans, which include musty/earthy, piney, woody, brown, sweet, buttery, oily, astringent, and slightly acrid aromatics. Other aromatics may include musty/dusty, floral/fruity, and/or fruity-dark.	Ground Pecan pieces = 7.0 Preparation: Measure out 1 tbsp. of various cultivars into a food processor and blend for 30 seconds. Pour into 1 oz. cups.
Overall Nutty	A measurement that reflects the total of the nutty characteristics and the degree to which these characteristics fit together. These nutty characteristics are: sweet, oily, These nutty characteristics are: sweet, oily, light brown, slightly musty and/or buttery, earthy, woody, astringent, bitter, etc. Examples: nuts, wheat germ, certain whole grains.	Gold Medal Whole Wheat Flour = 4.5 Kretschmer Wheat Germ = 7.5 Mixture of Diamond Slivered Almonds and Kroger Chopped Hazelnuts = 7.5 Preparation: Puree the almonds and hazelnuts separately in blenders for 45 seconds on high speed. Combine equal amounts of the chopped nuts. Serve in individual 1 oz. cups. Serve pecans and walnuts in 1 oz cups. Diamond Shelled Walnuts = 8.0 Diamond Pecan Halves = 9.0
Nutty-Woody	A nutty aromatic characterized by the presence of woodiness, increased musty/dustiness, brown, astringent and bitter.	Diamond Pecan Halves = 7.5 Diamond Shelled Walnuts = 7.5
Nutty-Grain-like	A nutty aromatic characterized by the presence of a grainy aromatic, increased musty/dustiness and brown.	Gold Medal Whole Wheat Flour = 4.5 Kretschmer Wheat Germ = 7.5
Nutty-Buttery	A nutty aromatic characterized by a buttery impression, and/or increased fatty aromatics and musty/earthy character.	HyVee Dry Roasted and Salted Macadamia Nuts = 5.0

Brown	A rich, full aromatic impression always characterized with some degree of darkness generally associated with attributes (i.e. toasted, nutty, sweet).	Bush's Best Pinto Beans (Canned) = 5.0 Preparation: Drain beans and rinse with de-ionized water. Kretschmer Wheat Germ = 7.5
Caramelized	A round, full-bodied, medium brown aromatic.	C&H Golden Brown Sugar = 9.0
Acrid	The sharp/acrid, charred flavor note associated with something over baked or excessively browned in oil.	Alf's Natural Nutrition Puffed Red Wheat Cereal = 3.0
Burnt	A dark, brown, somewhat sharp, over-baked grain aromatic.	Alf's Natural Nutrition Puffed Red Wheat Cereal = 4.0
Musty/Earthy	Humus-like aromatics that may or may not include damp soil, decaying vegetation, or cellar like characteristics.	Sliced Button mushroom = 10.5
Woody	The sweet, brown, musty, dark, dry aromatics associated with the bark of a tree.	Diamond Shelled Walnuts = 4.0
Roasted	Dark brown impression characteristic of products cooked to a high temperature by dry heat. Does not include bitter or burnt notes.	'Planters Dry Roasted Unsalted Peanuts= 5.0
Overall Sweet	An aromatic associated with the impression of sweet substances.	Post Shredded Wheat = 1.5

		General Mills Wheaties = 3.0 Lorna Doone Cookie = 4.5
Oily	The light aromatics associated with vegetable oil such as corn or soybean oil.	Kroger Slivered and Blanched Almonds = 4.0 HyVee Dry Roasted and Salted Macadamia Nuts = 9.0
Rancid	An aromatic commonly associated with oxidized fat and oils.	Wesson Vegetable Oil = 2.5 <u>Preparation</u>: Microwave 1/3 cup of oil on high power for 2 1/2 minutes. Let cool and serve in individual covered cups.
Oxidized	The aromatic associated with aged or highly used oil and fat.	Microwave Oven Heated Wesson Vegetable Oil = 6.0 <u>Preparation:</u> Add 300ml of oil from a newly purchased and opened bottle of Wesson Vegetable Oil to a 1000ml glass beaker. Heat in the microwave oven on high power for 3 minutes. Remove from microwave and let sit at room temperature to cool for approximately 25 minutes. Then heat another 3 minutes, let cool another 25 minutes, and heat for one additional 3 minute interval. Let beaker sit on counter uncovered overnight.
Astringent	A feeling of a puckering or a tingling sensation on the surface and/or edge of the tongue and mouth.	0.030% Alum solution = 1.5 0.050% Alum solution = 2.5 0.075% Alum solution = 3.5 0.10% Alum solution = 5.0

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 samples and references.

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 pecans were removed from the freezer the afternoon prior to testing and allowed to thaw at room temperature (23C ± 1C) prior to evaluation. The morning of evaluation each panelist was served 10 g of each cultivar in a plastic 92 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 on paper ballots with erasable red pencils. Researchers used descriptive sensory analysis and panelists 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. A tray with references for the flavor attributes was provided for each panelist along with definition/reference sheets. Panelists took 1/4 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 and reduce flavor carryover. Panelists evaluated the sixteen raw pecan samples in triple replicate for each cultivar. One replication of the pecan samples was completed over a two-day period. Eight samples, or half a replication, was completed in 1 day during a 120 min evaluation session. There was a total of 6 days of testing.

Statistical Analysis

Analysis of variance (ANOVA) was performed to test the significance of each flavor attribute across cultivars at the 5% level of significance. Using a Fisher's protected least significant difference (LSD) test, post-hoc means separation was also analyzed at the 5% level of significance. Statistical analyses were performed with SAS® statistical software (SAS® version 9.3, SAS Institute Inc., Cary, NC, USA) using PROC MIXED.

Principal Components Analysis (PCA) using the covariance matrix to evaluate the relationship(s) among attributes and cultivars. A PCA biplot visually depicts the spatial arrangement of the attributes and samples in order to draw conclusions on which attribute(s) describe particular sample(s). R software (R version 3.1.1, Ihaka R. and Gentleman, R., Auckland, New Zealand) was used to perform analysis.

Cluster Analysis (CA) classifies the data into uniquely defined sub groups. A hierarchical clustering graph showcases where the different cultivars fall into subgroups in order to further describe how they are similar to one another. R software (R version 3.1.1, Ihaka R. and Gentleman, R., Auckland, New Zealand) was used to perform analysis.

Results and Discussion

Mean intensity scores for the 20 attributes by cultivar are listed in Tables 2-2 and 2-3. These attributes can be divided into different subgroups. The basic tastes that are represented are sour, bitter, and sweet. The mouthfeel was assessed by describing the intensity of astringency. "Nuttiness" was described by the overall nutty attribute. Nutty-woody, nutty-grain-like, and nutty-buttery are subsets of the overall nutty characteristic (Miller 2013). There are several attributes that describe the processed aspects displayed in pecans (brown, caramelized, acrid, burnt, and roasted). Plant or tree characteristics were described by the woody and musty-earthy attributes. Attributes more specific to pecans were "pecan ID" and the oily and rancid attributes that are related to the high amount of fatty acids in pecans.

The only flavor attribute that has been used in previous research is the intensity of rancidity or off-flavors (Erickson *et al.* 1994; Heaton *et al.* 1975; Herrera 1994; and Resurreccion *et al.* 1987). Therefore, the attributes developed in the present study showcase other aspects of pecan flavor and contain more detailed descriptions. Lexicons developed for other nut species have provided more detailed descriptors. For example Ng and Dunford (2009) used three attributes characterizing the degree of roasting in peanuts as well as attributes for earthy, grainy, green and off-notes such as cardboard, painty, burnt, fishy, and skunky/mercaptan. Civille *et al.* (2010) dissected several of multi-dimensional descriptors of almonds into single-note descriptors (e.g., fruity, red fruit, and brown fruit). The authors of the current study used this same technique when defining the nutty attributes found in the pecans (i.e., overall nutty, nutty-buttery, nutty-grain-like, and nutty-woody). Miller *et al.* (2013) had similar attributes to the study on black walnut cultivars. This study further expands upon the literature for profiling the flavor attributes of pecans.

Table 2-2. Mean intensity scores and separation of flavor attributes for 16 pecan cultivars*

Cultivar	Attribute									
	Pecan ID	**Overall Nutty**	**Nutty Woody**	**Nutty Grain like**	**Nutty Buttery**	**Brown**	**Caramelized**	**Acrid**	**Burnt**	**Musty Earthy**
Giles	6.42	6.08^{d}	5.92	5.92	1.28^{f}	5.64	0.89^{f}	0.06^{bc}	0.00	0.53^{c}
Hirschi	6.50	6.50^{abc}	6.22	6.03	1.94^{cd}	5.86	1.31^{abcdef}	0.06^{bc}	0.00	0.56^{c}
Maramec	6.58	6.47^{abc}	5.94	6.06	2.08^{bcd}	5.53	0.92^{ef}	0.06^{bc}	0.00	1.08^{a}
Oswego	6.17	6.39^{bcd}	6.00	6.06	2.17^{bcd}	5.50	1.19^{bcdef}	0.06^{bc}	0.00	0.86^{ab}
Lakota	6.36	6.44^{abc}	6.19	5.92	1.42^{ef}	5.72	1.00^{def}	0.11^{abc}	0.00	0.67^{bc}
Chetopa	6.78	6.78^{a}	6.44	6.00	2.25^{abc}	5.86	1.53^{abc}	0.17^{ab}	0.00	0.75^{bc}
Colby	6.42	6.64^{ab}	6.14	6.06	2.36^{ab}	5.64	1.53^{abc}	0.00^{c}	0.00	0.67^{bc}
Witte	6.56	6.50^{abc}	6.08	5.92	1.92^{cd}	5.86	1.67^{a}	0.14^{abc}	0.00	0.67^{bc}
Dooley	6.56	6.50^{abc}	6.06	6.06	1.81^{de}	5.33	1.36^{abcde}	0.00^{c}	0.00	0.72^{bc}
Kanza	6.42	6.39^{bcd}	6.03	6.06	2.17^{bcd}	5.72	1.39^{abcd}	0.11^{abc}	0.00	0.69^{bc}
Pawnee	6.69	6.61^{ab}	6.00	6.14	2.58^{a}	5.75	1.56^{abc}	0.00^{c}	0.00	0.75^{bc}
Stuart	6.61	6.72^{ab}	6.08	6.28	2.25^{abc}	5.81	1.25^{abcdef}	0.06^{bc}	0.00	0.75^{bc}
Chickasaw	6.47	6.39^{bcd}	6.11	5.92	2.06^{bcd}	5.67	1.14^{cdef}	0.14^{abc}	0.00	0.86^{ab}
Peruque	6.50	6.64^{ab}	6.14	6.14	2.42^{ab}	5.75	1.64^{ab}	0.00^{c}	0.00	0.61^{bc}
Major	6.61	6.67^{ab}	5.94	6.08	2.14^{bcd}	5.81	1.25^{abcdef}	0.00^{c}	0.00	0.67^{bc}
Henning	6.31	6.25^{cd}	6.08	5.86	1.89^{cd}	5.92	1.17^{cdef}	0.22^{a}	0.00	0.72^{bc}

*Means with different super scripts within a column are significantly different ($P \leq 0.05$) according to Fisher's protected least significant difference (LSD) test.

Table 2-3. Mean intensity scores and separation of flavor attributes for 16 pecan cultivars*; A continuation of Table 2-2

Cultivar	Attribute									
	Woody	**Roasted**	**Overall Sweet**	**Oily**	**Rancid**	**Oxidized**	**Astringent**	**Bitter**	**Sour**	**Sweet**
Giles	3.03^{bcde}	0.00	1.42^{f}	1.75^{g}	0.00	0.00	2.97^{ab}	3.25^{ab}	1.75	0.78
Hirschi	3.03^{bcde}	0.00	1.53^{cdef}	2.36^{cdef}	0.00	0.00	2.89^{bcd}	3.06^{abc}	1.67	0.83
Maramec	2.86^{cde}	0.00	1.64^{abcde}	2.50^{bcde}	0.00	0.00	2.61^{d}	2.81^{cd}	1.58	0.86
Oswego	2.94^{bcde}	0.00	1.47^{ef}	2.44^{bcdef}	0.00	0.00	2.72^{bcd}	2.89^{cd}	1.81	0.89
Lakota	3.50^{a}	0.00	1.50^{def}	1.94^{fg}	0.00	0.00	3.25^{a}	3.33^{a}	1.78	0.78
Chetopa	3.11^{bcde}	0.00	1.72^{abc}	2.47^{bcde}	0.00	0.00	2.64^{cd}	2.97^{bcd}	1.86	1.00
Colby	2.97^{bcde}	0.00	1.61^{abcdef}	2.78^{abc}	0.00	0.00	2.75^{bcd}	3.06^{abc}	1.89	0.81
Witte	3.19^{abc}	0.00	1.72^{abc}	2.25^{defg}	0.00	0.00	2.94^{abc}	3.03^{abc}	1.83	0.86
Dooley	3.06^{bcde}	0.00	1.67^{abcde}	2.58^{bcde}	0.00	0.00	2.78^{bcd}	2.81^{cd}	1.78	1.03
Kanza	2.92^{cde}	0.00	1.67^{abcde}	2.42^{cdef}	0.00	0.00	2.89^{bcd}	2.89^{cd}	1.75	0.92
Pawnee	2.78^{e}	0.00	1.81^{a}	3.11^{a}	0.00	0.00	2.58^{d}	2.69^{d}	1.69	1.00
Stuart	3.08^{bcde}	0.00	1.75^{ab}	2.64^{abcd}	0.00	0.00	2.81^{bcd}	2.92^{cd}	1.67	0.89
Chickasaw	3.31^{ab}	0.00	1.67^{abcde}	2.33^{cdef}	0.00	0.00	2.94^{abc}	2.94^{bcd}	1.75	0.83
Peruque	3.00^{bcde}	0.00	1.69^{abcd}	2.94^{ab}	0.00	0.00	2.78^{bcd}	2.86^{cd}	1.61	0.83
Major	2.81^{de}	0.00	1.58^{bcdef}	2.47^{bcde}	0.00	0.00	2.75^{bcd}	2.81^{cd}	1.50	0.94
Henning	3.17^{abcd}	0.00	1.56^{bcdef}	2.11^{efg}	0.00	0.00	2.83^{bcd}	3.31^{a}	1.67	0.75

*Means with different super scripts within a column are significantly different ($P \leq 0.05$) according to Fisher's protected least significant difference (LSD) test.

Flavor among Cultivars

Ten flavor attributes differed significantly ($P \leq 0.05$) across cultivars. These included overall nutty, nutty buttery, caramelized, acrid, musty earthy, woody, overall sweet, oily, astringent, and bitter. Although significant differences ($P \leq 0.05$) were found for half the attributes evaluated, the ranges of intensities were fairly small. Most differences were found for 'Lakota', 'Giles', and 'Pawnee' compared to other samples. For example, of the attributes contrasting significantly ($P \leq 0.05$), the cultivars varied by less than 0.5 for overall sweet (greatest difference of 0.39) and acrid (greatest difference of 0.22). There were two attributes that diverged by more than 1.00 as well; these were nutty buttery (greatest difference of 1.31) and oily (greatest contrast of 1.36) attributes. Figure 2-1 showcases the cluster analysis results. According to the clustering, two distinct cultivar clusters form based on flavor attribute differences. One of these clusters includes 'Giles' and 'Lakota', while the second one encompasses of all the other cultivars analyzed. This affirms the ANOVA findings which indicated that many attribute differences were present for 'Lakota' and 'Giles' in comparison to the other thirteen cultivars.

'Lakota' had the highest intensity scores for woody, astringent, and bitter ($P \leq 0.05$). 'Giles' had the lowest intensity scores for overall nutty, nutty-buttery, musty-earthy, overall sweet, and oily (all significant at $P \leq 0.05$). 'Pawnee' had the highest intensity scores for nutty-buttery, overall sweet and oily, and had the lowest scores for astringent and bitter ($P \leq 0.05$). 'Pawnee' has more similarities to nuts grown in southern states due to its larger kernel and early maturation (University of Georgia College of Agricultural and Environmental Sciences, 2015). It is a USDA controlled cross between Mohawk and Starking Harding Giant (Reid 2010). It produces the largest nut that can consistently mature in the northern pecan production region of the United States (Reid 2000).

'Hirschi' and 'Maramec' were significantly different from each other for the musty/earthy attribute. This attribute is characteristic of damp vegetation or soil. Though this attribute is present in all cultivars the intensity level is very low. 'Maramec' had the highest musty/earthy intensity and 'Hirschi' had one of the lowest. Though attribute intensities differ in the 16 cultivars, it is the combination and overall impression that creates the characteristic pecan flavor.

Cultivar Effect

Principal Components Analysis (PCA) biplot can be used to showcase differences among cultivars and attributes. By looking at the "map" of cultivars in Figure 2-2 it is possible to examine the differences that can be noted among products. Although there were few differences in single attributes among the samples other than 'Lakota', 'Giles', and 'Pawnee', the multivariate map showed a more disparate picture. 'Dooley' and 'Major' appeared to be similar to each other as they were grouped together in the PCA biplot, 'Colby', 'Peruque', and 'Stuart' are also grouped near one another, which suggested shared traits among these three cultivars. 'Chickasaw' and 'Hirschi' were positioned near one another, implying shared traits. 'Chetopa' fell by itself in the component space, as does 'Maramec', 'Oswego', and 'Witte'. 'Witte' is positioned closer to the attributes brown and sour than the other cultivars. Despite the ANOVA statistics showing few to no significant differences in flavor attributes among these thirteen cultivars, there were differences among these cultivars that become apparent when all attributes are evaluated simultaneously.

The pecan ripening process may have impacted the flavor profiles of the cultivars. ‘Lakota’ has a tendency to over-produce as the pecan tree ages (Reid 2013). The samples for this study originate from a tree over 30 years old. When large nut clusters are produced the kernel doesn’t fill properly, which has an effect on the quality. The affected quality of the ‘Lakota’ cultivar could have an impact on the flavor attributes. This could explain why it was significantly different than other cultivars for several attributes.

‘Giles’ had poor nut quality for the 2013 growing season, which was caused by over production and drought. Since ‘Giles’ has a later ripening time already, with the addition of these other factors led to poor kernel development (Reid 2013). All cultivars with later ripening times had this issue at varying degrees. ‘Maramec’ and ‘Stuart’ are two other cultivars with later ripening times (Reid 2013).

Unfavorable weather conditions and over production could have adversely affected ‘Lakota’ and ‘Giles’ more than other samples, thus contributing to the differences in attribute ratings. Research indicates that nut quality parameters (for example, kernel size and kernel fill) can be affected by the promptness of harvest time (Heaton *et al.* 1975). The drought that occurred during the 2013 growing season may have had a greater impact on some cultivars (Reid 2013). ‘Pawnee’ has an earlier ripening time and was filling kernels before the dry conditions occurred. ‘Lakota’ and ‘Giles’, which have later ripening times, were filling kernel during the depth of the dry period when tree water uptake was limited (Reid 2013). Whether these observed attribute traits are characteristic of ‘Lakota’ and ‘Giles’ can be attributed to poor climatic and/or harvesting conditions is unclear, thus more research is needed to validate these findings.

There are some limitations to the current study. This study focused solely on northern pecan cultivars. Though northern pecans are known for being small and hard-shelled, in reality they are manifold due to their wild origin (Reid 2000). Though they are diverse when they are compared to each other, how they compare to pecans produced in southern states is unknown. Evaluating cultivars from only one growing season also limits the depth of results. Growing season temperatures can vary year to year, as can the time it takes to harvest. These factors could all potentially have an effect on the flavor characteristics of pecan cultivars.

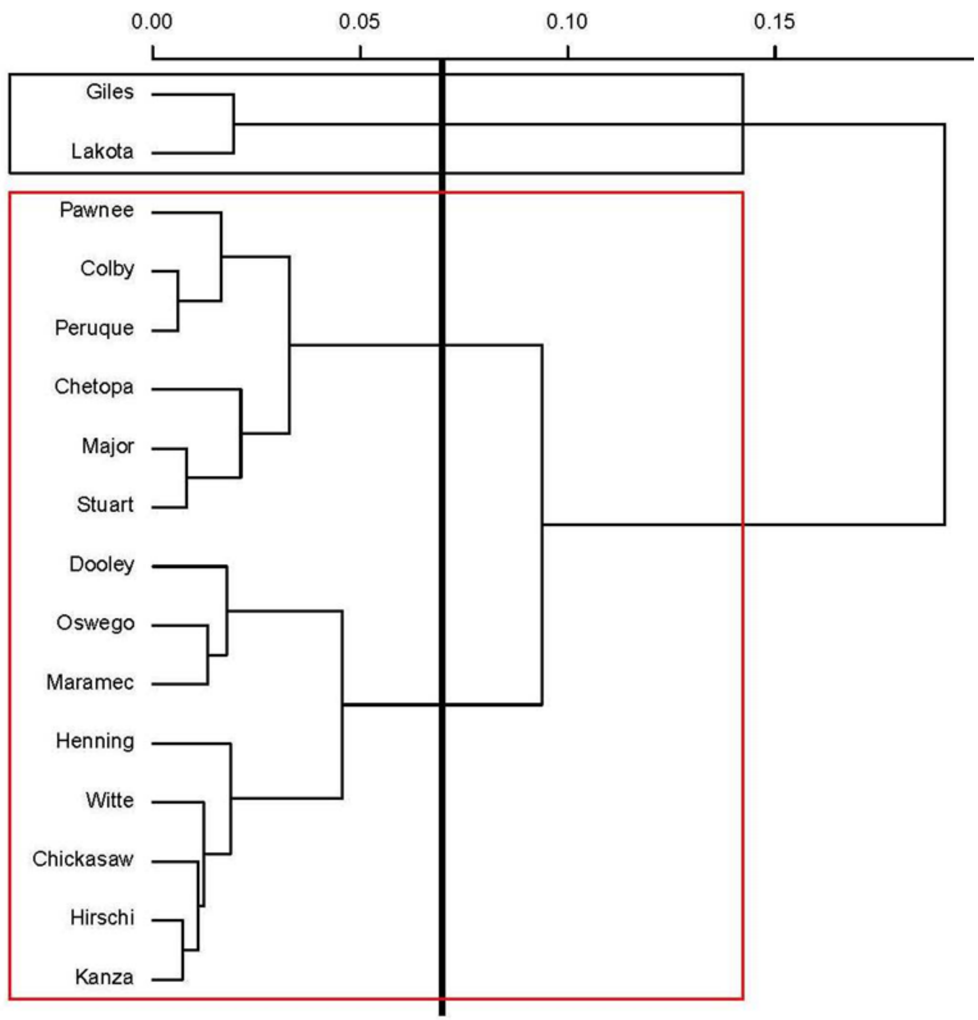

Figure 2-1. Cluster analysis (CA) graph showcasing groupings of the 16 different pecan cultivars based on their flavor profiles

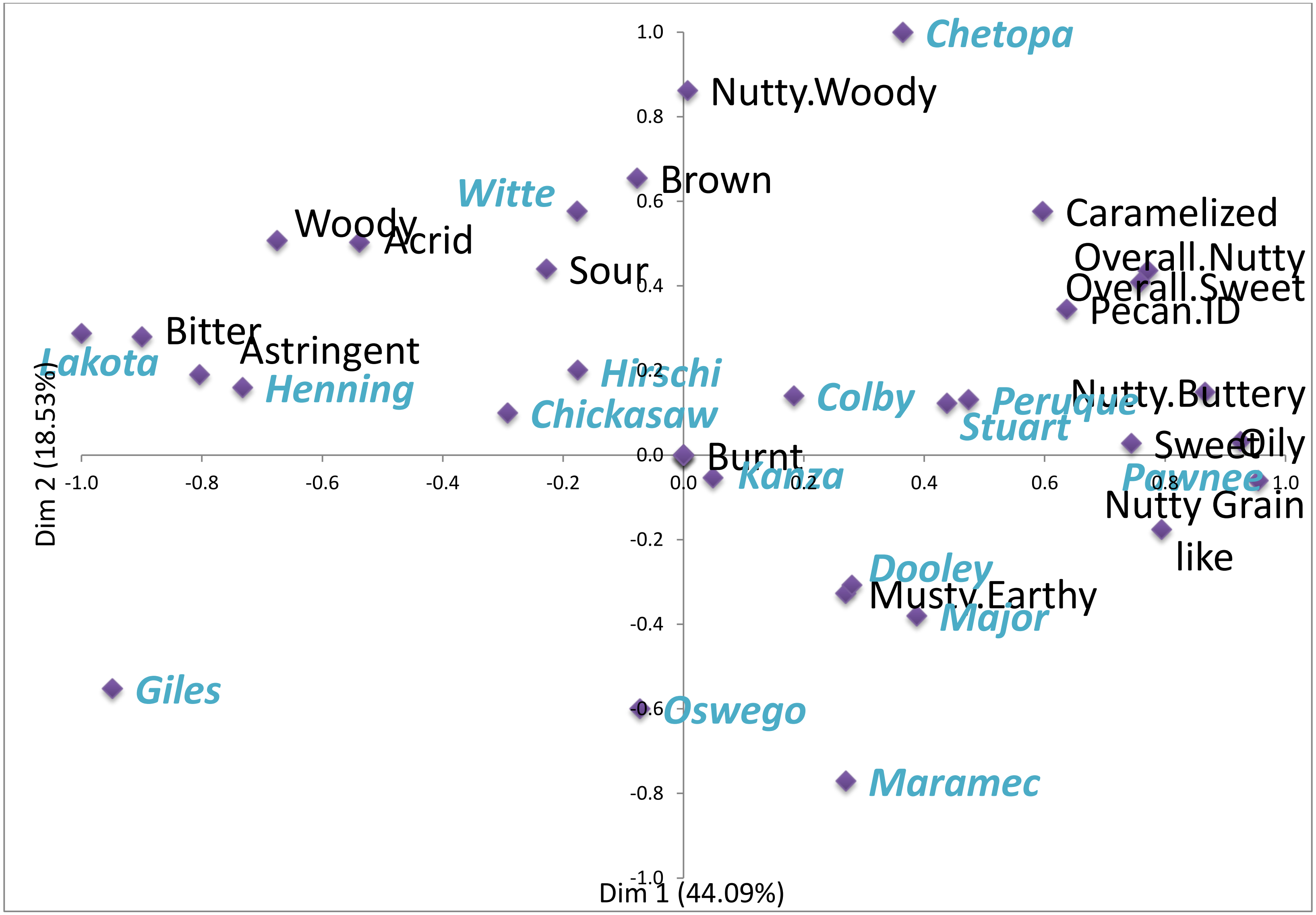

Figure 2-2. Principal components analysis (PCA) biplot showcasing dimensions 1 and 2 for the 16 pecan cultivars and the 20 descriptive flavor attributes

Conclusions

The sixteen pecan cultivars evaluated in this study differed significantly across 10 descriptive flavor attributes, and the cultivars ‘Lakota’, ‘Giles’, and ‘Pawnee’ most often differed from the other cultivars (‘Dooley’, ‘Chickasaw’, ‘Hirschi’, ‘Major’, ‘Witte’, ‘Chetopa’, ‘Maramec’, ‘Henning’, ‘Colby’, ‘Peruque’, ‘Stuart’, ‘Kanza’, and ‘Oswego’). These thirteen cultivars appear to provide similar flavors and could provide equivalency for pecan growers if the data are found to be consistent in other harvest years and conditions. The vocabulary created in this study can be used as a baseline for future pecan flavor research. Distinguished by their pecan ID, overall nutty, nutty-buttery, and oily notes these cultivars had low ratings for rancid, acrid, and sour. Future research should focus on consumer evaluation for these pecan cultivars to determine acceptance of those commonly harvested for commercial production. Descriptive analysis should also be conducted on future growing seasons to explore possible seasonal variation.

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Chapter 3 - A Comparison of Flavor and Texture Characteristics between Raw and Roasted Pecan Cultivars

Abstract

Pecan [*Carya illinoinensis(Wangenh.)* K. Koch], a large hardwood tree native to North America, produces an increasingly popular edible nut with desirable nutritional properties. The objective of this study was to evaluate sensory (flavor and texture) differences in raw and roasted pecan cultivars. Sixteen cultivars ('Dooley', 'Pawnee', 'Witte', 'Hirschi', 'Chickasaw', 'Kanza', 'Oswego', 'Major', 'Henning', 'Stuart', 'Lakota', 'Giles', 'Maramec', 'Peruque', 'Chetopa', and 'Colby'), were evaluated by descriptive sensory analysis. Six trained panelists evaluated all 16 cultivars when they were raw and roasted and scored intensities of the samples for 20 flavor attributes and 3 texture attributes. Results showed that 4 attributes (roasted, pecan ID, brown, and overall nutty) differed significantly across all cultivars when raw and roasted flavor was compared. Ten of the flavor attributes (roasted, pecan ID, brown, overall nutty, caramelized, nutty-woody, nutty-grain-like, nutty-buttery, overall sweet, bitter, sweet, oily) had higher intensities for the roasted pecans than for the raw pecans. Most of these attributes fell within the categories of 'nutty' and 'sweet'. Overall the roasting process has the effect of intensifying flavor attributes, as compared to when they were raw.

Introduction

Pecan (*Carya illinoinensis*) is the most commercially important nut tree native to North America. Pecans are growing in popularity due to an increased awareness of their desirable nutritional properties. Pecans contain phenolic compounds that possess antioxidant properties. Studies have found that antioxidants have the ability to lower the incidence of chronic diseases such as Alzheimer's disease, Parkinson's disease, some types of cancer, and other degenerative diseases (Mertens-Talcott *et al.* 2005; Tam *et al.* 2006). Pecans also have high levels of unsaturated fatty acids, which may have a role in reducing the risk of heart disease (Rajaram *et al*. 2000, 2001).

Pecans are a high value crop with its timber and pecan kernels having applications in industry. Pecan nut kernels are used in baking, confections, and ice cream. The nut kernels are sold as gift-packs, retail cello packs, and in bulk boxes to wholesale outlets or various food service outlets (Wood 2001).). Purchasing pecans in a prepared form such as chocolate covered or roasted is also popular (Lombardini *et al.* 2008). Roasting is a process that intensifies the color, texture, appearance, and flavor of pecans. The resulting product has different texture properties such as higher crispness and brittleness (Saklar *et al.* 2001). Though the effect of roasting has been described for other nuts, only one study has been conducted for how roasting impacts pecans (Erickson *et al.* 1994).

Erickson *et al.* (1994) assessed the oxidative stability in 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. No significant differences were found in the rancid aroma and flavor of the raw and roasted pecan samples. No significant difference for internal lightness among the samples was found either.

Since research on the evaluation of flavor differences between raw and roasted pecans has been limited in the past, mainly focusing on how flavor changes in the context of oxidation, describing how flavor attributes change during roasting may be useful for pecan growers who want to gather more information on how their cultivars perform in different applications. Therefore, the objectives of this study were to determine differences in flavor and texture attributes among raw and roasted pecan cultivars using descriptive sensory analysis and to determine differences in flavor and texture attributes among roasted pecan cultivars using descriptive sensory analysis.

Materials and Methods

Samples

Sixteen pecan cultivars (~18.15 kg per cultivar, in shell) were collected from orchards located at Kansas State University's Pecan Experiment Field 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 (23C ± 1C). The pecan shelling was completed over a two-month period using a Duke Pecan Walnut Cracker (Duke Pecan Company, West Point, MS, USA) and Channel Lock model number 436, 15.24 cm cutting pliers (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) and were kept under frozen conditions (-18C ± 1C) to maintain freshness and delay oil oxidation in the nuts (Reid 2011).

Descriptive Analysis

Six panelists (five female, one male) from the Sensory Analysis Center at Kansas State University in Manhattan, 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. Twenty flavor attributes and three texture attributes were evaluated (Table 3-1).

Table 3-1. Flavor attributes, definitions, and references for descriptive analysis of pecans*

Attribute	Definition	Reference
Pecan ID	The aromatics commonly associated with pecans, which include musty/earthy, piney, woody, brown, sweet, buttery, oily, astringent, and slightly acrid aromatics. Other aromatics may include musty/dusty, floral/fruity, and/or fruity-dark.	Ground Pecan pieces =7.0 Preparation: Measure out 1 tbsp. of various cultivars into a food processor and blend for 30 seconds. Pour into 1 oz. cups.
Overall Nutty	A measurement that reflects the total of the nutty characteristics and the degree to which these characteristics fit together. These nutty characteristics are: sweet, oily, These nutty characteristics are: sweet, oily, light brown, slightly musty and/or buttery, earthy, woody, astringent, bitter, etc. Examples: nuts, wheat germ, certain whole grains.	Gold Medal Whole Wheat Flour = 4.5 Kretschmer Wheat Germ = 7.5 Mixture of Diamond Slivered Almonds and Kroger Chopped Hazelnuts = 7.5 Preparation: Puree the almonds and hazelnuts separately in blenders for 45 seconds on high speed. Combine equal amounts of the chopped nuts. Serve in individual 1 oz. cups. Serve pecans and walnuts in 1 oz cups. Diamond Shelled Walnuts = 8.0 Diamond Pecan Halves = 9.0
Nutty-Woody	A nutty aromatic characterized by the presence of woodiness, increased musty/dustiness, brown, astringent and bitter.	Diamond Pecan Halves = 7.5 Diamond Shelled Walnuts = 7.5
Nutty-Grain-like	A nutty aromatic characterized by the presence of a grainy aromatic, increased musty/dustiness and brown.	Gold Medal Whole Wheat Flour = 4.5 Kretschmer Wheat Germ = 7.5

Nutty-Buttery	A nutty aromatic characterized by a buttery impression, and/or increased fatty aromatics and musty/earthy character.	HyVee Dry Roasted and Salted Macadamia Nuts = 5.0
Brown	A rich, full aromatic impression always characterized with some degree of darkness generally associated with attributes (i.e. toasted, nutty, sweet).	Bush's Best Pinto Beans (Canned) = 5.0 Preparation: Drain beans and rinse with de-ionized water. Kretschmer Wheat Germ = 7.5
Caramelized	A round, full-bodied, medium brown aromatic.	C&H Golden Brown Sugar = 9.0
Acrid	The sharp/acrid, charred flavor note associated with something over baked or excessively browned in oil.	Alf's Natural Nutrition Puffed Red Wheat Cereal=3.0
Burnt	A dark, brown, somewhat sharp, over-baked grain aromatic.	Alf's Natural Nutrition Puffed Red Wheat Cereal=4.0
Musty/Earthy	Humus-like aromatics that may or may not include damp soil, decaying vegetation, or cellar like characteristics.	Sliced Button mushroom = 10.5
Woody	The sweet, brown, musty, dark, dry aromatics associated with the bark of a tree.	Diamond Shelled Walnuts = 4.0

Roasted	Dark brown impression characteristic of products cooked to a high temperature by dry heat. Does not include bitter or burnt notes.	'Planters Dry Roasted Unsalted Peanuts= 5.0
Overall Sweet	An aromatic associated with the impression of sweet substances.	Post Shredded Wheat = 1.5 General Mills Wheaties = 3.0 Lorna Doone Cookie = 4.5
Oily	The light aromatics associated with vegetable oil such as corn or soybean oil.	Kroger Slivered and Blanched Almonds = 4.0 HyVee Dry Roasted and Salted Macadamia Nuts = 9.0
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 1/2 minutes. Let cool and serve in individual covered cups.
Oxidized	The aromatic associated with aged or highly used oil and fat.	Microwave Oven Heated Wesson Vegetable Oil = 6.0 Preparation: Add 300ml of oil from a newly purchased and opened bottle of Wesson Vegetable Oil to a1000mlglass beaker. Heat in the microwave oven on high power for 3 minutes. Remove from microwave and let sit at room temperature to cool for approximately 25 minutes. Then heat another 3 minutes, let cool another 25 minutes, and heat for one additional 3 minute interval. Let beaker sit on counter uncovered overnight.

Astringent	A feeling of a puckering or a tingling sensation on the surface and/or edge of the tongue and mouth.	0.030% Alum solution = 1.5 0.050% Alum solution = 2.5 0.075% Alum solution = 3.5 0.10%Alum solution = 5.0
Bitter	A fundamental taste factor of which caffeine is typical.	0.010%CaffeineSolution = 2.0 0.020%CaffeineSolution = 3.5 0.035%CaffeineSolution = 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
Firmness	The amount of force required to bite the sample until molars meet. This is measured by placing the sample between molars and biting down one time.	Kraft Mild Cheddar Cheese = 5.0 Wonder English Muffin = 7.5 Preparation: Cheddar cheese: cut into ½" cubes, serve 3 pieces in 1 oz cup. Muffin: Serve ½ piece of the bottom in Ziploc bag
Tooth Packing	The amount of sample packed in and between the molar teeth after swallowing.	Cheerios = 3.5 Wheaties = 7

Particles	The amount of small pieces of sample remaining in mouth just after swallowing. This does not incorporate tooth packing and refers only to particulate matter on mouth surfaces other than in and between the molar teeth.	Cheerios = 3.0 Wheaties = 7.0

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

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 pecans used for raw evaluation were removed from the freezer the afternoon prior to testing and allowed to thaw at room temperature (23C ± 1C) prior to evaluation. The pecans used for roasted evaluation were removed from the freezer two days prior to testing and allowed to thaw at room temperature (23C ± 1C). The pecans were roasted the afternoon before evaluation. 100 g of each cultivar was placed on separate baking sheets and roasted at 176C for a total of 10 minutes. The pecans were mixed after 5 minutes, and after 8 minutes. After the roasting process the pecans were allowed to cool to ambient temperature (23C ± 1C).

The morning of evaluation each panelist was served 10 g of each cultivar in a plastic 92 g cup with plastic lid (Solo Cup Company, Lake Forest, IL, USA). The cups were labeled with a three-digit blinding code. The evaluation was conducted under ambient lighting and temperature conditions. The panelists evaluated attribute intensities using 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 *et al.* 2014, Miller *et al.* 2013, Suwonsichon *et al.* 2012). A tray with references for the flavor attributes (Table 3-1) was provided for each panelist along with definition/reference sheets. A quarter piece of pecan was determined appropriate to ensure approximately equal sampling amounts for attribute intensity scoring. 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. One replication of the pecan samples was completed over a two-day period. Eight samples, or half a replication, was completed in 1 day during a 120 min evaluation session. Total of 6 days of testing was conducted. This was repeated with the sixteen roasted pecan samples.

Statistical Analysis

Analysis of variance (ANOVA) was performed to test the significance of each flavor attribute across cultivars at the 5% level of significance. Using a Fisher's protected least significant difference (LSD) test, post-hoc means separation was also analyzed at the 5% level of significance. Statistical analysis was performed with SAS® statistical software (SAS® version 9.3, SAS Institute Inc., Cary, NC, USA) using PROC MIXED.

Principal Components Analysis (PCA) using the covariance matrix to evaluate the relationship(s) among attributes and cultivars. A PCA biplot visually depicts the spatial arrangement of the attributes and samples in order to draw conclusions on which attribute(s) describe particular sample(s). R software (R version 3.1.1, Ihaka R. and Gentleman, R., Auckland, New Zealand) was used to perform analysis.

Cluster Analysis (CA) is similar to discriminant analysis. It is used to classify the data into uniquely defined sub groups. A hierarchical clustering graph showcases where the different cultivars fall into subgroups in order to further describe how they are related to one another. R software (R version 3.1.1, Ihaka R. and Gentleman, R., Auckland, New Zealand) was used to perform analysis.

Results and Discussion

Effect of Roasting

Four attributes differed significantly ($P \leq 0.05$) between raw and roasted for all sixteen cultivars. These were pecan ID, overall nutty, brown, and roasted. The roasted pecans had a higher intensity for all four of these attributes, for every cultivar. Flavor attribute differences were measured in a previous study with raw and roasted hazelnuts (Alasalvar *et al.* 2003). Sixteen flavor attributes were assessed (aftertaste, bitter, burnt, coffee/chocolate-like, caramel-like, fruity, green/grassy, nutty, oily, painty, pungent, rancid, roasty, sour, sweet, and woody). There were no significant differences for half of the attributes (Alasalvar *et al.* 2003). In this study, burnt was significantly different for raw and roasted hazelnuts, but had negligible differences for most of the pecan cultivars. This could be due to differences in the nuts, or roasting procedure. Rancidity was not detected in either study. This contrasts with a previous study whose primary focus was comparing oxidative stability of raw and roasted pecans (Erickson *et al.* 1994). In the study comparing oxidative stability, a ‘slight’ rancid flavor was detected in both raw and roasted pecans (Erickson *et al.* 1994).

Nutty woody, nutty grain like and nutty buttery are subsets of the overall nutty attribute (Miller *et al.* 2013). Thirteen or more cultivars were found to be significantly ($P \leq 0.05$) different for all of these nutty attributes. Fifteen of the 16 cultivars were significantly ($P \leq 0.05$) different for the caramelized attribute, all cultivars tested except for ‘Dooley’. All cultivars had at least 8 flavor differences that were significantly ($P \leq 0.05$) different between the raw and roasted treatments. The graphs in Figure 3-1 through Figure 3-9 depict cultivar differences and differences between the intensities of raw and roasted pecans for 9 of the 23 attributes. The intensities of the other eleven flavor attributes have been depicted in Table 3-2 and Table 3-3. Phenolic compounds and fatty acid composition can vary depending on the cultivar (Malik *et al.* 2009). This could have impacted the flavor attributes of oily and nutty-buttery. The basic tastes (astringent, bitter, sweet, and sour) all had intensities under 3.5 (on a scale from 0 to 15). Sweet and sour had intensities under 2.0. Acrid, burnt, oxidized, and rancid all had negligible intensities. The highest intensity level for acrid is a little above 0.5 (on a scale from 0 to 15), the highest for burnt is under 0.20, oxidized is 0.08, and all intensities for rancid were 0.0. When oxidative stability was assessed in a previous study (Erickson *et al.* 1994) no significant differences were found for rancid flavor either.

The three texture attribute intensities for raw and roasted pecans are shown in Table 3-4. There were only several cultivars that were significantly ($P \leq 0.05$) different. Five cultivars were significantly ($P \leq 0.05$) different for firmness ('Oswego', 'Dooley', 'Chickasaw', 'Peruque', and 'Major'). Tooth packing and particles both had two cultivars that were significantly ($P \leq 0.05$) different ('Dooley' and 'Peruque' for Tooth packing and 'Giles' and 'Stuart' for particles).

When the flavor intensities for raw and roasted pecans were compared, it was determined that the intensities for 10 of the 23 attributes (all flavor) were higher for the roasted pecans across all cultivars. These included: pecan ID, overall nutty, nutty woody, nutty grain like, nutty buttery, brown, caramelized, roasted, overall sweet, and sweet. The intensity of 1 attribute (musty earthy) was higher across all cultivars for the raw pecans. Since the rancid characteristic was not present for any cultivar, the intensity (0.0) was equal for raw and roasted.

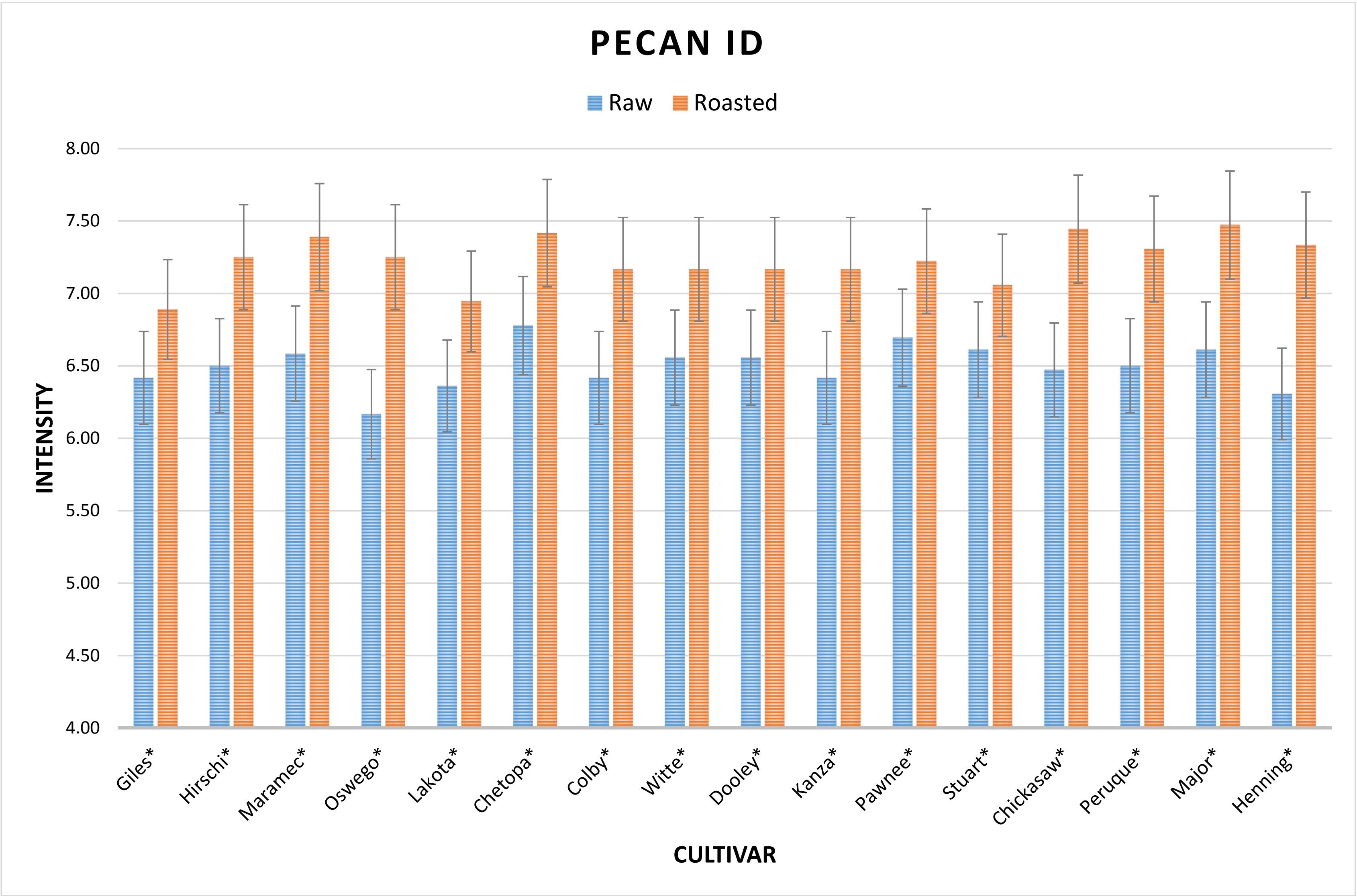

Figure 3-1. Pecan ID attribute intensities for raw and roasted cultivars. *Denotes a cultivar that was significantly different ($P \leq 0.05$) between raw and roasted treatments

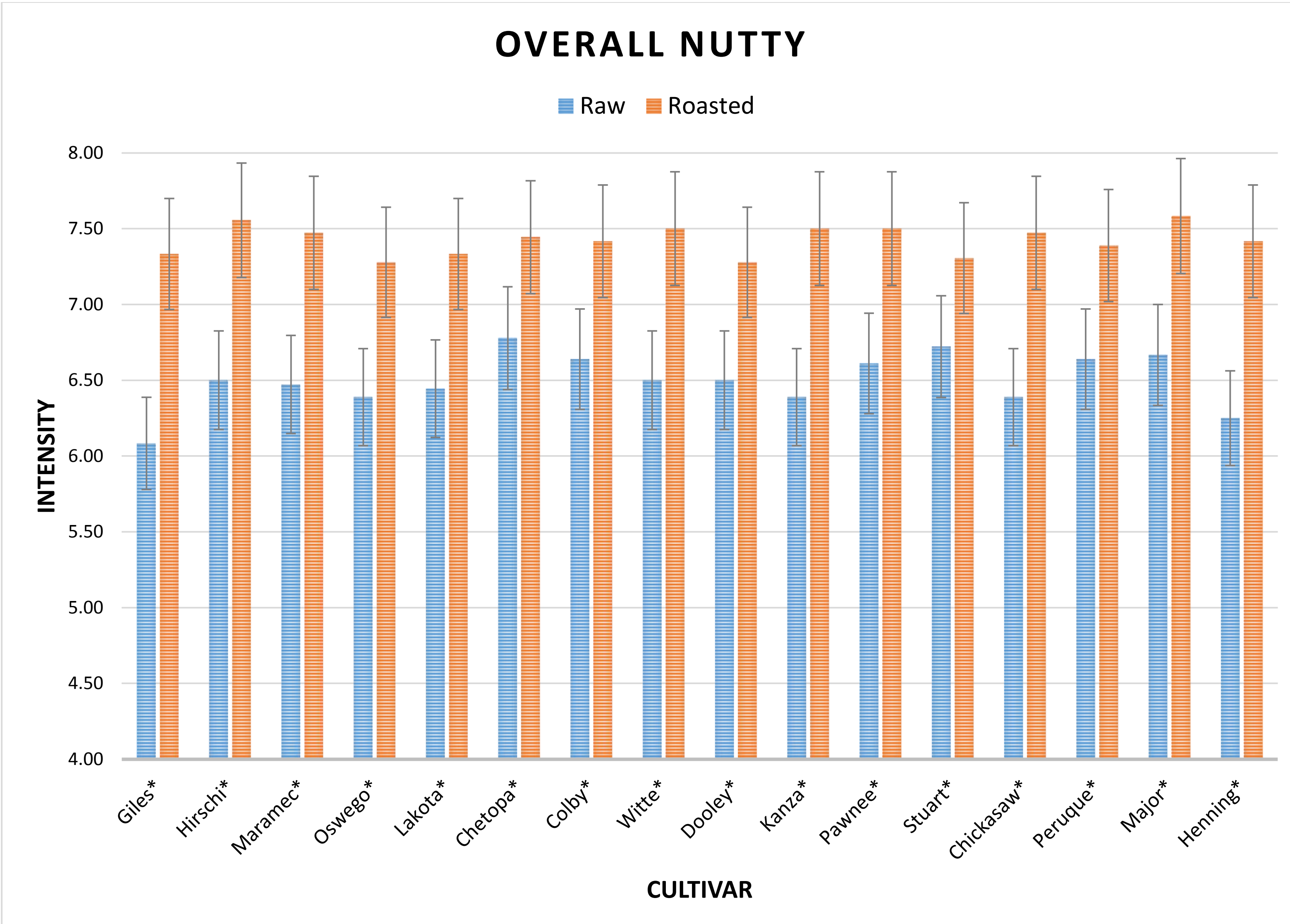

Figure 3-2. Overall Nutty attribute intensities for raw and roasted cultivars . *Denotes a cultivar that was significantly different (P≤0.05) between raw and roasted treatments

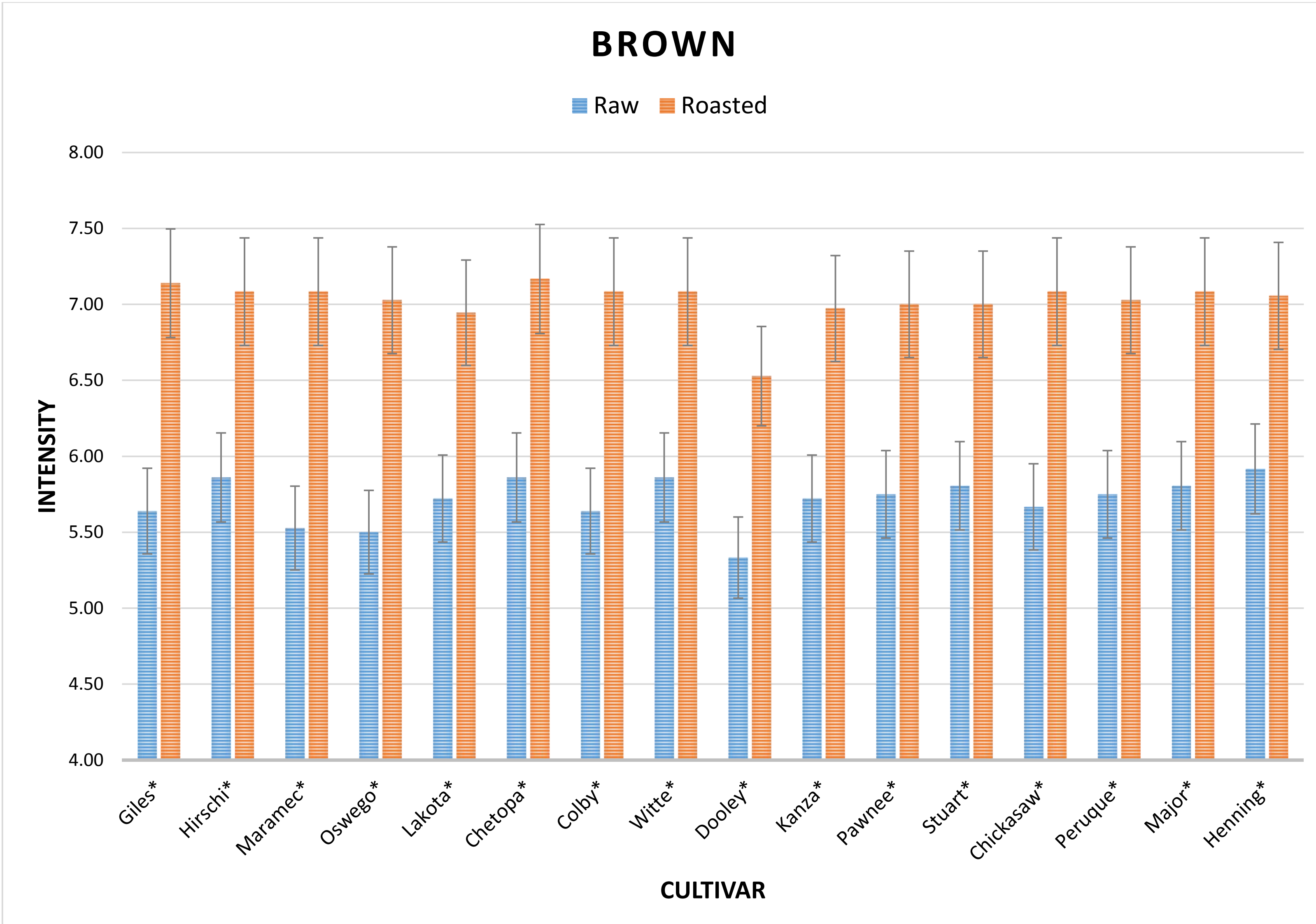

Figure 3-3. Brown attribute intensities for raw and roasted cultivars. *Denotes a cultivar that was significantly different ($P \leq 0.05$) between raw and roasted treatments

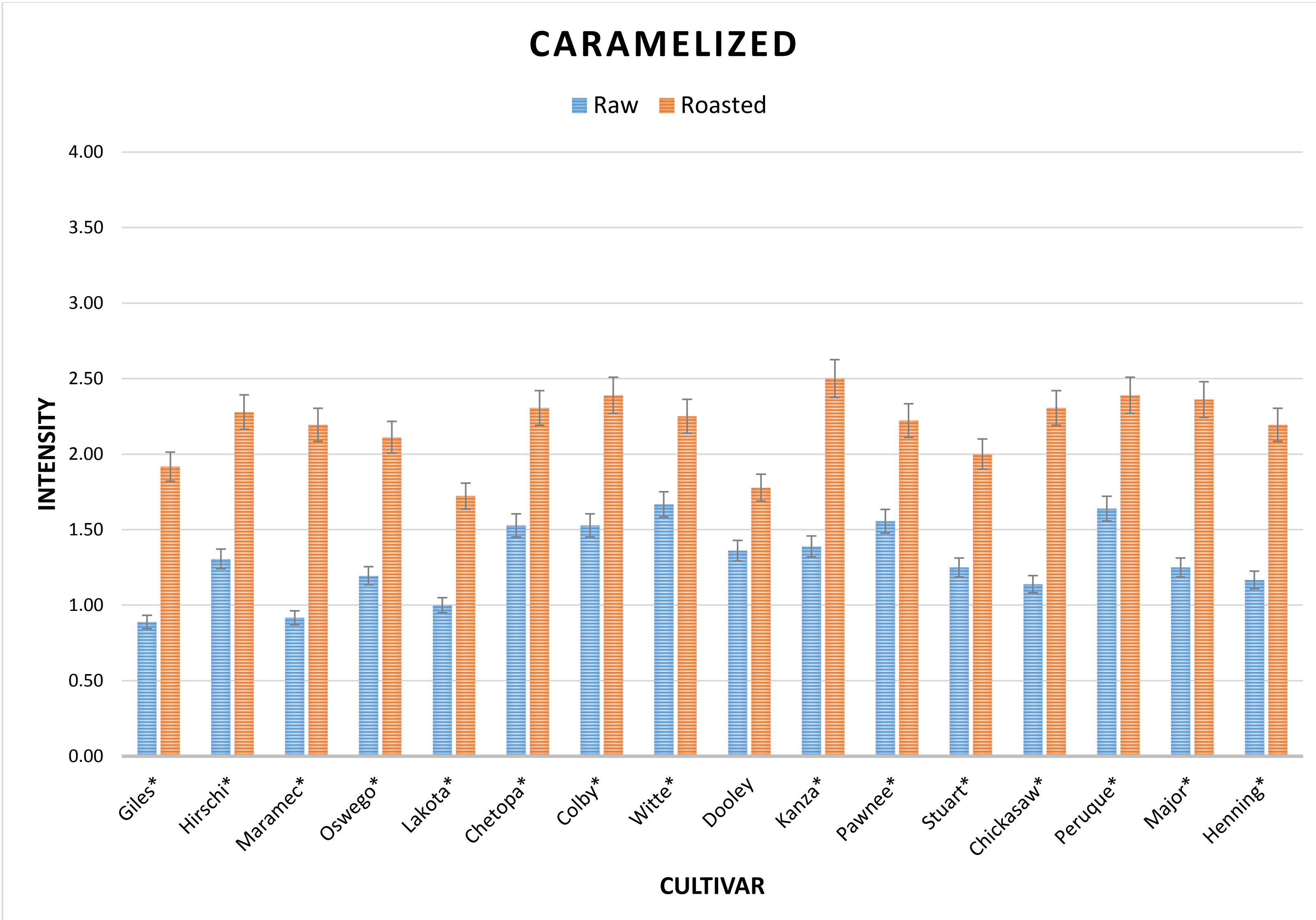

Figure 3-4. Caramelized attribute intensities for raw and roasted cultivars. *Denotes a cultivar that was significantly different ($P \leq 0.05$) between raw and roasted treatments

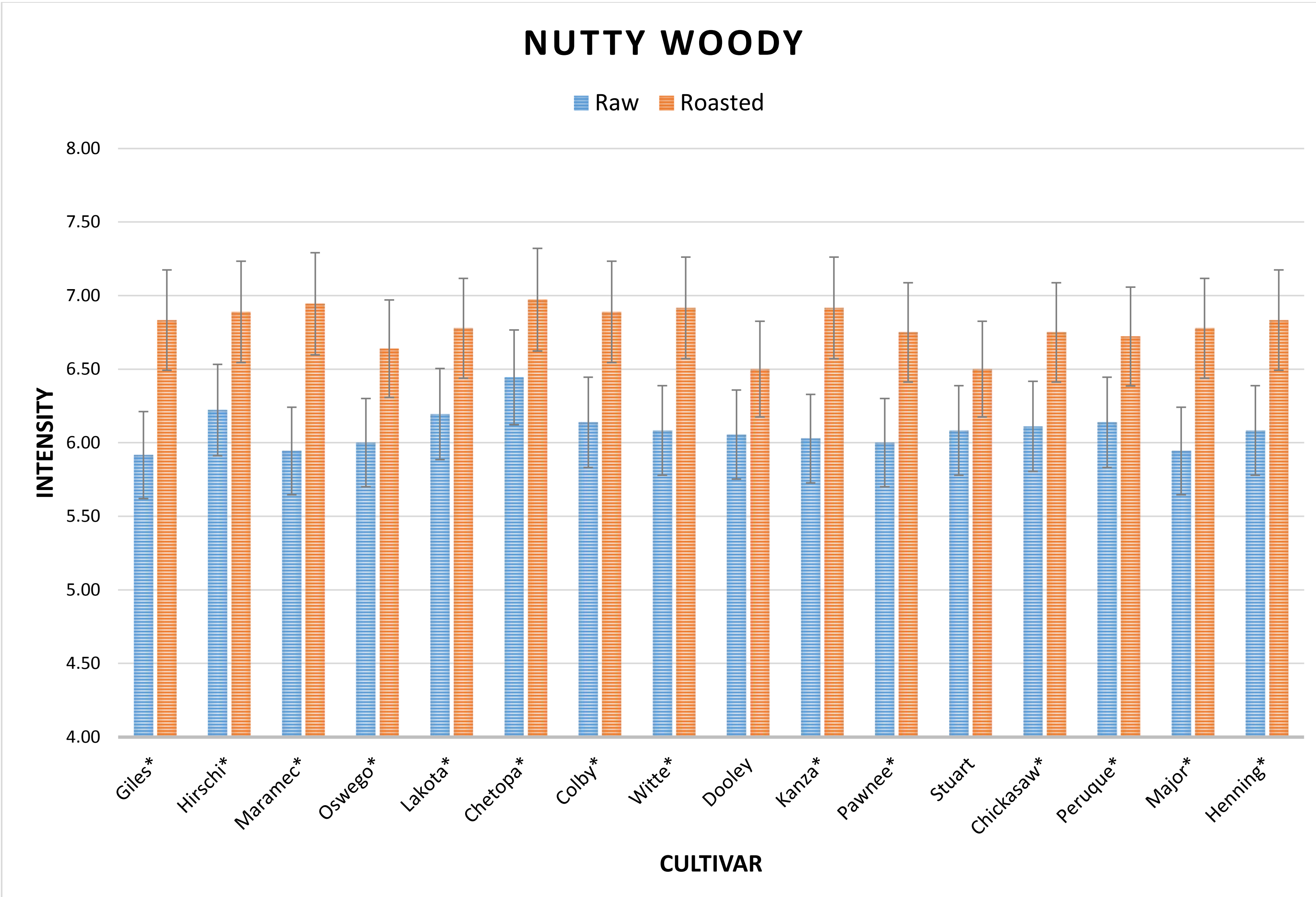

Figure 3-5. Nutty Woody attribute intensities for raw and roasted cultivars . *Denotes a cultivar that was significantly different (P≤0.05) between raw and roasted treatments

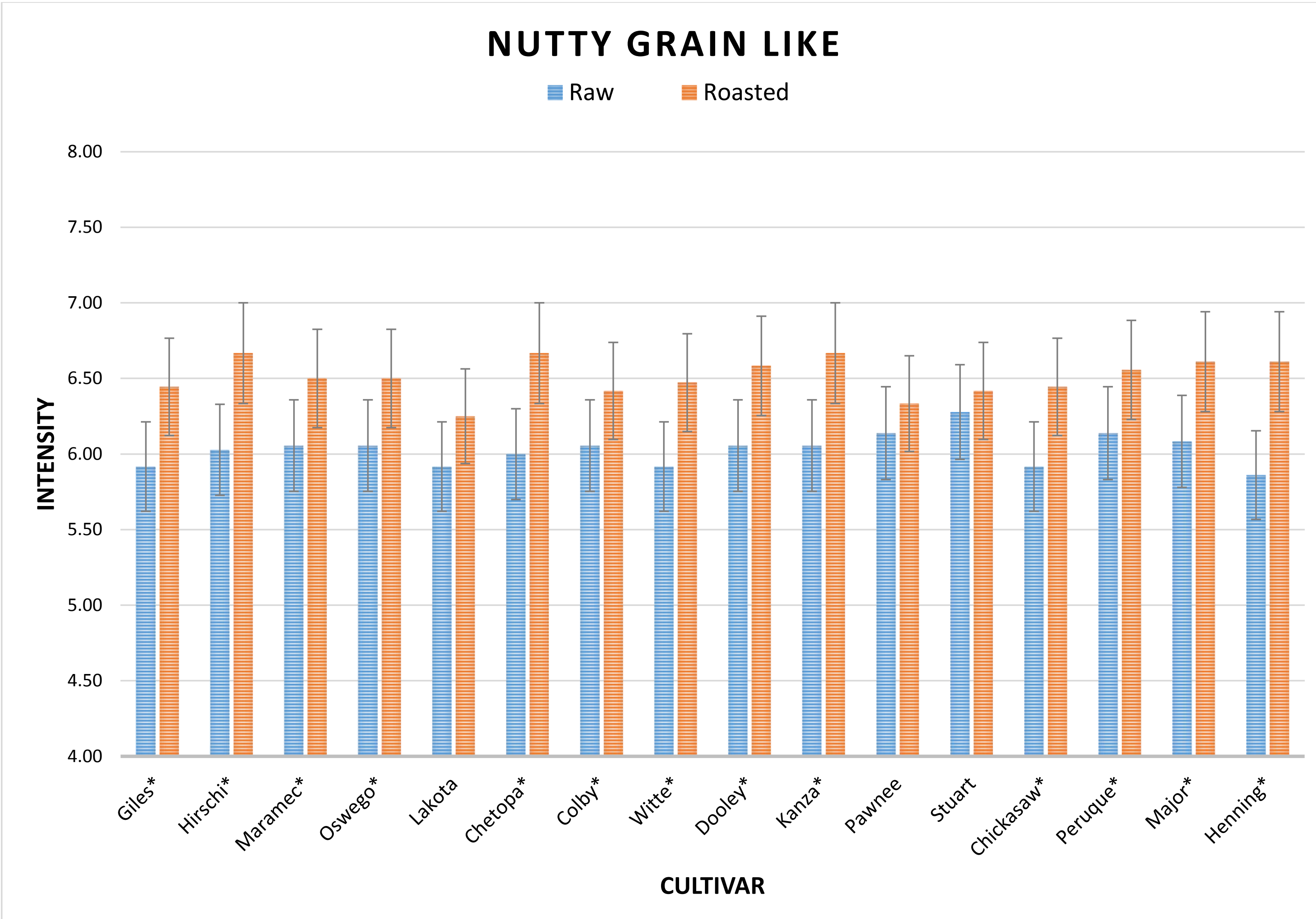

Figure 3-6. Nutty Grain Like attribute intensities for raw and roasted cultivars. *Denotes a cultivar that was significantly different ($P \leq 0.05$) between raw and roasted treatments

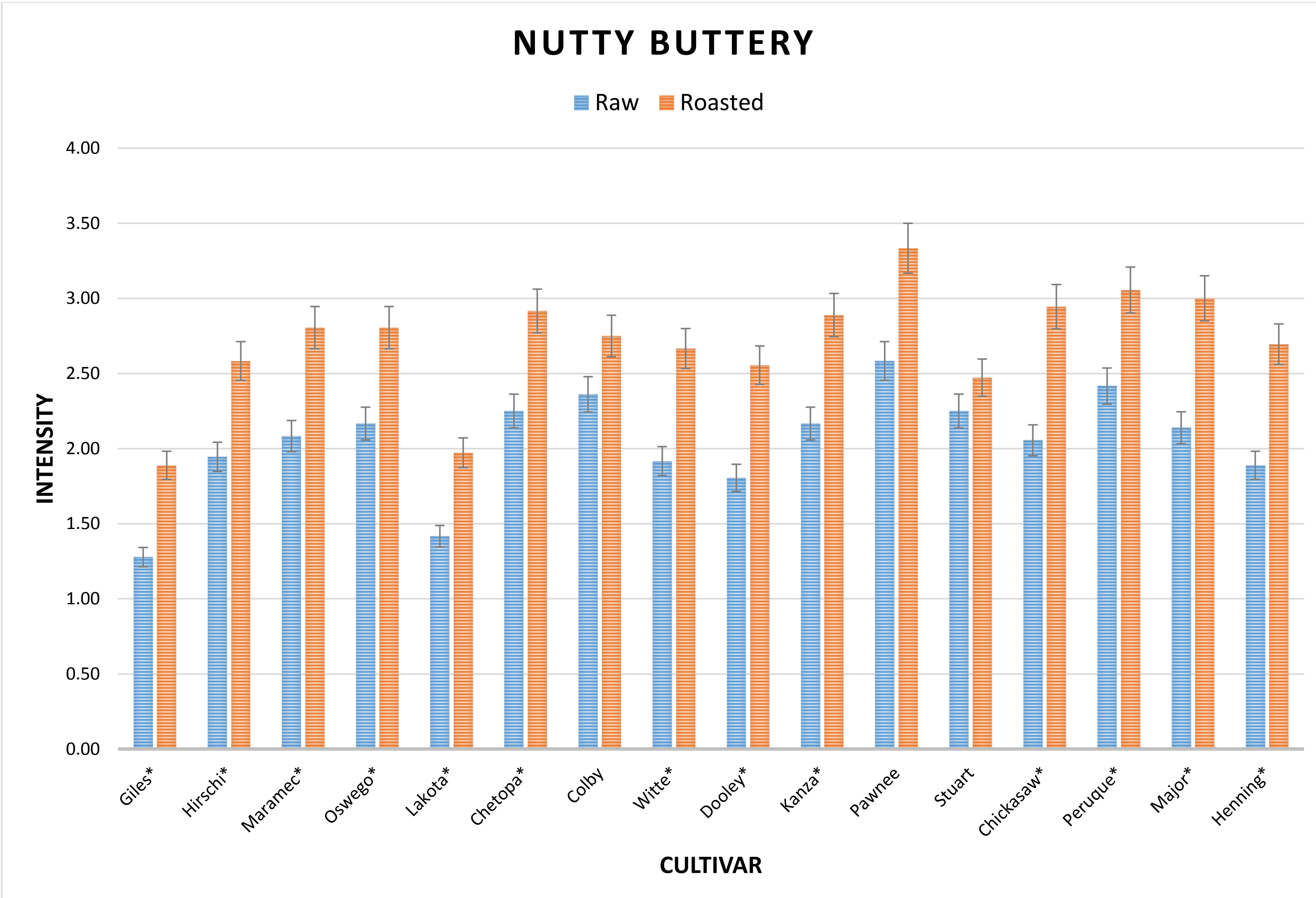

Figure 3-7. Nutty Buttery attribute intensities for raw and roasted cultivars. *Denotes a cultivar that was significantly different (P≤0.05) between raw and roasted treatments

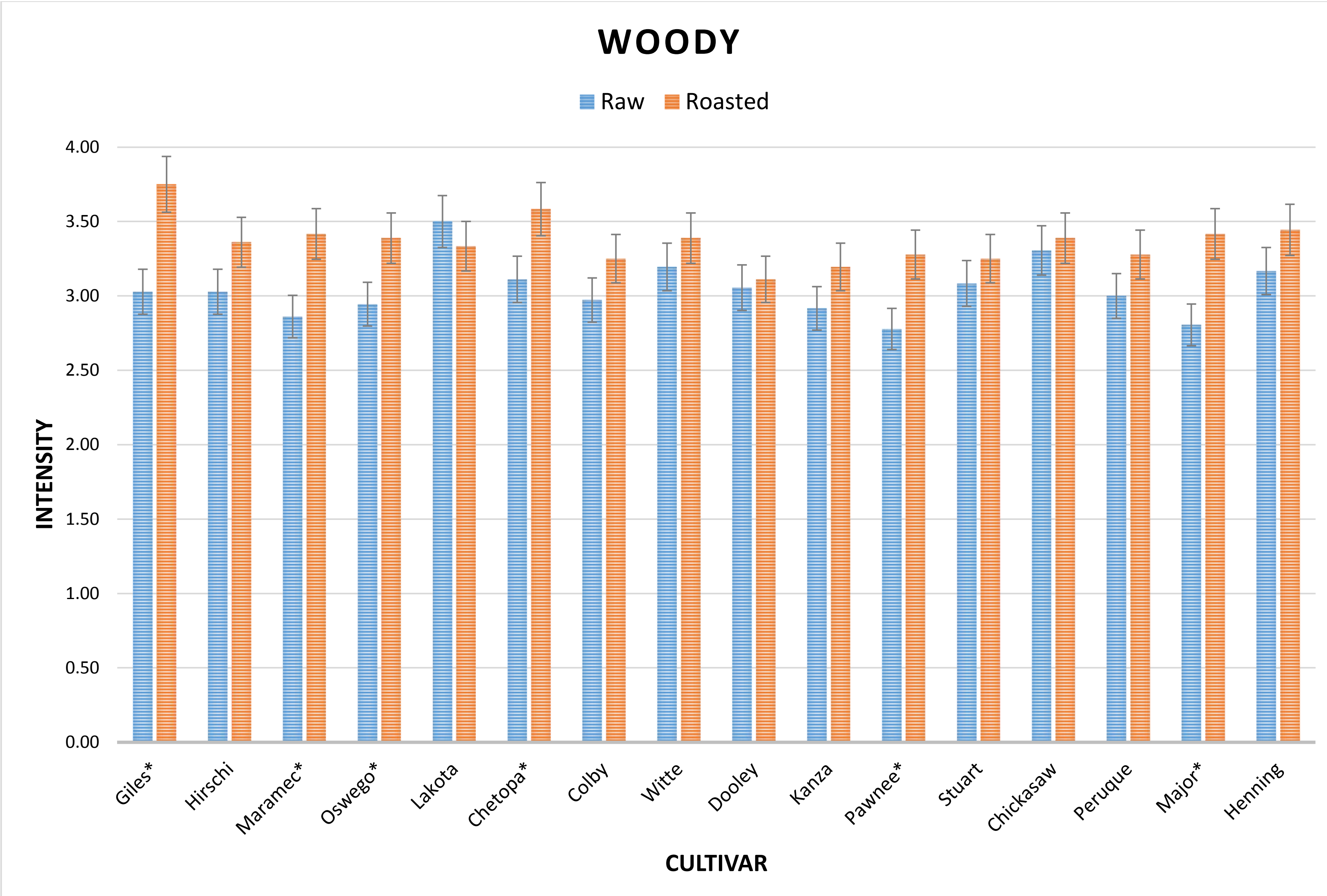

Figure 3-8. Woody attribute intensities for raw and roasted cultivars. *Denotes a cultivar that was significantly different ($P \leq 0.05$) between raw and roasted treatments

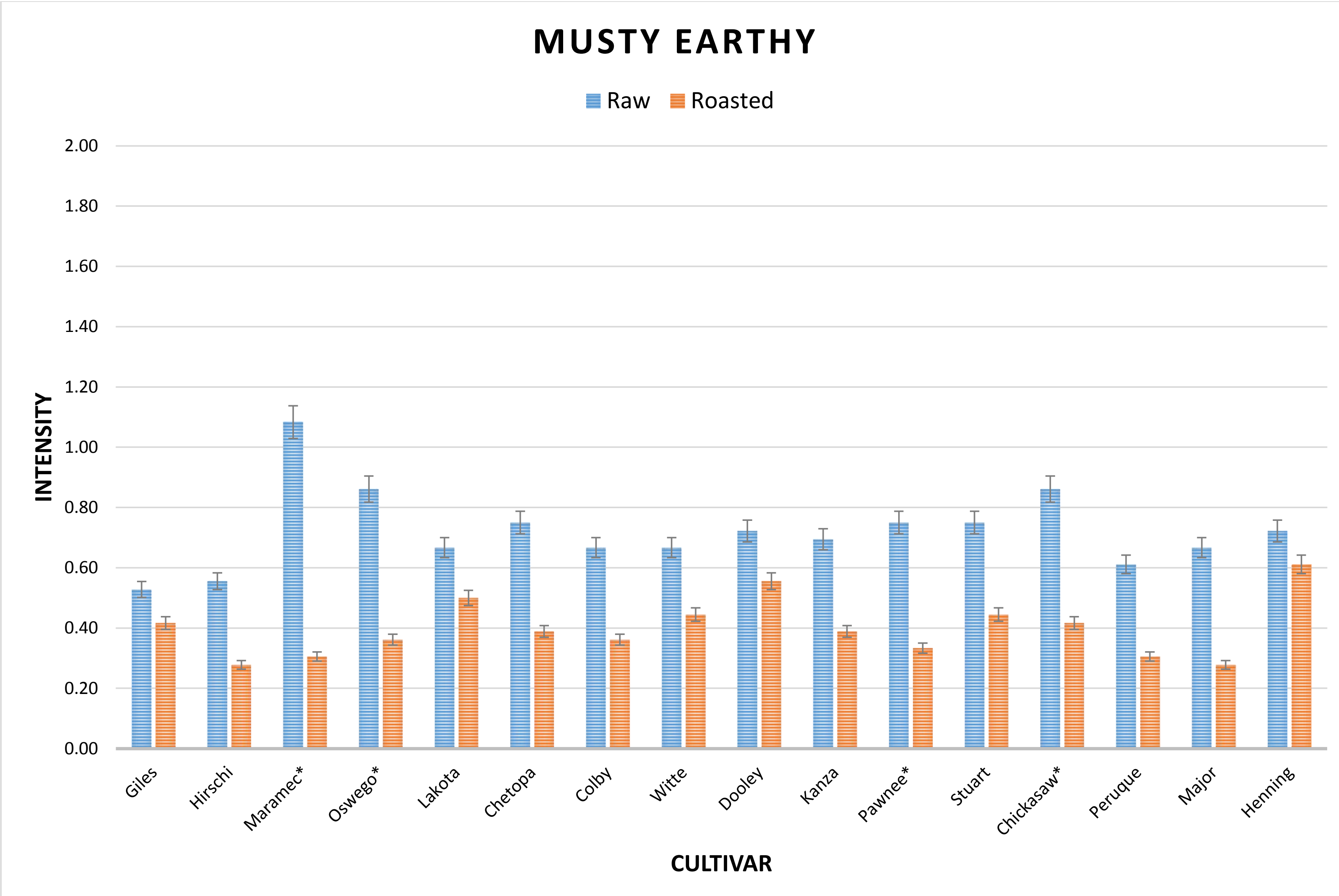

Figure 3-9. Musty Earthy attribute intensities for raw and roasted cultivars. *Denotes a cultivar that was significantly different ($P \leq 0.05$) between raw and roasted treatments

Table 3-2. Mean intensity scores of six flavor attributes, a comparison of raw and roasted for each cultivar *denotes attribute that was significantly different for raw versus roasted at P<0.05.

	Roasted		Overall Sweet		Oily		Rancid		Oxidized		Acrid	
Cultivar	**Raw**	**Roasted**	**Raw**	**Roasted**	**Raw**	**Roasted**	**Raw**	**Roasted**	**Raw**	**Roasted**	**Raw**	**Roasted**
Giles	0.00*	3.92*	1.42*	1.94*	1.75	1.89	0.00	0.00	0.00*	0.08*	0.06	0.28
Hirschi	0.00*	3.69*	1.53*	2.00*	2.36	2.75	0.00	0.00	0.00	0.00	0.06	0.06
Maramec	0.00*	3.61*	1.64*	2.03*	2.50*	3.11*	0.00	0.00	0.00	0.00	0.06	0.22
Oswego	0.00*	3.36*	1.47*	2.06*	2.44*	3.17*	0.00	0.00	0.00	0.00	0.06	0.08
Lakota	0.00*	3.69*	1.50	1.72	1.94	2.11	0.00	0.00	0.00	0.00	0.11*	0.53*
Chetopa	0.00*	3.69*	1.72	1.97	2.47*	3.03*	0.00	0.00	0.00	0.00	0.17	0.25
Colby	0.00*	3.44*	1.61*	1.92*	2.78	3.14	0.00	0.00	0.00	0.00	0.00	0.06
Witte	0.00*	3.69*	1.72*	2.03*	2.25*	2.83*	0.00	0.00	0.00	0.00	0.14	0.11
Dooley	0.00*	2.97*	1.67*	1.97*	2.58	2.72	0.00	0.00	0.00*	0.08*	0.00	0.08
Kanza	0.00*	3.42*	1.67*	2.19*	2.42*	3.11*	0.00	0.00	0.00	0.00	0.11	0.11
Pawnee	0.00*	3.39*	1.81*	2.08*	3.11	3.25	0.00	0.00	0.00	0.00	0.00	0.00
Stuart	0.00*	3.92*	1.75	1.97	2.64	2.64	0.00	0.00	0.00	0.00	0.06	0.25
Chickasaw	0.00*	3.78*	1.67*	2.11*	2.33*	2.92*	0.00	0.00	0.00	0.00	0.14	0.25
Peruque	0.00*	3.58*	1.69*	2.17*	2.94	3.08	0.00	0.00	0.00	0.00	0.00	0.00
Major	0.00*	3.58*	1.58*	2.17*	2.47*	3.06*	0.00	0.00	0.00	0.00	0.00	0.00
Henning	0.00*	3.56*	1.56*	2.03*	2.11*	3.00*	0.00	0.00	0.00	0.00	0.22	0.08

Table 3-3. Mean intensity scores of five flavor attributes, a comparison of raw and roasted for each cultivar *denotes attribute that was significantly different for raw versus roasted at P<0.05.

	Burnt		Astringent		Bitter		Sweet		Sour	
Cultivar	**Raw**	**Roasted**	**Raw**	**Roasted**	**Raw**	**Roasted**	**Raw**	**Roasted**	**Raw**	**Roasted**
Giles	0.00	0.08	2.97	3.14	3.25	3.36	0.78*	1.08*	1.75	1.83
Hirschi	0.00	0.00	2.89	3.03	3.06	3.31	0.83*	1.08*	1.67	1.64
Maramec	0.00	0.00	2.61*	3.14*	2.81*	3.25*	0.86*	1.08*	1.58	1.81
Oswego	0.00	0.00	2.72	2.94	2.89*	3.36*	0.88*	1.06*	1.81	1.75
Lakota	0.00	0.11	3.25	3.14	3.33	3.42	0.78*	1.03*	1.78	1.72
Chetopa	0.00	0.08	2.64	2.97	2.97*	3.47*	1.00	1.00	1.86	1.72
Colby	0.00	0.00	2.75	2.81	3.06	3.00	0.81*	1.03*	1.89*	1.61*
Witte	0.00	0.00	2.94	3.06	3.03*	3.44*	0.86	1.03	1.83	1.78
Dooley	0.00	0.00	2.78*	3.22*	2.81*	3.28*	1.03	1.08	1.78	1.81
Kanza	0.00	0.11	2.89	2.97	2.89*	3.22*	0.92*	1.22*	1.75	1.89
Pawnee	0.00	0.00	2.58	2.86	2.69*	3.08*	1.00	1.11	1.69	1.47
Stuart	0.00*	0.17*	2.81*	3.22*	2.92*	3.44*	0.89	0.97	1.67	1.75
Chickasaw	0.00	0.11	2.94	3.11	2.94	3.19	0.83*	1.08*	1.75	1.75
Peruque	0.00	0.00	2.78	3.00	2.86*	3.28*	0.83*	1.08*	1.61	1.58
Major	0.00	0.00	2.75	3.06	2.81*	3.14*	0.94	1.08	1.50	1.71
Henning	0.00	0.00	2.83	3.08	3.31	3.33	0.75*	1.06*	1.67	1.67

Table 3-4. Mean intensity scores of three texture attributes, a comparison of raw and roasted for each cultivar *denotes attribute that was significantly different for raw versus roasted at P<0.05.

	Firmness		Tooth Packing		Particles	
Cultivar	**Raw**	**Roasted**	**Raw**	**Roasted**	**Raw**	**Roasted**
Giles	8.14	7.92	5.17	4.97	5.81*	6.36*
Hirschi	7.22	7.42	5.25	5.11	5.78	5.83
Maramec	7.50	7.31	5.28	5.00	5.86	6.00
Oswego	7.61*	6.81*	5.28	4.92	5.92	6.14
Lakota	8.33	8.31	5.14	5.28	6.06	6.14
Chetopa	7.47	7.17	5.19	5.31	5.72	6.03
Colby	7.36	7.14	5.14	4.94	5.64	5.86
Witte	7.75	7.33	5.11	5.33	5.97	6.19
Dooley	7.69*	6.86*	5.50*	4.83*	5.69	5.78
Kanza	7.94	7.47	5.22	5.19	5.97	6.06
Pawnee	7.44	6.64	5.25	4.94	5.72	6.03
Stuart	7.61	7.14	5.33	5.03	5.78*	6.11*
Chickasaw	7.97*	7.19*	5.47	5.17	5.92	6.08
Peruque	7.44*	6.81*	5.25*	4.78*	6.11	5.92
Major	7.89*	7.00*	5.39	5.11	5.81	6.03
Henning	7.75	7.47	5.25	5.22	6.14	6.22

Roasted Flavor

Limited research has been done on flavor characteristics of nuts, though Buckholz Jr. *et al.* (1980) assessed the strength of flavor of two different roasted peanut varieties. Differences were found in the flavor intensity for the two varieties, though detailed results were not described. The differences in flavor and texture attribute intensities for the roasted pecan cultivars are displayed in Table 3-5 and Table 3-6. For the current study, eight flavor attributes differed significantly ($P \leq 0.05$) across roasted cultivars. They included nutty buttery, caramelized, acrid, woody, overall sweet, oily, sour, and bitter. Although significant differences ($P \leq 0.05$) were found for almost half the attributes on the ballot, the ranges were fairly small. For example the cultivars differed by less than 0.5 (on a 15 point scale) for overall sweet (greatest difference of 0.47), bitter (greatest difference of 0.47), and sour (greatest difference of 0.42). There were two attributes that differed by more than 1.00 as well, nutty buttery (greatest difference of 1.44) and oily (greatest difference of 1.36). An area of opportunity for future research is to correlate volatiles that develop during roasting and correlate that with flavor characteristics. Volatiles of roasted hazelnuts were studied by Alasalvar, *et al.* 2003. They determined that new volatiles were created and existing volatiles increased when the roasting process occurred. Seventy-one compounds were detected in roasted hazelnuts, including ketones, aldehydes, pyrazines, alcohols, aromatic hydrocarbons, furans, pyrroles, terpenes, and acids (Alasalvar, *et al.* 2003). Nutty, roasty, and fruity aromatics may be caused by ketones, aldehydes, and pyrazines. Chocolate-like aromas may be due to the presence of aldehydes and pyrazines. Sweet aromatics are due to pyrazines, alcohols, and furans (Alasalvar *et al.* 2003).

Most differences in roasted flavor intensities were found for the cultivars ‘Lakota’ and ‘Giles’ compared to other samples. ‘Giles’ had the lowest intensity for nutty buttery and oily ($P \leq 0.05$) and the highest intensity for acrid and woody attributes ($P \leq 0.05$). ‘Lakota’ had the lowest intensity for caramelized and overall sweet attributes ($P \leq 0.05$). ‘Pawnee’ was significantly different from both ‘Stuart’ and ‘Dooley’ for the nutty buttery attribute. ‘Pawnee’ had the highest intensity of all sixteen cultivars for nutty buttery. ‘Kanza’ and ‘Dooley’ were significantly different from each other in the caramelized attribute. ‘Kanza’ had the highest intensity of all sixteen cultivars for caramelized flavor. ‘Kanza’ and ‘Pawnee’ were significantly different from each other in the sour attribute. ‘Kanza’ had the highest intensity for all sixteen cultivars, and ‘Pawnee’ had the lowest. Though there are differences in flavor intensities between the cultivars assessed, they all can still be described as tasting like “pecans”. This is due to the combination or overall impression of the flavor attributes present.

Roasted Texture

Two of the three texture attributes differed significantly ($P \leq 0.05$) across cultivars. The two attributes were firmness and particles. The range for both attributes was relatively small. For particles, the cultivars differed by less than 0.6 (on a scale from 0 to 15). The largest difference between intensities for firmness was less than 1.70. As with the flavor attributes, most of the differences were for ‘Lakota’ and ‘Giles’ as compared to the others samples. During the roasting process the moisture content decreases and oxidation of lipids occurs (Erickson *et al.* 1994). No previous research has been conducted using the attributes of tooth packing and particles. Firmness was assessed in pistachio nuts (Nikzadeh *et al.* 2008) at different roasting temperatures and after storage. It was found that firmness decreased when the temperature of roasting increased. Firmness increased over time, though (Nikzadeh *et al.* 2008). Previous research has evaluated crunchiness in roasted hazelnuts (Saklar *et al.* 2001) and roasted pecans (Erikson *et al.* 1994) and crispness in roasted hazelnuts (Saklar *et al.* 2001). The crunchiness of roasted pecans at different relative humidities were assessed. When the percentage of humidity increased, the crunchiness decreased (Erickson *et al.* 1994). The variables for roasting hazelnuts were altering the air temperature while roasting, the air velocity, and the amount of time roasting. When these three factors increased, the crispness and crunchiness of the roasted hazelnuts increased as well (Saklar *et al.* 2001). Since roasting does have an impact on texture properties of nuts, future studies should be conducted to compare a wider variety of texture attributes, including crispness and crunchiness, and what their intensities are in roasted pecans.

Table 3-5. Mean intensity scores and separation of sensory attributes for sixteen roasted pecan cultivars*

Cultivar	Attributes: Pecan ID	Overall Nutty	Nutty Woody	Nutty Grain like	Nutty Buttery	Brown	Caramelized	Acrid	Burnt	Musty Earthy	Woody
Giles	6.89	7.33	6.83	6.44	1.89^{f}	7.14	1.92^{cd}	0.28^{ab}	0.08	0.42	3.75^{a}
Hirschi	7.25	7.56	6.89	6.67	2.58^{cde}	7.08	2.28^{abc}	0.06^{bc}	0.00	0.28	3.36^{bcd}
Maramec	7.39	7.47	6.94	6.50	2.81^{bcde}	7.08	2.19^{abc}	0.22^{bc}	0.00	0.31	3.42^{bcd}
Oswego	7.25	7.28	6.64	6.50	2.81^{bcde}	7.03	2.11^{abcd}	0.08^{bc}	0.00	0.36	3.39^{bcd}
Lakota	6.94	7.33	6.78	6.25	1.97^{f}	6.94	1.72^{d}	0.53^{a}	0.11	0.50	3.33^{bcd}
Chetopa	7.42	7.44	6.97	6.67	2.92^{abcd}	7.17	2.31^{abc}	0.25^{bc}	0.08	0.39	3.58^{ab}
Colby	7.17	7.42	6.89	6.42	2.75^{bcde}	7.08	2.39^{ab}	0.06^{bc}	0.00	0.36	3.25^{cd}
Witte	7.17	7.50	6.92	6.47	2.67^{bcde}	7.08	2.25^{abc}	0.11^{bc}	0.00	0.44	3.39^{bcd}
Dooley	7.17	7.28	6.50	6.58	2.56^{de}	6.53	1.78^{d}	0.08^{bc}	0.00	0.56	3.11^{d}
Kanza	7.17	7.50	6.92	6.67	2.89^{bcde}	6.97	2.50^{a}	0.11^{bc}	0.11	0.39	3.19^{cd}
Pawnee	7.22	7.50	6.75	6.33	3.33^{a}	7.00	2.22^{abc}	0.00^{c}	0.00	0.33	3.28^{bcd}
Stuart	7.06	7.31	6.50	6.42	2.47^{e}	7.00	2.00^{bcd}	0.25^{bc}	0.17	0.44	3.25^{cd}
Chickasaw	7.44	7.47	6.75	6.44	2.94^{abcd}	7.08	2.31^{abc}	0.25^{bc}	0.11	0.42	3.39^{bcd}
Peruque	7.31	7.39	6.72	6.56	3.06^{ab}	7.03	2.39^{ab}	0.00^{c}	0.00	0.31	3.28^{bcd}
Major	7.47	7.58	6.78	6.61	3.00^{abc}	7.08	2.36^{ab}	0.00^{c}	0.00	0.28	3.42^{bcd}
Henning	7.33	7.42	6.83	6.61	2.69^{bcde}	7.06	2.19^{abc}	0.08^{bc}	0.00	0.61	3.44^{abc}

*Means with different superscripts within a column are significantly different (P<0.05) according to Fisher's protected least significant difference (LSD) test

Table 3-6. Mean intensity scores and separation of sensory attributes for sixteen roasted pecan cultivars*; A continuation of Table 3-5

	Attribute											
Cultivar	**Roasted**	**Overall Sweet**	**Oily**	**Rancid**	**Oxidized**	**Astringent**	**Bitter**	**Sour**	**Sweet**	**Firmness**	**Tooth Packing**	**Particles**
Giles	3.92	1.94^{bcd}	1.89^{f}	0.00	0.08	3.14	3.36^{abc}	1.83^{ab}	1.08	7.92^{a}	4.97	6.36^{ab}
Hirschi	3.69	2.00^{abc}	2.75^{cde}	0.00	0.00	3.03	3.31^{abc}	1.64^{bcd}	1.08	7.42^{bcd}	5.11	5.83^{bcd}
Maramec	3.61	2.03^{abc}	3.11^{abcd}	0.00	0.00	3.14	3.25^{abcd}	1.81^{abc}	1.08	7.31^{cde}	5.00	6.00^{cde}
Oswego	3.36	2.06^{abc}	3.17^{ab}	0.00	0.00	2.94	3.36^{abc}	1.75^{abc}	1.06	6.81^{ef}	4.92	6.14^{ef}
Lakota	3.69	1.72^{d}	2.11^{f}	0.00	0.00	3.14	3.42^{ab}	1.72^{abc}	1.03	8.31^{a}	5.28	6.14^{a}
Chetopa	3.69	1.97^{abc}	3.03^{abcde}	0.00	0.00	2.97	3.47^{a}	1.72^{abc}	1.00	7.17^{cdef}	5.31	6.03^{cdef}
Colby	3.44	1.92^{cd}	3.14^{abc}	0.00	0.00	2.81	3.00^{d}	1.61^{bcd}	1.03	7.14^{cdef}	4.94	5.86^{cdef}
Witte	3.69	2.03^{abc}	2.83^{bcde}	0.00	0.00	3.06	3.44^{a}	1.78^{abc}	1.03	7.33^{cde}	5.33	6.19^{cdef}
Dooley	2.97	1.97^{abc}	2.72^{de}	0.00	0.08	3.22	3.28^{abcd}	1.81^{abc}	1.08	6.86^{def}	4.83	5.78^{def}
Kanza	3.42	2.19^{a}	3.11^{abcd}	0.00	0.00	2.97	3.22^{abcd}	1.89^{a}	1.22	7.47^{bc}	5.19	6.06^{bc}
Pawnee	3.39	2.08^{abc}	3.25^{a}	0.00	0.00	2.86	3.08^{cd}	1.47^{d}	1.11	6.64^{f}	4.94	6.03^{f}
Stuart	3.92	1.97^{abc}	2.64^{e}	0.00	0.00	3.22	3.44^{a}	1.75^{abc}	0.97	7.14^{cdef}	5.03	6.11^{cdef}
Chickasaw	3.78	2.11^{abc}	2.92^{abcde}	0.00	0.00	3.11	3.19^{abcd}	1.75^{abc}	1.08	7.19^{cdef}	5.17	6.08^{cdef}
Peruque	3.58	2.17^{ab}	3.08^{abcd}	0.00	0.00	3.00	3.28^{abcd}	1.58^{cd}	1.08	6.81^{ef}	4.78	5.92^{ef}
Major	3.58	2.17^{ab}	3.06^{abcd}	0.00	0.00	3.06	3.14^{bcd}	1.71^{abc}	1.08	7.00^{cdef}	5.11	6.03^{cdef}
Henning	3.56	2.03^{abc}	3.00^{abcde}	0.00	0.00	3.08	3.33^{abc}	1.67^{abcd}	1.06	7.47^{bc}	5.22	6.22^{bc}

*Means with different superscripts within a column are significantly different ($P<0.05$) according to Fisher's protected least significant different (LSD) test

Roasted Cultivar Effect

A Principal Components Analysis (Figure 3-10) was conducted to display relationships between attributes and cultivars. PC1 explained 36.35% of the variation. The attributes sour, bitter, nutty-buttery, overall sweet, and pecan ID were more highly correlated to this first dimension. PC2 explained 20.21% of the variation. The attributes brown, tooth packing, nutty-woody, woody, and roasted were more highly correlated to this second dimension.

There were several groupings of attributes. The attributes of acrid, burnt, bitter, sour, astringent, musty/earthy, oxidized, firmness, and particles were all in the same region. Three cultivars (‘Giles’, ‘Lakota’, and ‘Stuart’) also fell within this region, meaning that these cultivars exhibited higher intensities of these attributes. The 2013 growing season may have impacted the flavor profiles of these three cultivars. The weather may have had an impact on ‘Giles’ and ‘Stuart’ (Reid 2013). The summer of 2013 had a shortage of summer heat. This shortage caused nut development to be delayed and the kernel filling process was not able to be completed before the cooler temperatures of fall approached (Reid 2013). All cultivars with later ripening times experienced this issue at varying levels. ‘Maramec’ was another cultivar with a later ripening time (Reid 2013). ‘Lakota’ has an inclination to over-produce as the pecan tree ages (Reid 2013). The samples for this study originated from a tree over 30 years old. The kernel does not fill properly when large nut clusters are produced. This can have an effect on the quality of the kernel. This change in quality for the ‘Lakota’ cultivar could influence the intensity of the flavor attributes. This could explain why ‘Lakota’ is significantly different from other cultivars on several attributes. Roasted, tooth packing, and woody formed their own grouping on the graph, though no cultivars fell in the same area. This was also true of the grouping of brown, nutty woody, overall nutty, and caramelized. ‘Dooley’ did not have high correlations with any attribute, causing it to fall in its own area of the graph. The other 12 cultivars all fell in the same region and were near the attributes of nutty grain like, sweet, overall sweet, nutty buttery, oily, and pecan ID. Clustering can show the relationships of the different cultivars to one another by dividing them into sub-groups (Figure 3-11). ‘Lakota’, ‘Giles’, ‘Stuart’, and ‘Dooley’ formed a separate cluster from the other 12 cultivars. This was affirmed in the ANOVA, where significant differences were found for ‘Lakota’ and ‘Giles’ compared to other cultivars.

This study focused primarily on pecan cultivars that are grown in the northern region of the United States. If a wider selection of pecans from other regions were studied this could lead to other potential flavor profiles. The growing season could be another possible limitation. The samples used were from only one growing season so any impact that seasonal variation has on attribute intensities cannot be displayed. The use of one roasting procedure could also be a limiting factor. Future studies could focus on how the temperature and time of roasting could impact the flavor profile of pecans, potentially increasing attribute intensities. A comparison of how raw and roasted pecans change over time could also be studied to determine if processing has an impact on sensory characteristics over time. This would be useful to give a heightened understanding of pecans and cultivar interactions and the acceptable amount of time they should be stored.

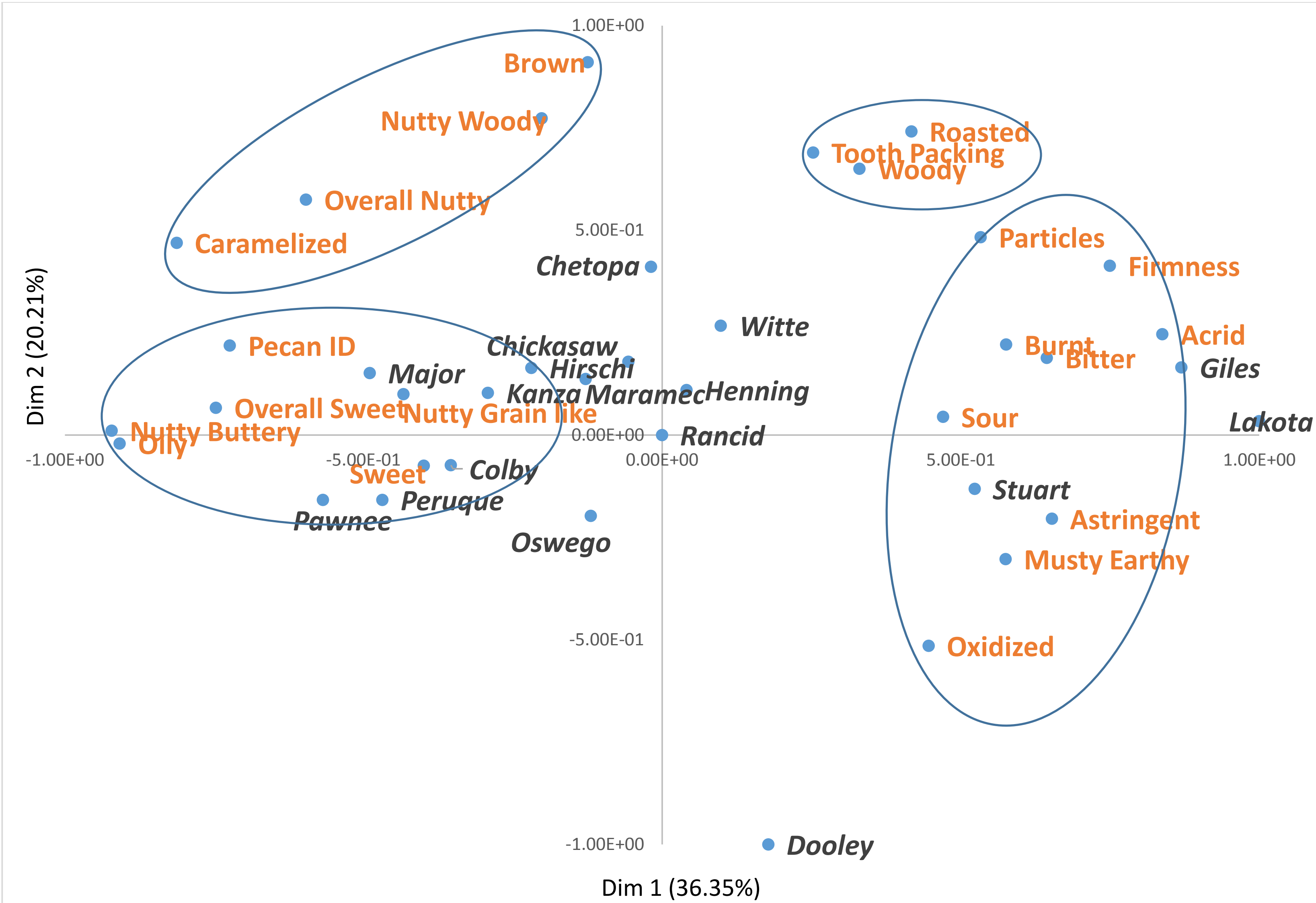

Figure 3-10. Principal components analysis (PCA) biplot showcasing dimensions 1 and 2 for the 16 roasted pecan cultivars and 23 descriptive flavor and texture attributes. Oval groupings around like attributes.

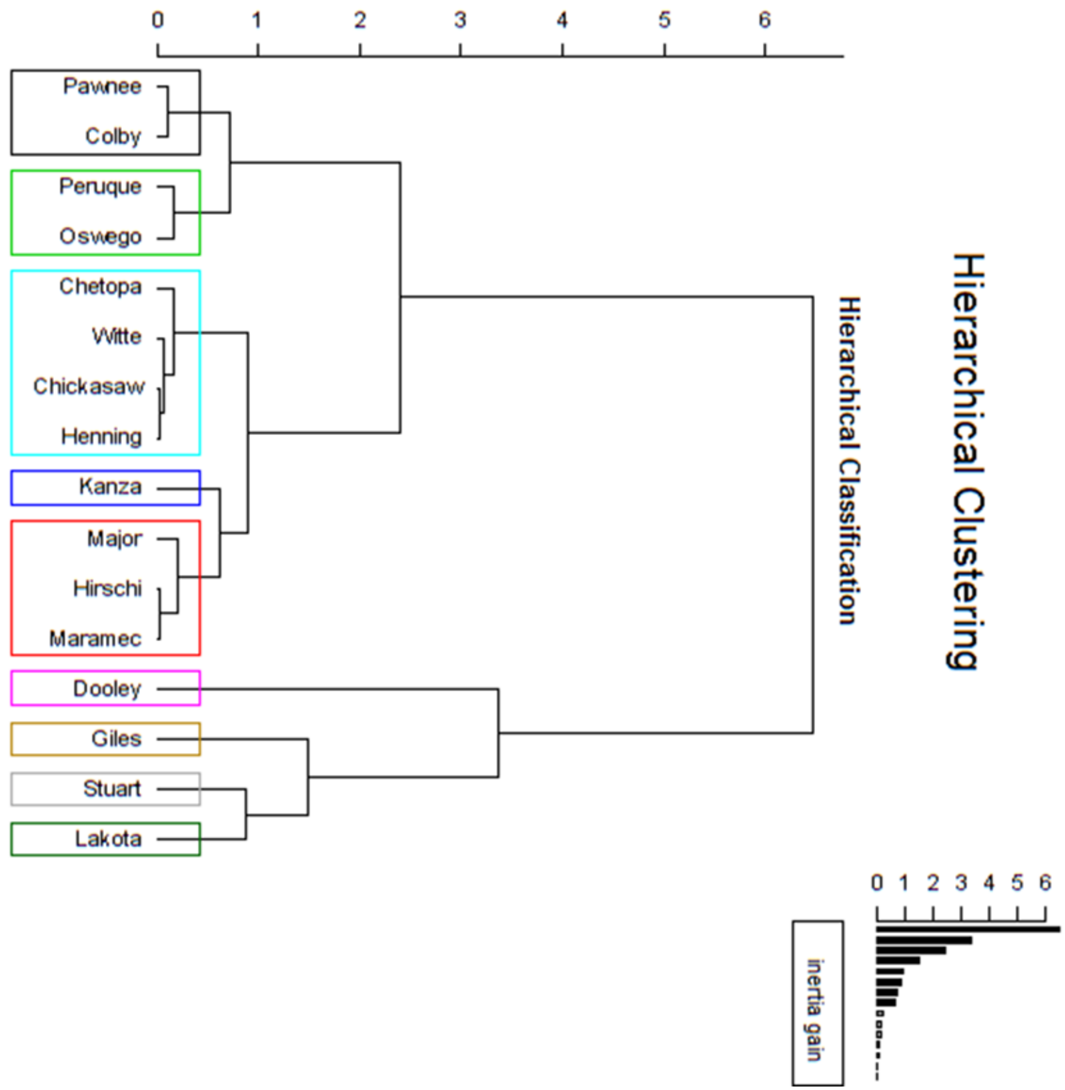

Figure 3-11. Cluster analysis (CA) graph showcasing groupings of the 16 different roasted pecan cultivars based on their flavor profiles.

Conclusions

Roasting does have an effect on flavor and texture characteristics of pecans. Sixteen pecan cultivars were evaluated in this study, both raw and roasted. Roasting had an effect on 4 flavor attributes and had a higher intensity for all 16 cultivars. The attributes that roasting intensified fell into the categories of 'nutty' and 'sweet'. When the roasted cultivars were compared to each other, 8 descriptive flavor attributes and 2 descriptive texture attributes were significantly different across all cultivars. 'Lakota' and 'Giles' differed most often from the other 14 cultivars. Roasting diminished the intensity of musty-earthy, woody, astringent, and bitter attributes for most cultivars. Future research should focus on consumer acceptance evaluation for these cultivars that have been heat treated via roasting. This could help determine acceptance of commonly grown cultivars for commercial production, and how successful this application is for pecans.

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Chapter 4 - Pecan Flavor Changes during Shelf-Life

Abstract

Sixteen pecan 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 access changes in their flavor profiles as kernels age at room temperature. Six trained panelists evaluated four flavor attributes at over 1 year to determine how the flavor of cultivars changed. Results showed that there was an interaction between time and cultivar for rancid, bitter, and sweet. The rancidity, bitterness, and sourness increased over time for all 16 cultivars. The sweetness decreased for all cultivars over time. 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 selecting cultivars for different applications.

Introduction

Pecan (*Carya illinoinensis*) 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 *et al.* 1991). The harvest of nuts from native trees and from short-season, cold-hardy pecan cultivars have created a pecan industry in northern states that is ever increasing (Reid *et al.* 2000). Most of pecan production in northern states is from cultivars that originated from the wild (Reid *et al.* 2000). Pecan farmers assess naturally occurring seedlings, choosing the most productive, thin shelled, and large fruited to be propagated and named (Reid *et al.* 2000). Though cultivar preferences vary with location for northern growers, two cultivars ('Pawnee' and 'Kanza') have been widely grafted (Reid *et al.* 2000). In this study, these two cultivars plus an additional fourteen cultivars commonly grown in northern states were evaluated.

Pecans 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 deteriorate the quality of the pecans (Baldwin *et al.* 2006).

Limited past research has focused on how sensory properties of pecans change over time. Only two previous studies have focused on how storage can have an impact on quality of pecans. Baldwin *et al.* 2006 evaluated the sensory properties of pecans that had different edible coating treatments and how they changed over a 9-month period. Eighteen to twenty panelists were given three kernels of 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 in 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 5 different time points (0 days, 136 days, 157 days, 199 days, 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 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 (23C ± 1C). The pecan shelling was completed over a two-month period using a Duke Pecan Walnut Cracker (Duke Pecan Company, West Point, MS, USA) and Channel Lock model number 436, 15.24 cm cutting pliers (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) and were kept under frozen conditions (-26C ± 1C) to maintain freshness and delay oil oxidation in the nuts (Reid 2011).

Sample Preparation

Five time points (fresh, 3 months, 6 months, 9 months, 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. (22C ± 1 and 50% ± 1 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.

Descriptive Analysis

Six panelists (five female, one male) from the Sensory Analysis Center at Kansas State University in Manhattan, 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 4-1).

Table 4-1. 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 1/2 minutes. Let cool and serve in individual covered cups.
Bitter	A fundamental taste factor of which caffeine is typical.	0.010%CaffeineSolution = 2.0 0.020%CaffeineSolution = 3.5 0.035%CaffeineSolution = 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

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 pecans for the 0 month time point were removed from the freezer the afternoon prior to testing and allowed to thaw at room temperature (23C ± 1C) prior to evaluation. The pecans for the other four time points were removed from the environmental chamber the day of testing.

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 *et al.* 2014; Miller *et al.* 2013; Suwonsichon *et al.* 2012). A tray with references for the flavor attributes was provided for each panelist along with definition/reference sheets. Panelists took 1/4 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 and 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 4 days of testing for each time point.

Statistical Analysis

Analysis of variance (ANOVA) was performed to test the significance of each flavor attribute across cultivars at the 5% level of significance. Cultivar, panelist, and replication were used as sources of variation with panelist and replication as random effects. 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

Rancid Flavor

Four flavor attributes that were evaluated for pecan kernels stored at room temperature for five periods of time: 0 months (fresh), 3 months, 6 months, 9 months, and 12 months. The attributes evaluated were rancid, bitter, sour, and sweet. Since pecans have high oil content, it was important to evaluate how rancidity changed over time (Baldwin *et al.* 2006). The rancid attribute was not present in fresh samples for any of the 16 cultivars. This attribute increased in intensity for every cultivar over 12 months, but the rate at which the intensity increased differed for each cultivar. Figures 4-1 through 4-5 compare the cultivars to one another at each time point. When the cultivars were fresh all 16 did not display the rancid attribute. The rancid attribute was significantly different (P≤0.05) across all cultivars for the 3 month through 12 month time point. At 3 months the rancid attribute was significantly different (P≤0.05) across all 16 cultivars. ‘Colby’, ‘Witte’, and ‘Pawnee’ still do not display the rancid attribute. ‘Maramec’ has the highest rancid intensity in comparison to the other cultivars. At 6 months the rancid attribute as still highest for ‘Maramec’ and lowest for ‘Colby’, ‘Witte’, ‘Kanza’, ‘Pawnee’, ‘Chickasaw’, ‘Peruque’, and ‘Major’. At 9 months ‘Henning’ and ‘Maramec’ had the 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’ and ‘Henning’, ‘Hirschi’, ‘Oswego’, ‘Chetopa’ and ‘Stuart’ all had higher intensities of rancid flavor.

Twelve of the 16 cultivars had significant differences (P≤0.05) in rancid intensity over the 12 months. ‘Maramec’ and ‘Henning’ had a significant (P≤0.05) increase in intensity after 3 months had passed. ‘Giles’, ‘Hirschi’, ‘Oswego’, ‘Chetopa’, and ‘Stuart’ had a significant (P≤0.05) increase in intensity after 6 months had passed. ‘Peruque’ had a significant (P≤0.05) increase in intensity after 9 months. ‘Witte’, ‘Colby’, ‘Pawnee’, and ‘Major’ had a significant (P≤0.05) increase in intensity after 12 months. Previous studies have affirmed this finding that the intensity of rancidity increases over time (Erickson *et al.* 1994, Heaton *et al.* 1975). Though ‘Lakota’, ‘Dooley’, ‘Kanza’, and ‘Chickasaw’ did experience an increase in rancid intensity over time, the increase was not significant (P≤0.05). The mean intensity scores of all cultivars are represented in Table 4-2. It would be beneficial to conduct consumer research at these time points to see if consumers still find these pecan cultivars acceptable with these low levels of rancidity. This research could be done on selected cultivars such as ‘Major’, ‘Kanza’,’Chickasaw’, and ‘Dooley’ which still had low levels of rancidity after 1 year had passed.

Table 4-2. Mean intensity scores and separation of rancid flavor for sixteen pecan cultivars at 5 time points*

Cultivar	Storage (months)				
	0	3	6	9	12
Giles	0.00^{c}	0.06^{c}	1.22^{b}	1.00^{b}	2.31^{a}
Hirschi	0.00^{c}	0.19^{c}	0.94^{b}	1.59^{b}	2.47^{a}
Maramec	0.00^{c}	1.42^{b}	2.81^{a}	2.38^{a}	2.92^{a}
Oswego	0.00^{c}	0.39^{c}	1.44^{b}	1.17^{b}	2.67^{a}
Lakota	0.00	0.11	0.58	0.44	0.47
Chetopa	0.00^{c}	0.53^{c}	1.42^{b}	1.76^{b}	2.78^{a}
Colby	0.00^{b}	0.00^{b}	0.22^{b}	0.29^{b}	1.19^{a}
Witte	0.00^{b}	0.00^{b}	0.14^{b}	0.24^{ab}	0.53^{a}
Dooley	0.00	0.11	0.47	0.74	0.75
Kanza	0.00	0.14	0.19	0.22	0.53
Pawnee	0.00^{b}	0.00^{ab}	0.19^{ab}	0.53^{ab}	1.75^{a}
Stuart	0.00^{c}	0.19^{c}	1.36^{b}	1.65^{b}	2.56^{a}
Chickasaw	0.00	0.08	0.11	0.26	0.41
Peruque	0.00^{c}	0.11^{c}	0.06^{c}	1.03^{b}	2.64^{a}
Major	0.00^{b}	0.08^{b}	0.00^{b}	0.24^{ab}	0.61^{a}
Henning	0.00^{d}	0.75^{c}	2.00^{b}	2.58^{ab}	2.94^{a}

*Means with different superscripts within a row are significantly different ($P \leq 0.05$) according to Fisher's protected least significant difference (LSD) test

Bitter

All pecan cultivars had high bitter intensities in comparison to the other three attributes. Figures 4-1 through 4-5 display how the bitter attribute compares among cultivars at each time point. Bitter is significantly different ($P \leq 0.05$) across all cultivars at every time point. ‘Henning’ has a high intensity of bitter at every time point. At 0 months or “fresh” in addition to ‘Henning’, ‘Lakota’ also has a high intensity. ‘Pawnee’ has the lowest intensity. At 3 months ‘Witte’ has the lowest intensity. ‘Dooley’ has the lowest bitter intensity at 9 months and 12 months. At 9 months ‘Hirschi’ and ‘Maramec’ have higher intensities that are not significantly different ($P \leq 0.05$) from ‘Henning’. At 12 months ‘Oswego’, ‘Stuart’, and ‘Peruque’ have also increased in bitter intensity and have high intensities.

Though the intensity of the bitter attribute was the highest 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 ($P \leq 0.05$) increase in intensity over 12 months. ‘Pawnee’ had a significant ($P \leq 0.05$) increase in bitter intensity after 12 months had passed. ‘Hirschi’, ‘Oswego’, and ‘Peruque’ had a significant ($P \leq 0.05$) increase in intensity after 9 months. ‘Stuart’ had a significant ($P \leq 0.05$) increase after 6 months had passed and ‘Maramec’ had a significant ($P \leq 0.05$) increase in bitter intensity after only 3 months. The mean intensity scores of all cultivars are represented in Table 4-3. A study conducted by Grosso *et al.* (2002) examined how flavor of different peanut samples changed over time. They also determined that the intensity of bitter increased as time increased. Bitter 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 *et al.* 2000). Acquiring 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.

Table 4-3. Mean intensity scores and separation of bitter flavor for sixteen pecan cultivars at 5 time points*

Cultivar	Storage (months)				
	0	3	6	9	12
Giles	3.25	3.19	3.36	3.44	3.69
Hirschi	3.06[b]	3.14[b]	3.44[ab]	3.62[a]	3.78[a]
Maramec	2.81[b]	3.44[a]	3.64[a]	3.59[a]	3.81[a]
Oswego	2.89[c]	3.03[bc]	3.06[bc]	3.42[ab]	3.83[a]
Lakota	3.33	3.14	3.39	3.18	3.31
Chetopa	2.97	3.22	3.25	3.38	3.58
Colby	3.06	2.92	3.19	3.15	3.31
Witte	3.03	2.86	3.08	3.21	3.22
Dooley	2.81	3.08	2.86	3.09	3.11
Kanza	2.89	3.06	3.08	3.14	3.14
Pawnee	2.69[b]	3.06[ab]	3.06[ab]	3.06[ab]	3.42[a]
Stuart	2.92[c]	3.28[bc]	3.58[ab]	3.44[b]	3.94[a]
Chickasaw	2.94	3.11	3.19	3.26	3.06
Peruque	2.86[c]	3.14[bc]	3.00[bc]	3.31[b]	3.86[a]
Major	2.81	3.22	2.94	3.21	3.36
Henning	3.31	3.56	3.72	3.69	3.92

*Means with different superscripts within a row are significantly different ($P \leq 0.05$) according to Fisher's protected least significant difference (LSD) test

Sour

The sour attribute was significantly different ($P \leq 0.05$) across all 16 cultivars at 3 of the 5 time points (3 months, 9 months, and 12 months). How the sour attribute compares among cultivars at each time point is shown in Figures 4-1 through 4-5. 'Henning' has the highest sour intensity at 3 months and has one of the highest at 12 months. 'Pawnee' has the lowest intensity at 3 months. 'Chetopa' has the highest intensity at 9 months and one of the highest at 12 months. 'Colby' has the lowest intensity at 9 months. In addition to 'Henning' and 'Chetopa', 'Oswego' has a high intensity at 12 months that is not significantly different ($P \leq 0.05$) from the other two. 'Chickasaw' has the lowest intensity after a year.

The mean intensity scores of all cultivars for the sour attribute have been presented in Table 4-4. The sour attribute had the second highest intensity for all cultivars for the first 3 months of testing. For the 6 months and 9-month time points it had the second highest intensity for 14 of the 16 cultivars, only 'Maramec' and 'Henning' had higher intensities of the rancid attribute than sour. At 12 months, the intensity of the sour attribute had increased for every cultivar. 'Colby', 'Witte', 'Dooley', and 'Kanza' did not have a significant ($P \leq 0.05$) change in sour intensity throughout the study. 'Giles', 'Oswego', 'Pawnee', and 'Stuart' all had a significant ($P \leq 0.05$) increase in sour intensity after 12 months has passed. 'Hirschi', 'Peruque', 'Lakota', and 'Chetopa' had significant ($P \leq 0.05$) increases in intensity after 9 months. 'Major' had a significant ($P \leq 0.05$) increase in sour intensity after 6 months and 'Maramec' and 'Henning' had a significant ($P \leq 0.05$) increase after just 3 months had passed. Grosso *et al.* (2002) studied how bitterness changes in peanuts, also evaluated the sour flavor. Those researchers found that the sour attribute increases as time increases (Grosso *et al.* 2002), which was again proven in the current study. The perception of sour is related to bitter in that it has an instinctive negative perception by consumers (Clark 1998).

Table 4-4. Mean intensity scores and separation of sour flavor for sixteen pecan cultivars at 5 time points*

Cultivar	Storage (months)				
	0	**3**	**6**	**9**	**12**
Giles	1.75[b]	1.92[b]	1.94[b]	2.00[b]	2.42[a]
Hirschi	1.67[c]	1.86[bc]	1.89[bc]	2.06[ab]	2.28[a]
Maramec	1.58[b]	2.11[a]	2.14[a]	2.06[a]	2.33[a]
Oswego	1.81[b]	1.92[b]	1.94[b]	1.94[b]	2.47[a]
Lakota	1.78[b]	1.69[b]	2.03[ab]	1.85[b]	2.28[a]
Chetopa	1.86[c]	2.06[bc]	1.89[bc]	2.21[ab]	2.50a
Colby	1.89	1.75	1.75	1.71	2.14
Witte	1.83	1.97	1.75	1.91	2.14
Dooley	1.78	1.81	1.83	1.88	2.15
Kanza	1.75	1.81	1.81	1.94	2.19
Pawnee	1.69[b]	1.67[b]	1.72[b]	1.97[b]	2.39[a]
Stuart	1.67[b]	1.92[b]	2.03[b]	2.00[b]	2.44[a]
Chickasaw	1.75	1.83	1.92	2.00	2.06
Peruque	1.61[c]	1.78[bc]	1.83[bc]	2.06[b]	2.44[a]
Major	1.50[c]	1.83[bc]	1.97[ab]	1.91[ab]	2.22[a]
Henning	1.67[c]	2.22[ab]	2.00[b]	2.14[b]	2.47[a]

*Means with different superscripts within a row are significantly different ($P \leq 0.05$) according to Fisher's protected least significant difference (LSD) test

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). Figures 4-1 through 4-5 showcase how the 16 cultivars differed from one another at each time point. Sweetness was significantly different ($P \leq 0.05$) across all cultivars at 9 months and 12 months. ‘Major’ had the highest intensity of sweet at 12 months and one of the highest intensities at 9 months. Seven cultivars were not significantly different ($P \leq 0.05$) from ‘Major’ at 9 months. ‘Chetopa’ had the lowest intensity of sweet at 12 months and one of the lowest intensities at 9 months. Seven cultivars were not significantly different ($P \leq 0.05$) from ‘Chetopa’ at 9 months.

The mean intensity scores of all cultivars for the sweet attribute have been presented in Table 4-5. The sweetness scores remained fairly constant for the first 6 months of testing. Six cultivars (‘Kanza’, ‘Chickasaw’, ‘Major’, ‘Colby’, ‘Witte’, and ‘Dooley’) did not have any significant ($P \leq 0.05$) differences in intensity scores throughout the 12 months. The scores started to decrease at the 9-month mark, 8 cultivars showed significant ($P \leq 0.05$) 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 ($P \leq 0.05$) decrease at the final time point. Grosso *et al.* (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 will be less desirable to consumers who have an inherent preference to sweetness.

Table 4-5. Mean intensity scores and separation of sweet flavor for sixteen pecan cultivars at 5 time points*

Cultivar	Storage (months)				
	0	**3**	**6**	**9**	**12**
Giles	0.78^{a}	0.86^{a}	0.97^{a}	0.38^{b}	0.69^{ab}
Hirschi	0.83^{a}	0.86^{a}	0.78^{a}	0.35^{b}	0.64^{ab}
Maramec	0.86^{a}	0.69^{ab}	0.69^{ab}	0.21^{c}	0.56^{b}
Oswego	0.89^{a}	0.89^{a}	0.86^{a}	0.42^{b}	0.67^{ab}
Lakota	0.78^{ab}	1.08^{a}	0.89^{ab}	0.74^{b}	0.83^{ab}
Chetopa	1.00^{a}	0.81^{a}	0.86^{a}	0.38^{b}	0.33^{b}
Colby	0.81	0.89	0.92	0.65	0.78
Witte	0.86	0.75	0.94	0.65	0.83
Dooley	1.03	0.89	0.94	0.68	0.78
Kanza	0.92	0.92	0.89	0.81	0.89
Pawnee	1.00^{a}	1.03^{a}	0.94^{a}	0.76^{ab}	0.56^{b}
Stuart	0.89^{a}	0.97^{a}	0.86^{a}	0.44^{b}	0.42^{b}
Chickasaw	0.83	0.94	1.06	0.74	0.85
Peruque	0.83^{a}	0.89^{a}	0.92^{a}	0.44^{b}	0.39^{b}
Major	0.94	0.94	0.94	0.85	0.97
Henning	0.75^{a}	0.78^{a}	0.78^{a}	0.28^{b}	0.39^{b}

*Means with different superscripts within a row are significantly different ($P \leq 0.05$) according to Fisher's protected least significant difference (LSD) test.

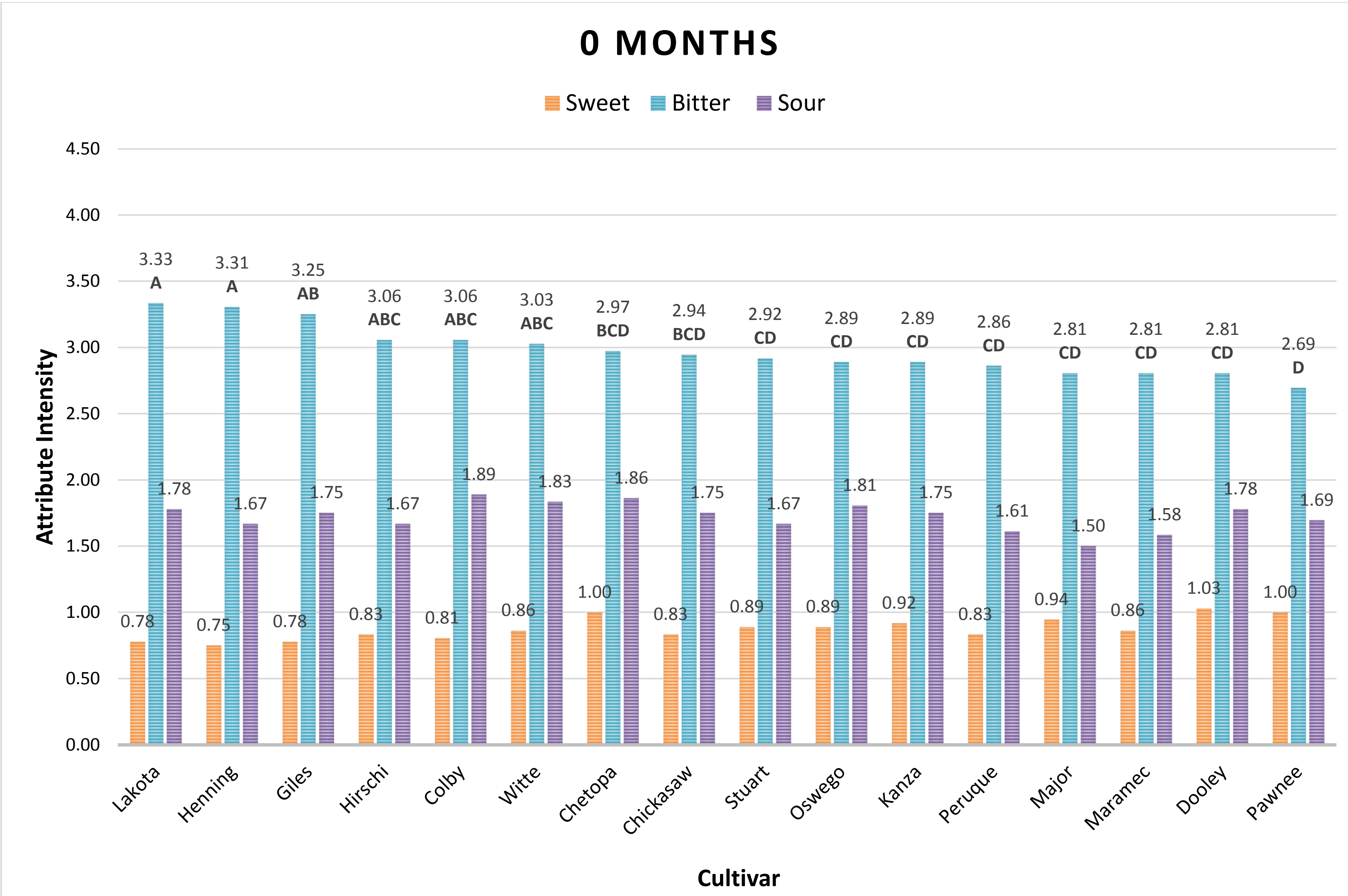

Figure 4-1. Attribute mean intensities and separation of mean scores at the 0 month time point*

*Means with different letters for an attribute are significantly different (P≤0.05) according to Fisher's protected least significant difference (LSD) test; Rancidity was non-existent at this time point

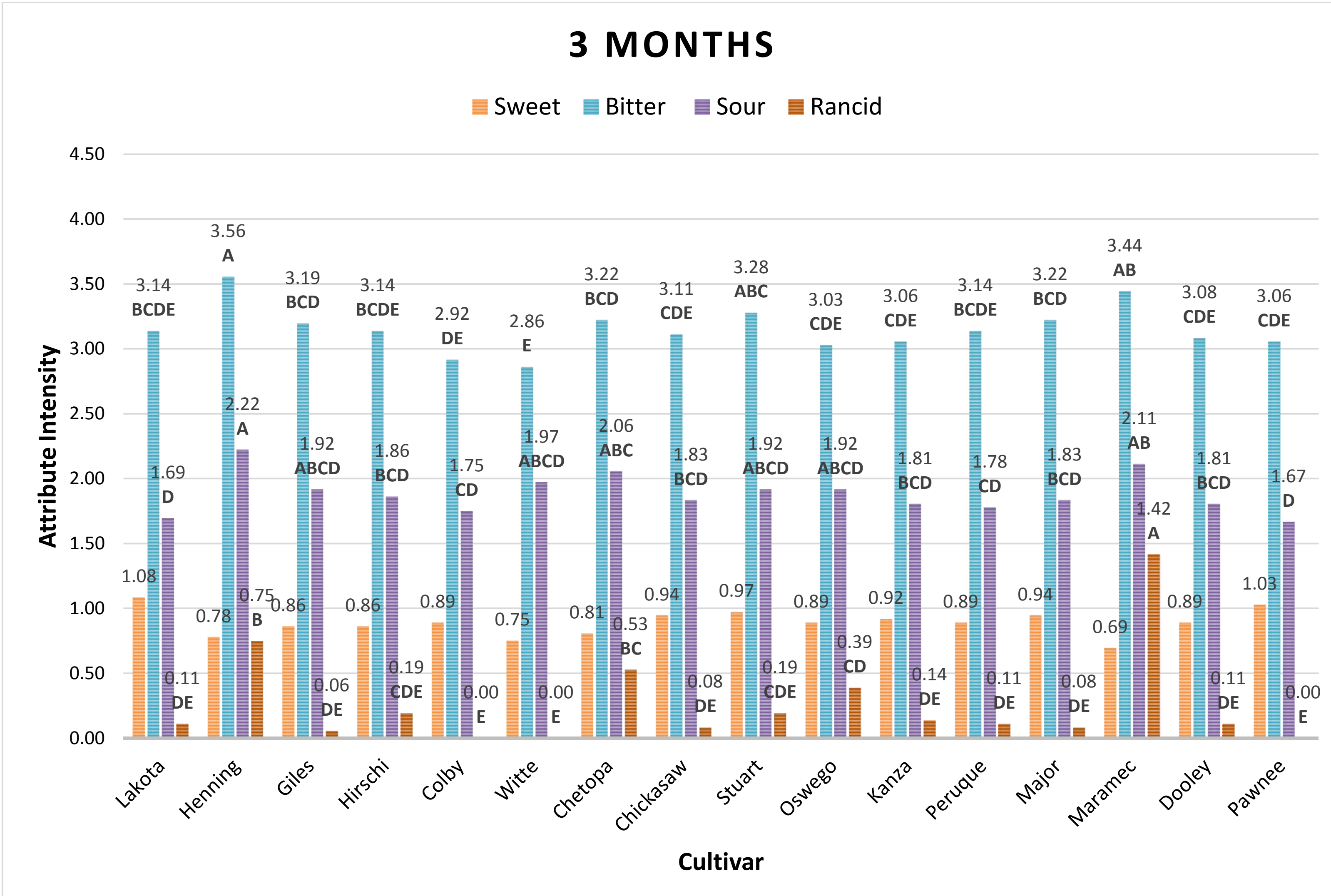

Figure 4-2. Attribute mean intensities and separation of mean scores at the 3 month time point*

*Means with different letters for an attribute are significantly different (P≤0.05) according to Fisher's protected least significant difference (LSD) test

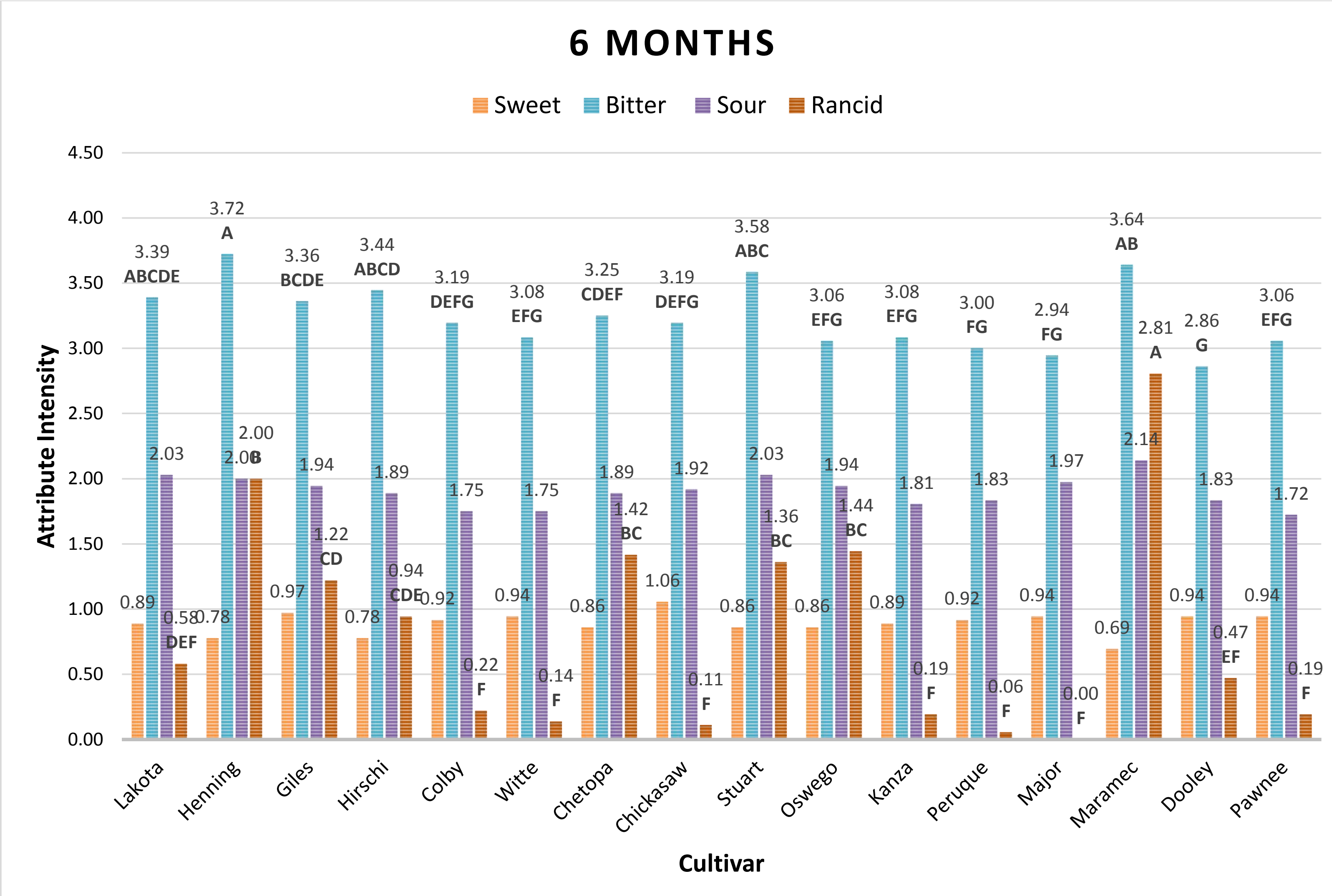

Figure 4-3. Attribute mean intensities and separation of mean scores at the 6 month time point

*Means with different letters for an attribute are significantly different (P≤0.05) according to Fisher's protected least significant difference (LSD) test

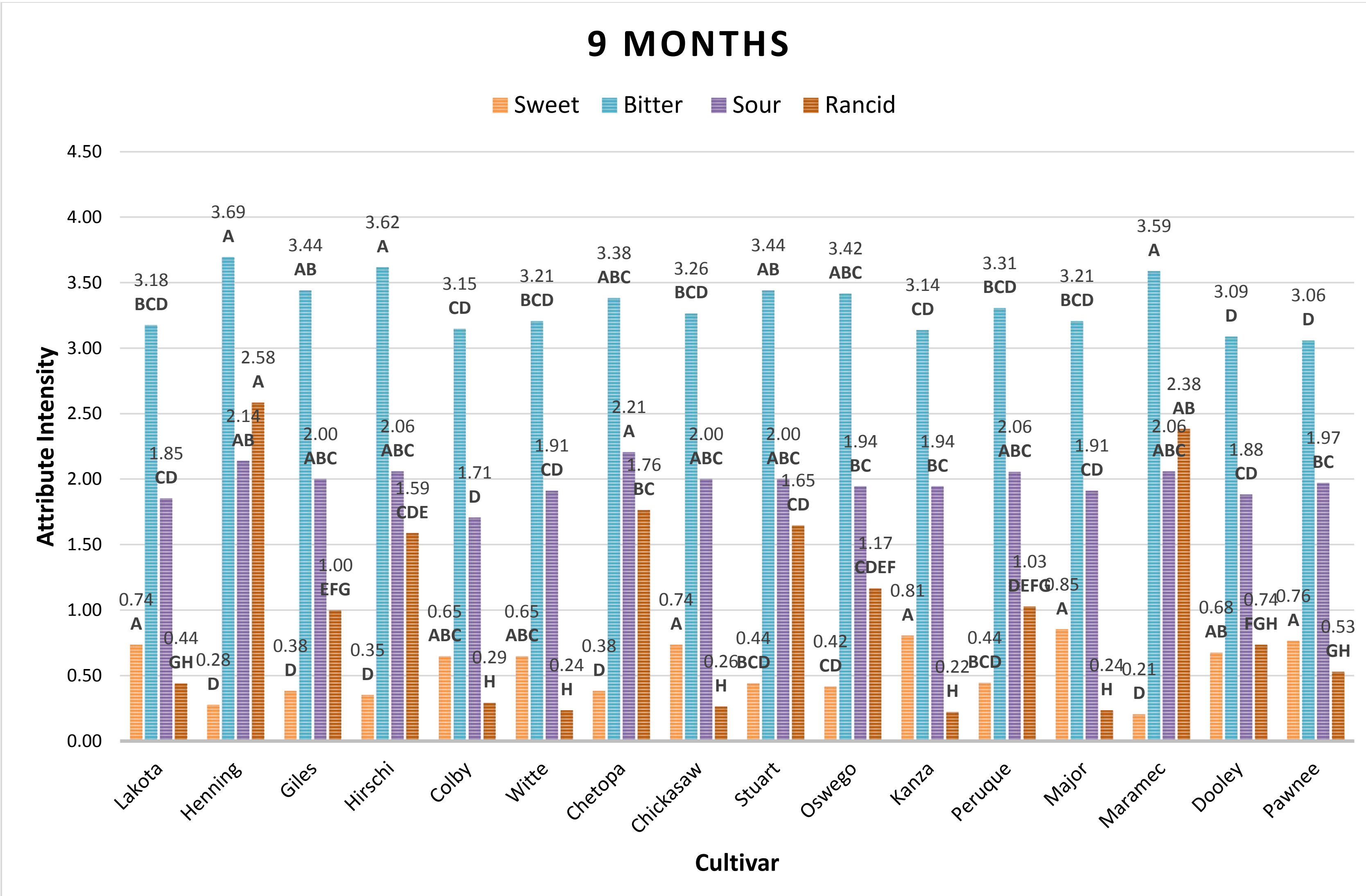

Figure 4-4. Attribute mean intensities and separation of mean scores at the 9 month time point

*Means with different letters for an attribute are significantly different (P≤0.05) according to Fisher's protected least significant difference (LSD) test

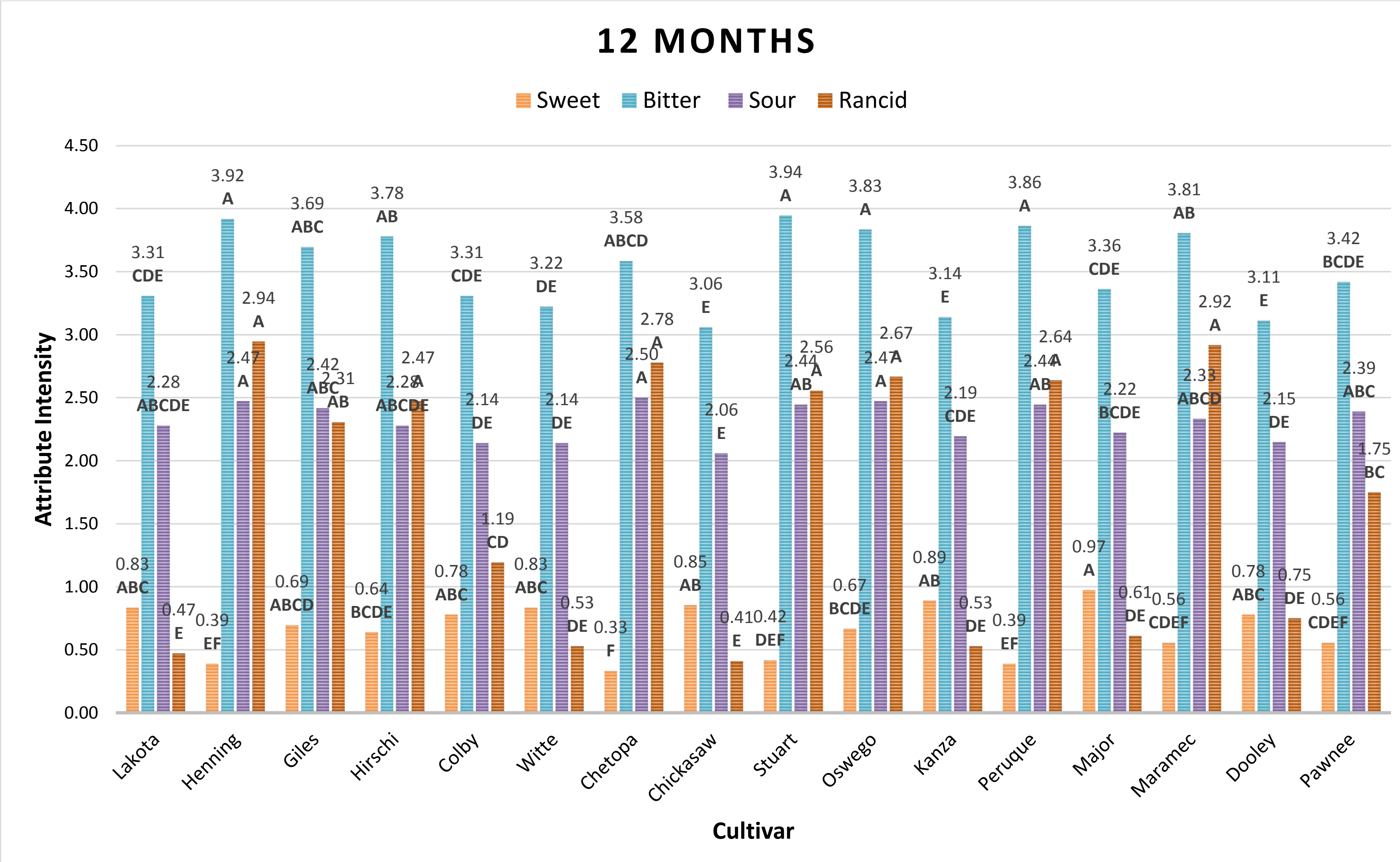

Figure 4-5. Attribute mean intensities and separation of mean scores at the 12 month time point

*Means with different letters for an attribute are significantly different (P≤0.05) according to Fisher's protected least significant difference (LSD) test

The pecan cultivars used in this study were all 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 the understanding. The samples used for this study were all 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 how they 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 *et al.* 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 every time point 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 change over a period of time. The information from this study plus future studies can aid consumers in selecting cultivars for different applications and to help encourage pecan storage to move to a freezer instead of on 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 throughout time for all 16 cultivars. Bitter had the highest intensity for every cultivar at every time point and sweet 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 level of rancidity, bitter, sour, and sweet 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 to be sold commercially.

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Appendix A - SAS® Codes

SAS® Codes for Latin Square Designs

```
dm'log;clear;output;clear;';
TITLE 'Latin Square (REP 1)';
ods rtf;
proc factex;
  factors Block / nlev=6;
  output out=Blocks Block nvals=(1 2 3 4 5 6) randomize(65317);
run;
  factors Treatment / nlev=11;
  output out=RCBD
      designrep=Blocks
      randomize(65317)
      Treatment cvals=('A' 'B' 'C' 'D' 'E' 'F' 'G' 'H' 'I' 'J' 'K');
run;
quit;
proc print data=RCBD;
run;
ods rtf close; quit;
```

Notes

1. The five digit randomize number was changed for each repetition for all phases of the descriptive testing (raw pecans, roasted pecans, and shelf life pecans) to generate unique Latin Square Designs.

SAS® Codes for Analyzing Descriptive Test Data (For Raw, Roasted, and Shelf Life Evaluations)

```
dm 'log;clear;output;clear;';
options nodate nonumber;
data (data name);
input Cultivar$ Panelist$ Rep$ atr1 atr2 atr3 atr4 atr5 atr6 atr7 atr8 atr9 atr10 atr11 atr12 atr13
atr14 atr15 atr16 atr17 atr18 atr19 atr20 atr21 atr22 atr23;
cards;
(input raw data here)
;
ods rtf;
proc mixed data= (data name) covtest cl;
class rep panelist cultivar;
model atr# = cultivar/outp = (data name);
```

```
title '(attribute name)';
random rep panelist;
lsmeans cultivar/cl pdiff;
ods output diffs=ppp lsmeans=mmm;
run;

ods rtf close;
quit;
```

Notes

1. The number of “atr#” input variables corresponds to the number of attributes on the respective ballots (i.e. 20 attributes for raw pecans, 23 attributes for roasted pecans, and 4 attributes for shelf life).
2. The PROC MIXED procedure is repeated for each attribute resulting in 20 individual codes for the raw pecan attributes, 23 individual codes for the roasted pecans, and 4 individual codes for shelf life attributes.
3. “atr#” is replaced by “atr1”, “atr2”, …, “atrXX” for each of the attributes. The “title” variable is named according to the specific attribute (i.e. atr1 is ‘Pecan ID’).

SAS® Code for Analyzing Comparison of Raw and Roasted Pecan Descriptive Data

```
data PECAN;
input PecanN Set $ Day $ Panelist $ Cultivar $ PecanID OverallNutty NuttyWoody
NuttyGrainlike
NuttyButtery Brown Caramelized Acrid        Burnt   MustyEarthy   Woody Roasted
OverallSweet Oily
Rancid Oxidized Astringent Bitter Sour Sweet;
if PecanN=1 then Pecan="Raw";
if PecanN=2 then Pecan="Roasted";
datalines;
run;
*proc print data=PECAN;
*run;
ods rtf file='C:\Users\weiyanmc\Desktop\GRA\Shelby\output\output_Raw vs roasted.rtf';
%MACRO multi(resp=);
title "Raw VS Roasted in Attribute=&resp";
proc mixed data=PECAN contest cl;
class Pecan Set Day Panelist Cultivar;
model &resp=Pecan|Cultivar;
random Set Day(set) Panelist Set*Panelist  Panelist*Day(set);
lsmeans Pecan/pdiff ;
estimate "Attribute=&resp Raw vs roast in Cultivar=1" Pecan 1 -1
```

```
                         Pecan*Cultivar 1    0    0    0    0    0    0    0
        0    0    0    0    0    0    0    0
-1      0    0    0    0    0    0    0    0    0    0    0    0
        0    0    0;
estimate "Attribute=&resp Raw vs roast in Cultivar=2" Pecan 1 -1
                         Pecan*Cultivar 0    0    0    0    0    0    0    0
        1    0    0    0    0    0    0    0
0       0    0    0    0    0    0    0    -1   0    0    0    0
        0    0    0;
estimate "Attribute=&resp Raw vs roast in Cultivar=3" Pecan 1 -1
                         Pecan*Cultivar 0    0    0    0    0    0    0    0
        0    1    0    0    0    0    0    0
0       0    0    0    0    0    0    0    0    -1   0    0    0
        0    0    0;
estimate "Attribute=&resp Raw vs roast in Cultivar=4" Pecan 1 -1
                         Pecan*Cultivar 0    0    0    0    0    0    0    0
        0    0    1    0    0    0    0    0
0       0    0    0    0    0    0    0    0    0    -1   0    0
        0    0    0;
estimate "Attribute=&resp Raw vs roast in Cultivar=5" Pecan 1 -1
                         Pecan*Cultivar 0    0    0    0    0    0    0    0
        0    0    0    1    0    0    0    0
0       0    0    0    0    0    0    0    0    0    0    -1   0
        0    0    0;
estimate "Attribute=&resp Raw vs roast in Cultivar=6" Pecan 1 -1
                         Pecan*Cultivar 0    0    0    0    0    0    0    0
        0    0    0    0    1    0    0    0
0       0    0    0    0    0    0    0    0    0    0    0    -1
        0    0    0;
estimate "Attribute=&resp Raw vs roast in Cultivar=7" Pecan 1 -1
                         Pecan*Cultivar 0    0    0    0    0    0    0    0
        0    0    0    0    0    1    0    0
0       0    0    0    0    0    0    0    0    0    0    0    0
        -1   0    0;
estimate "Attribute=&resp Raw vs roast in Cultivar=8" Pecan 1 -1
                         Pecan*Cultivar 0    0    0    0    0    0    0    0
        0    0    0    0    0    0    1    0
0       0    0    0    0    0    0    0    0    0    0    0    0
        0    -1   0;


estimate "Attribute=&resp Raw vs roast in Cultivar=9" Pecan 1 -1
                         Pecan*Cultivar 0    0    0    0    0    0    0    0
        0    0    0    0    0    0    0    1
0       0    0    0    0    0    0    0    0    0    0    0    0
        0    0    -1;
```

```
estimate "Attribute=&resp Raw vs roast in Cultivar=10" Pecan 1 -1
                                Pecan*Cultivar 0    1    0    0    0    0    0    0
          0    0    0    0    0    0    0    0
0    -1   0    0    0    0    0    0    0    0    0    0    0
          0    0    0;


estimate "Attribute=&resp Raw vs roast in Cultivar=11" Pecan 1 -1
                                Pecan*Cultivar 0    0    1    0    0    0    0    0
          0    0    0    0    0    0    0    0
0    0    -1   0    0    0    0    0    0    0    0    0    0
          0    0    0;
estimate "Attribute=&resp Raw vs roast in Cultivar=12" Pecan 1 -1
                                Pecan*Cultivar 0    0    0    1    0    0    0    0
          0    0    0    0    0    0    0    0
0    0    0    -1   0    0    0    0    0    0    0    0    0
          0    0    0;
estimate "Attribute=&resp Raw vs roast in Cultivar=13" Pecan 1 -1
                                Pecan*Cultivar 0    0    0    0    1    0    0    0
          0    0    0    0    0    0    0    0
0    0    0    0    -1   0    0    0    0    0    0    0    0
          0    0    0;
estimate "Attribute=&resp Raw vs roast in Cultivar=14" Pecan 1 -1
                                Pecan*Cultivar 0    0    0    0    0    1    0    0
          0    0    0    0    0    0    0    0
0    0    0    0    0    -1   0    0    0    0    0    0    0
          0    0    0;
estimate "Attribute=&resp Raw vs roast in Cultivar=15" Pecan 1 -1
                                Pecan*Cultivar 0    0    0    0    0    0    1    0
          0    0    0    0    0    0    0    0
0    0    0    0    0    0    -1   0    0    0    0    0    0
          0    0    0;
estimate "Attribute=&resp Raw vs roast in Cultivar=16" Pecan 1 -1
                                Pecan*Cultivar 0    0    0    0    0    0    0    1
          0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    -1   0    0    0    0    0
          0    0    0;
run;
%mend multi;
%multi (resp=PecanID);
%multi (resp=OverallNutty);
%multi (resp=NuttyWoody);
%multi (resp=NuttyGrainlike);
%multi (resp=NuttyButtery);
%multi (resp=Brown);
%multi (resp=Caramelized);
```

```
%multi (resp=Acrid);
%multi (resp=Burnt);
%multi (resp=MustyEarthy);
%multi (resp=Woody);
%multi (resp=Roasted);
%multi (resp=OverallSweet);
%multi (resp=Oily);
%multi (resp=Rancid);
%multi (resp=Oxidized);
%multi (resp=Astringent);
%multi (resp=Bitter);
%multi (resp=Sour);
%multi (resp=Sweet);
ods rtf close;
```

Notes

1. The PROC MIXED procedure is repeated for each attribute resulting in 23 individual codes for the roasted pecans.

Appendix B - Descriptive Analysis Test Designs

Raw Pecan Kernel Evaluation

Evaluation Day 1

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Panelist 1	Colby	Lakota	Henning	Pawnee	Major	HIrschi	Maramec	Peruque
Panelist 2	HIrschi	Maramec	Chickasaw	Giles	Pawnee	Major	Peruque	Lakota
Panelist 3	Chetopa	Colby	Oswego	HIrschi	Kanza	Maramec	Lakota	Dooley
Panelist 4	Peruque	Dooley	Oswego	Major	Henning	Chetopa	Pawnee	HIrschi
Panelist 5	Pawnee	Chickasaw	Colby	Kanza	Witte	Lakota	Chetopa	Giles
Panelist 6	Major	Chickasaw	Giles	Oswego	Lakota	Dooley	Peruque	Stuart

Evaluation Day 2

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Panelist 1	Giles	Kanza	Witte	Dooley	Chetopa	Oswego	Stuart	Chickasaw
Panelist 2	Henning	Dooley	Witte	Stuart	Chetopa	Oswego	Colby	Kanza
Panelist 3	Witte	Pawnee	Major	Chickasaw	Stuart	Henning	Giles	Peruque
Panelist 4	Lakota	Kanza	Chickasaw	Stuart	Giles	Maramec	Witte	Colby
Panelist 5	Henning	Dooley	Major	Oswego	Maramec	Stuart	HIrschi	Peruque
Panelist 6	Witte	Kanza	Chetopa	Maramec	HIrschi	Henning	Pawnee	Colby

Evaluation Day 3

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Panelist 1	Peruque	Pawnee	Stuart	Chetopa	Dooley	Kanza	Chickasaw	Henning
Panelist 2	Chickasaw	Stuart	Pawnee	Colby	Witte	Peruque	Hirschi	Oswego
Panelist 3	Hirschi	Chetopa	Chickasaw	Oswego	Peruque	Lakota	Maramec	Pawnee
Panelist 4	Colby	Witte	Chetopa	Hirschi	Pawnee	Maramec	Major	Kanza
Panelist 5	Witte	Pawnee	Lakota	Major	Henning	Stuart	Maramec	Chickasaw
Panelist 6	Major	Dooley	Colby	Pawnee	Kanza	Henning	Hirschi	Chickasaw

Evaluation Day 4

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Panelist 1	Lakota	Giles	Major	Oswego	Colby	Maramec	Hirschi	Witte
Panelist 2	Henning	Chetopa	Dooley	Lakota	Giles	Kanza	Maramec	Major
Panelist 3	Kanza	Major	Stuart	Henning	Giles	Witte	Dooley	Colby
Panelist 4	Henning	Lakota	Stuart	Giles	393	Dooley	Oswego	Peruque
Panelist 5	Giles	Hirschi	Peruque	Oswego	Chetopa	Dooley	Colby	Kanza
Panelist 6	Giles	Maramec	Lakota	Oswego	Witte	Peruque	Stuart	Chetopa

Evaluation Day 5

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Panelist 1	Chetopa	Witte	Lakota	Dooley	Giles	Henning	Major	Hirschi
Panelist 2	Chickasaw	Lakota	Stuart	Dooley	Pawnee	Maramec	Giles	Witte
Panelist 3	Hirschi	Dooley	Maramec	Oswego	Kanza	Major	Henning	Chickasaw
Panelist 4	Colby	Chetopa	Stuart	Oswego	Peruque	Dooley	Major	Pawnee
Panelist 5	Witte	Major	Chetopa	Dooley	Stuart	Colby	Chickasaw	Hirschi
Panelist 6	Hirschi	Henning	Oswego	Chickasaw	Stuart	Chetopa	Major	Witte

Evaluation Day 6

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Panelist 1	Oswego	Pawnee	Maramec	Stuart	Colby	Chickasaw	Kanza	Peruque
Panelist 2	Major	Oswego	Chetopa	Kanza	Colby	Hirschi	Henning	Peruque
Panelist 3	Colby	Witte	Giles	Chetopa	Stuart	Peruque	Lakota	Pawnee
Panelist 4	Maramec	Witte	Lakota	Kanza	Chickasaw	Hirschi	Henning	Giles
Panelist 5	Kanza	Oswego	Lakota	Giles	Henning	Peruque	Maramec	Pawnee
Panelist 6	Peruque	Lakota	Pawnee	Dooley	Giles	Maramec	Colby	Kanza

Roasted Pecan Kernel Evaluation

Evaluation Day 1

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Panelist 1	Hirschi	Lakota	Kanza	Oswego	Pawnee	Major	Chetopa	Henning
Panelist 2	Oswego	Henning	Chetopa	Lakota	Witte	Hirschi	Peruque	Stuart
Panelist 3	Pawnee	Stuart	Oswego	Maramec	Lakota	Dooley	Henning	Giles
Panelist 4	Colby	Chickasaw	Major	Pawnee	Giles	Maramec	Henning	Oswego
Panelist 5	Chetopa	Maramec	Major	Witte	Dooley	Chickasaw	Peruque	Colby
Panelist 6	Kanza	Oswego	Major	Lakota	Chickasaw	Pawnee	Henning	Giles

Evaluation Day 2

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Panelist 1	Colby	Maramec	Chickasaw	Witte	Dooley	Peruque	Giles	Stuart
Panelist 2	Pawnee	Major	Maramec	Giles	Kanza	Chickasaw	Colby	Dooley
Panelist 3	Witte	Chetopa	Hirschi	Major	Kanza	Colby	Peruque	Chickasaw
Panelist 4	Kanza	Dooley	Lakota	Hirschi	Stuart	Peruque	Witte	Chetopa
Panelist 5	Pawnee	Henning	Giles	Hirschi	Kanza	Lakota	Stuart	Oswego
Panelist 6	Chetopa	Hirschi	Maramec	Dooley	Colby	Stuart	Peruque	Witte

Pecan Evaluation Day 3

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Panelist 1	Lakota	Dooley	Witte	Chetopa	Henning	Major	Pawnee	Colby
Panelist 2	Dooley	Giles	Lakota	Henning	Maramec	Peruque	Oswego	Major
Panelist 3	Pawnee	Chetopa	Oswego	Henning	Hirschi	Dooley	Chickasaw	Maramec
Panelist 4	Chickasaw	Pawnee	Hirschi	Colby	Giles	Henning	Stuart	Dooley
Panelist 5	Maramec	Colby	Stuart	Pawnee	Kanza	Hirschi	Henning	Major
Panelist 6	Giles	Colby	Kanza	Peruque	Lakota	Maramec	Hirschi	Major

Pecan Evaluation Day 4

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Panelist 1	Giles	Hirschi	Chickasaw	Peruque	Kanza	Stuart	Oswego	Maramec
Panelist 2	Pawnee	Chetopa	Kanza	Witte	Chickasaw	Colby	Stuart	Hirschi
Panelist 3	Lakota	Major	Kanza	Peruque	Colby	Giles	Witte	Stuart
Panelist 4	Peruque	Maramec	Lakota	Kanza	Witte	Oswego	Major	Chetopa
Panelist 5	Chickasaw	Dooley	Witte	Giles	Peruque	Lakota	Oswego	Chetopa
Panelist 6	Dooley	Chetopa	Witte	Oswego	Chickasaw	Pawnee	Henning	Stuart

Evaluation Day 5

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Panelist 1	Major	Kanza	Giles	Hirschi	Chickasaw	Lakota	Chetopa	Witte
Panelist 2	Peruque	Dooley	Lakota	Chickasaw	Pawnee	Henning	Hirschi	Kanza
Panelist 3	Chetopa	Colby	Pawnee	Dooley	Major	Hirschi	Peruque	Stuart
Panelist 4	Oswego	Chickasaw	Stuart	Colby	Chetopa	Dooley	Kanza	Peruque
Panelist 5	Henning	Chetopa	Hirschi	Kanza	Major	Witte	Pawnee	Stuart
Panelist 6	Peruque	Hirschi	Witte	Giles	Henning	Kanza	Chetopa	Dooley

Evaluation Day 6

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Panelist 1	Peruque	Dooley	Stuart	Maramec	Oswego	Colby	Pawnee	Henning
Panelist 2	Oswego	Major	Stuart	Giles	Maramec	Colby	Witte	Chetopa
Panelist 3	Giles	Witte	Henning	Oswego	Maramec	Kanza	Chickasaw	Lakota
Panelist 4	Giles	Witte	Major	Lakota	Hirschi	Pawnee	Henning	Maramec
Panelist 5	Giles	Dooley	Maramec	Peruque	Oswego	Chickasaw	Lakota	Colby
Panelist 6	Major	Colby	Pawnee	Stuart	Oswego	Lakota	Chickasaw	Maramec

Shelf Life Pecan Kernel Evaluation

3 Months Evaluation Day 1

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Witte	Pawnee	Chickasaw	Henning	Kanza	Dooley	Hirschi	Giles	Major	Maramec	Chetopa	Colby
Panelist 2	Chetopa	Lakota	Giles	Dooley	Oswego	Pawnee	Peruque	Colby	Chickasaw	Maramec	Kanza	Hirschi
Panelist 3	Maramec	Chetopa	Chickasaw	Pawnee	Colby	Stuart	Oswego	Giles	Kanza	Lakota	Witte	Major
Panelist 4	Major	Oswego	Lakota	Chetopa	Maramec	Dooley	Colby	Pawnee	Witte	Giles	Hirschi	Henning
Panelist 5	Chetopa	Stuart	Henning	Hirschi	Chickasaw	Oswego	Kanza	Peruque	Pawnee	Witte	Major	Dooley
Panelist 6	Oswego	Pawnee	Kanza	Maramec	Colby	Giles	Witte	Major	Stuart	Chetopa	Henning	Hirschi

3 Months\ Evaluation Day 2

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Stuart	Peruque	Lakota	Oswego	Peruque	Hirschi	Chickasaw	Pawnee	Major	Lakota	Oswego	Chetopa
Panelist 2	Major	Witte	Stuart	Henning	Chetopa	Hirschi	Kanza	Dooley	Witte	Major	Lakota	Stuart
Panelist 3	Hirschi	Henning	Peruque	Dooley	Major	Witte	Lakota	Chickasaw	Dooley	Henning	Maramec	Peruque
Panelist 4	Peruque	Stuart	Kanza	Chickasaw	Oswego	Pawnee	Witte	Chickasaw	Hirschi	Giles	Peruque	Kanza
Panelist 5	Lakota	Colby	Giles	Maramec	Maramec	Hirschi	Lakota	Kanza	Witte	Chickasaw	Oswego	Peruque
Panelist 6	Peruque	Lakota	Chickasaw	Dooley	Henning	Colby	Kanza	Peruque	Pawnee	Chetopa	Stuart	Witte

3 Months Evaluation Day 3

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Colby	Witte	Maramec	Stuart	Giles	Kanza	Dooley	Henning	Giles	Witte	Lakota	Chickasaw
Panelist 2	Maramec	Chickasaw	Giles	Colby	Pawnee	Oswego	Henning	Peruque	Oswego	Chetopa	Lakota	Major
Panelist 3	Giles	Colby	Chetopa	Oswego	Hirschi	Stuart	Kanza	Pawnee	Dooley	Hirschi	Oswego	Peruque
Panelist 4	Lakota	Stuart	Chetopa	Major	Henning	Maramec	Colby	Dooley	Oswego	Dooley	Major	Colby
Panelist 5	Stuart	Giles	Henning	Dooley	Pawnee	Major	Colby	Chetopa	Oswego	Giles	Lakota	Peruque
Panelist 6	Lakota	Giles	Chickasaw	Major	Hirschi	Maramec	Dooley	Oswego	Dooley	Hirschi	Peruque	Oswego

3 Months Evaluation Day 4

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Major	Chetopa	Colby	Pawnee	Hirschi	Kanza	Maramec	Henning	Dooley	Peruque	Stuart	Oswego
Panelist 2	Colby	Kanza	Peruque	Pawnee	Hirschi	Witte	Giles	Maramec	Chickasaw	Dooley	Henning	Stuart
Panelist 3	Chickasaw	Chetopa	Maramec	Stuart	Colby	Henning	Giles	Witte	Lakota	Pawnee	Kanza	Major
Panelist 4	Chetopa	Stuart	Pawnee	Giles	Lakota	Chickasaw	Henning	Kanza	Peruque	Witte	Maramec	Hirschi
Panelist 5	Kanza	Major	Chetopa	Pawnee	Maramec	Colby	Witte	Dooley	Chickasaw	Henning	Stuart	Hirschi
Panelist 6	Stuart	Chetopa	Witte	Pawnee	Maramec	Colby	Chickasaw	Major	Giles	Kanza	Lakota	Henning

6 Months Evaluation Day 1

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Pawnee	Oswego	Kanza	Witte	Lakota	Colby	Dooley	Chetopa	Chickasaw	Giles	Maramec	Major
Panelist 2	Chetopa	Witte	Giles	Maramec	Dooley	Lakota	Major	Peruque	Oswego	Chickasaw	Colby	Pawnee
Panelist 3	Witte	Giles	Major	Maramec	Kanza	Lakota	Henning	Chickasaw	Dooley	Chetopa	Colby	Oswego
Panelist 4	Kanza	Peruque	Chickasaw	Henning	Witte	Oswego	Hirschi	Maramec	Lakota	Giles	Chetopa	Pawnee
Panelist 5	Dooley	Witte	Stuart	Lakota	Giles	Oswego	Pawnee	Hirschi	Chickasaw	Henning	Major	Chetopa
Panelist 6	Chetopa	Maramec	Dooley	Giles	Stuart	Pawnee	Colby	Peruque	Chickasaw	Henning	Lakota	Witte

6 Months Evaluation Day 2

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Hirschi	Stuart	Peruque	Henning	Henning	Chickasaw	Colby	Kanza	Pawnee	Maramec	Witte	Oswego
Panelist 2	Henning	Stuart	Kanza	Hirschi	Peruque	Chickasaw	Lakota	Oswego	Henning	Dooley	Colby	Giles
Panelist 3	Pawnee	Stuart	Peruque	Hirschi	Dooley	Colby	Lakota	Giles	Peruque	Chickasaw	Oswego	Chetopa
Panelist 4	Dooley	Major	Stuart	Colby	Colby	Henning	Witte	Giles	Chetopa	Major	Dooley	Maramec
Panelist 5	Peruque	Kanza	Maramec	Colby	Major	Henning	Chickasaw	Giles	Witte	Hirschi	Colby	Chetopa
Panelist 6	Kanza	Major	Hirschi	Oswego	Chetopa	Witte	Dooley	Hirschi	Chickasaw	Major	Maramec	Kanza

6 Months Evaluation Day 3

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Lakota	Chetopa	Peruque	Major	Dooley	Stuart	Hirschi	Giles	Peruque	Kanza	Henning	Stuart
Panelist 2	Pawnee	Maramec	Chetopa	Stuart	Major	Hirschi	Witte	Kanza	Witte	Lakota	Giles	Maramec
Panelist 3	Hirschi	Henning	Witte	Kanza	Pawnee	Major	Maramec	Stuart	Chickasaw	Maramec	Lakota	Dooley
Panelist 4	Chickasaw	Pawnee	Stuart	Lakota	Peruque	Kanza	Oswego	Hirschi	Henning	Dooley	Witte	Peruque
Panelist 5	Oswego	Lakota	Stuart	Maramec	Peruque	Kanza	Pawnee	Dooley	Stuart	Chetopa	Maramec	Dooley
Panelist 6	Peruque	Lakota	Oswego	Giles	Henning	Stuart	Colby	Pawnee	Hirschi	Maramec	Major	Lakota

6 Months Evaluation Day 4

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Colby	Pawnee	Dooley	Major	Oswego	Chickasaw	Witte	Hirschi	Giles	Maramec	Lakota	Chetopa
Panelist 2	Peruque	Pawnee	Stuart	Kanza	Chetopa	Major	Chickasaw	Henning	Colby	Hirschi	Dooley	Oswego
Panelist 3	Henning	Oswego	Chetopa	Hirschi	Peruque	Colby	Giles	Witte	Pawnee	Stuart	Major	Kanza
Panelist 4	Major	Giles	Hirschi	Colby	Oswego	Stuart	Kanza	Chickasaw	Pawnee	Chetopa	Lakota	Maramec
Panelist 5	Witte	Hirschi	Colby	Giles	Major	Oswego	Henning	Lakota	Pawnee	Peruque	Kanza	Chickasaw
Panelist 6	Henning	Chetopa	Pawnee	Chickasaw	Colby	Giles	Dooley	Kanza	Peruque	Oswego	Witte	Stuart

9 Months Evaluation Day 1

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Chetopa	Lakota	Dooley	Maramec	Stuart	Pawnee	Henning	Chickasaw	Peruque	Hirschi	Giles	Colby
Panelist 2	Peruque	Kanza	Witte	Colby	Oswego	Stuart	Major	Giles	Maramec	Lakota	Chickasaw	Hirschi
Panelist 3	Stuart	Chickasaw	Pawnee	Giles	Colby	Oswego	Peruque	Chetopa	Witte	Lakota	Maramec	Major
Panelist 4	Lakota	Kanza	Henning	Peruque	Major	Hirschi	Chickasaw	Stuart	Chetopa	Dooley	Witte	Maramec
Panelist 5	Dooley	Stuart	Henning	Pawnee	Maramec	Lakota	Major	Chickasaw	Giles	Kanza	Hirschi	Chetopa
Panelist 6	Lakota	Major	Stuart	Colby	Kanza	Pawnee	Chetopa	Dooley	Witte	Giles	Oswego	Maramec

9 Months Evaluation Day 2

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Oswego	Major	Kanza	Witte	Witte	Major	Kanza	Dooley	Henning	Colby	Peruque	Pawnee
Panelist 2	Pawnee	Dooley	Chetopa	Henning	Stuart	Chetopa	Hirschi	Witte	Henning	Pawnee	Dooley	Oswego
Panelist 3	Kanza	Henning	Dooley	Hirschi	Pawnee	Kanza	Hirschi	Oswego	Chetopa	Dooley	Henning	Chickasaw
Panelist 4	Colby	Pawnee	Giles	Oswego	Stuart	Giles	Chetopa	Colby	Oswego	Maramec	Dooley	Kanza
Panelist 5	Witte	Oswego	Peruque	Colby	Oswego	Maramec	Pawnee	Chetopa	Giles	Witte	Lakota	Peruque
Panelist 6	Henning	Hirschi	Peruque	Chickasaw	Henning	Oswego	Chickasaw	Chetopa	Dooley	Pawnee	Giles	Major

9 Months Evaluation Day 3

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Hirschi	Oswego	Maramec	Giles	Chickasaw	Lakota	Stuart	Chetopa	Hirschi	Chickasaw	Chetopa	Witte
Panelist 2	Colby	Maramec	Giles	Chickasaw	Major	Kanza	Lakota	Peruque	Henning	Giles	Colby	Hirschi
Panelist 3	Peruque	Giles	Lakota	Maramec	Witte	Colby	Stuart	Major	Henning	Peruque	Kanza	Oswego
Panelist 4	Peruque	Chickasaw	Witte	Pawnee	Hirschi	Lakota	Major	Henning	Henning	Major	Chetopa	Colby
Panelist 5	Major	Chickasaw	Henning	Dooley	Stuart	Kanza	Hirschi	Colby	Chetopa	Hirschi	Major	Henning
Panelist 6	Hirschi	Kanza	Lakota	Peruque	Maramec	Colby	Witte	Stuart	Dooley	Chetopa	Maramec	Stuart

9 Months Evaluation Day 4

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Maramec	Peruque	Kanza	Oswego	Colby	Dooley	Pawnee	Major	Stuart	Henning	Giles	Lakota
Panelist 2	Chetopa	Peruque	Chickasaw	Kanza	Major	Oswego	Dooley	Witte	Pawnee	Maramec	Stuart	Lakota
Panelist 3	Colby	Stuart	Witte	Lakota	Giles	Dooley	Major	Chickasaw	Chetopa	Hirschi	Pawnee	Maramec
Panelist 4	Oswego	Giles	Maramec	Dooley	Hirschi	Stuart	Pawnee	Witte	Chickasaw	Peruque	Kanza	Lakota
Panelist 5	Stuart	Kanza	Lakota	Oswego	Dooley	Peruque	Colby	Pawnee	Witte	Maramec	Giles	Chickasaw
Panelist 6	Colby	Chickasaw	Oswego	Henning	Hirschi	Peruque	Lakota	Giles	Kanza	Witte	Major	Pawnee

12 Months Evaluation Day 1

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Stuart	Henning	Maramec	Colby	Pawnee	Chickasaw	Witte	Peruque	Oswego	Chetopa	Hirschi	Kanza
Panelist 2	Henning	Lakota	Stuart	Witte	Chickasaw	Chetopa	Kanza	Colby	Hirschi	Pawnee	Major	Dooley
Panelist 3	Giles	Stuart	Major	Oswego	Witte	Dooley	Maramec	Kanza	Colby	Pawnee	Henning	Chetopa
Panelist 4	Kanza	Pawnee	Colby	Giles	Chickasaw	Henning	Peruque	Lakota	Major	Chetopa	Oswego	Stuart
Panelist 5	Chetopa	Chickasaw	Kanza	Major	Witte	Henning	Dooley	Oswego	Stuart	Giles	Peruque	Lakota
Panelist 6	Hirschi	Lakota	Giles	Maramec	Henning	Dooley	Witte	Colby	Chickasaw	Pawnee	Kanza	Chetopa

12 Months Evaluation Day 2

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Major	Giles	Lakota	Dooley	Henning	Giles	Maramec	Colby	Peruque	Dooley	Pawnee	Kanza
Panelist 2	Maramec	Peruque	Oswego	Giles	Colby	Oswego	Stuart	Pawnee	Hirschi	Major	Chetopa	Kanza
Panelist 3	Lakota	Hirschi	Chickasaw	Peruque	Dooley	Peruque	Maramec	Witte	Hirschi	Chetopa	Kanza	Stuart
Panelist 4	Maramec	Witte	Dooley	Hirschi	Dooley	Lakota	Maramec	Stuart	Pawnee	Chetopa	Oswego	Kanza
Panelist 5	Colby	Hirschi	Maramec	Pawnee	Stuart	Peruque	Pawnee	Major	Henning	Lakota	Colby	Oswego
Panelist 6	Major	Stuart	Peruque	Oswego	Hirschi	Major	Maramec	Lakota	Chetopa	Chickasaw	Giles	Henning

12 Months Evaluation Day 3

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Oswego	Hirschi	Chickasaw	Major	Stuart	Chetopa	Lakota	Witte	Giles	Kanza	Oswego	Maramec
Panelist 2	Dooley	Peruque	Chickasaw	Henning	Witte	Giles	Lakota	Maramec	Pawnee	Colby	Dooley	Giles
Panelist 3	Major	Lakota	Pawnee	Henning	Chickasaw	Giles	Oswego	Colby	Hirschi	Giles	Chetopa	Peruque
Panelist 4	Chickasaw	Giles	Hirschi	Henning	Witte	Colby	Major	Peruque	Giles	Peruque	Oswego	Major
Panelist 5	Kanza	Giles	Hirschi	Chetopa	Witte	Dooley	Chickasaw	Maramec	Witte	Chickasaw	Chetopa	Pawnee
Panelist 6	Dooley	Kanza	Peruque	Witte	Colby	Pawnee	Oswego	Stuart	Major	Kanza	Pawnee	Peruque

12 Months Evaluation Day 4

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Panelist 1	Pawnee	Colby	Chetopa	Chickasaw	Peruque	Stuart	Major	Dooley	Henning	Lakota	Hirschi	Witte
Panelist 2	Chetopa	Stuart	Peruque	Chickasaw	Maramec	Henning	Hirschi	Witte	Oswego	Major	Lakota	Kanza
Panelist 3	Dooley	Major	Witte	Pawnee	Oswego	Lakota	Kanza	Colby	Maramec	Chickasaw	Stuart	Henning
Panelist 4	Maramec	Dooley	Hirschi	Pawnee	Chetopa	Colby	Lakota	Kanza	Witte	Stuart	Henning	Chickasaw
Panelist 5	Peruque	Kanza	Oswego	Lakota	Giles	Maramec	Colby	Major	Hirschi	Dooley	Henning	Stuart
Panelist 6	Colby	Witte	Oswego	Stuart	Henning	Lakota	Maramec	Giles	Chickasaw	Chetopa	Hirschi	Dooley

Appendix C - Pecan Ballot

Raw and Roasted Pecan Evaluation

Panelist ___________ **Sample ________________** **Date ______________________**

Flavor

Pecan ID	0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 **7** 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Overall Nutty	0 0.5 1 1.5 2 2.5 3 3.5 4 **4.5** 5 5.5 6 6.5 7 **7.5** **8** 8.5 **9** 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Nutty-Woody	0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 **7.5** 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Nutty-Grain-Like	0 0.5 1 1.5 2 2.5 3 3.5 4 **4.5** 5 5.5 6 6.5 7 **7.5** 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Nutty-Buttery	0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 **5** 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Brown	0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 **5** 5.5 6 6.5 7 **7.5** 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 **13** 13.5 14 14.5 15
Caramelized	0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 **9** 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Acrid	0 0.5 1 1.5 2 2.5 **3** 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Burnt	0 0.5 1 1.5 2 2.5 3 3.5 **4** 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Musty/Earthy	0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 **10.5** 11 11.5 12 12.5 13 13.5 14 14.5 15
Woody	0 0.5 1 1.5 2 2.5 3 3.5 **4** 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Roasted 0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 **5** 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Overall Sweet 0 0.5 1 **1.5** 2 2.5 **3** 3.5 4 **4.5** 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Oily 0 0.5 1 1.5 2 2.5 3 3.5 **4** 4.5 5 5.5 6 6.5 7 7.5 8 8.5 **9** 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Rancid 0 0.5 1 1.5 2 **2.5** 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Oxidized 0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 **6** 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Astringent 0 0.5 1 **1.5** 2 **2.5** 3 **3.5** 4 4.5 **5** 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Bitter 0 0.5 1 1.5 **2** 2.5 3 **3.5** 4 4.5 **5** 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Sour 0 0.5 1 **1.5** 2 **2.5** 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Sweet 0 0.5 **1** 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Texture

Firmness 0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 **5** 5.5 6 6.5 7 **7.5** 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Tooth Packing 0 0.5 1 1.5 2 2.5 3 **3.5** 4 4.5 5 5.5 6 6.5 **7** 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Particles(Residuals) 0 0.5 1 1.5 2 2.5 **3** 3.5 4 4.5 5 5.5 6 6.5 **7** 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Shelf Life Raw Pecan Evaluation

Panelist ___________ **Sample ________________** **Date ______________________**

<u>Flavor</u>

Rancid	0	0.5	1	1.5	2	**<u>2.5</u>**	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Bitter	0	0.5	1	1.5	**<u>2</u>**	2.5	3	**<u>3.5</u>**	4	4.5	**<u>5</u>**	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Sour	0	0.5	1	**<u>1.5</u>**	2	**<u>2.5</u>**	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Sweet	0	0.5	**<u>1</u>**	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
....	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
....	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15

Appendix D - Pecan Definition and Reference Sheets for Descriptive Analysis

Raw and Roasted Pecan Evaluation

Panelists: Use 1 piece for evaluation. Please swallow at least one sample during evaluation.

FLAVOR:

Pecan ID

The aromatics commonly associated with pecans which include musty/earthy, piney, woody, brown, sweet, buttery, oily, astringent, and slightly acrid aromatics. Other aromatics may include musty/dusty, floral/fruity, and/or fruity-dark.

References: Ground Pecan pieces = 7.0 (flavor)

Preparation: Measure out 1 tbsp. of various cultivars into a food processor and blend for 30 seconds. Pour into 1 oz. cups.

Overall Nutty

A measurement that reflects the total of the nutty characteristics and the degree to which these characteristics fit together. These nutty characteristics are: sweet, oily, light brown, slightly musty and/or buttery, earthy, woody, astringent, bitter, etc. Examples: nuts, wheat germ, certain whole grains.

References:
Gold Medal Whole Wheat Flour = 4.5 (flavor)
Kretschmer Wheat Germ = 7.5 (flavor)
Mixture of Diamond Slivered Almonds and Kroger Chopped Hazelnuts = 7.5 (flavor)
Diamond Shelled Walnuts = 8.0 (flavor)
Diamond Pecan Halves = 9.0 (flavor)

Preparation: Puree the almonds and hazelnuts separately in blenders for 45 seconds on high speed. Combine equal amounts of the chopped nuts. Serve in individual 1 oz. cups. Serve pecans and walnuts in 1 oz cups.

Nutty-Woody

A nutty aromatic characterized by the presence of woodiness, increased musty/dustiness, brown, astringent and bitter.

References:
Diamond Pecan Halves = 7.5 (flavor)
Diamond Shelled Walnuts = 7.5 (flavor)

Nutty-Grain-Like

A nutty aromatic characterized by the presence of a grainy aromatic, increased musty/dustiness and brown.

Reference:
Gold Medal Whole Wheat Flour = 4.5 (flavor)
Kretschmer Wheat Germ = 7.5 (flavor)

Nutty-Buttery

A nutty aromatic characterized by a buttery impression, and/or increased fatty aromatics and musty/earthy character.

	References:	HyVee Dry Roasted and Salted Macadamia Nuts = 5.0 (flavor)
Brown	A rich, full aromatic impressions always characterized with some degree of darkness generally associated with attributes (i.e. toasted, nutty, sweet).	
	References:	Bush's Best Pinto Beans (Canned) = 5.0 (flavor) Kretschmer Wheat Germ = 7.5 (flavor)
Caramelized	A round, full-bodied, medium brown aromatic.	
	Reference:	C&H Golden Brown Sugar = 9.0 (flavor)
Acrid	The sharp/acrid, charred flavor note associated with something over baked or excessively browned in oil.	
	Reference:	Alf's Natural Nutrition Puffed Red Wheat Cereal = 3.0 (flavor)
Burnt	A dark, brown, somewhat sharp, over-baked grain aromatic.	
	Reference:	Alf's Natural Nutrition Puffed Red Wheat Cereal = 4.0 (flavor)
Musty/Earthy	Humus-like aromatics that may or may not include damp soil, decaying vegetation, or cellar like characteristics.	
	Reference:	Sliced Button mushroom = 10.5 (flavor)
Woody	The sweet, brown, musty, dark, dry aromatics associated with the bark of a tree.	
	Reference:	Diamond Shelled Walnuts = 4.0 (flavor)
Roasted	Dark brown impression characteristic of products cooked to a high temperature by dry heat. Does not include bitter or burnt notes.	
	Reference:	'Planters Dry Roasted Unsalted Peanuts= 5.0 (flavor)
Overall Sweet	An aromatic associated with the impression of sweet substances.	
	Reference:	Post Shredded Wheat = 1.5 (flavor) General Mills Wheaties = 3.0 (flavor) Lorna Doone Cookie = 4.5 (flavor)
Oily	The light aromatics associated with vegetable oil such as corn or soybean oil.	
	Reference:	Kroger Slivered and Blanched Almonds = 4.0 (flavor) HyVee Dry Roasted and Salted Macadamia Nuts = 9.0 (flavor)
Rancid	An aromatic commonly associated with oxidized fat and oils.	
	Reference:	Wesson Vegetable Oil = 2.5

Preparation: Microwave 1/3 cup of oil on high power for 2 1/2 minutes. Let cool and serve in individual covered cups

Oxidized The aromatic associated with aged or highly used oil and fat.
Reference: Microwave Oven Heated Wesson Vegetable Oil = 6.0
Preparation: Add 300ml of oil from a newly purchased and opened bottle of Wesson Vegetable Oil to a 1000ml glass beaker. Heat in the microwave oven on high power for 3 minutes. Remove from microwave and let sit at room temperature to cool for approximately 25 minutes. Then heat another 3 minutes, let cool another 25 minutes, and heat for one additional 3 minute interval. Let beaker sit on counter uncovered overnight. Serve in 1 oz cup.

Astringent A feeling of a puckering or a tingling sensation on the surface and/or edge of the tongue and mouth.
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Reference: 0.030% Alum solution = 1.5
0.050% Alum solution = 2.5
0.075% Alum solution = 3.5
0.10% Alum solution = 5.0

Bitter A fundamental taste factor of which caffeine is typical.
Reference: 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.
Reference: 0.015% Citric Acid Solution = 1.5
0.025% Citric Acid Solution = 2.5

Sweet A fundamental taste factor of which sucrose is typical.
Reference: 1% Sucrose Solution = 1.0

TEXTURE:

Firmness The amount of force required to bite the sample until molars meet. This is measured by placing the sample between molars and biting down one time.
References: Kraft Mild Cheddar Cheese = 5.0
Wonder English Muffin = 7.5

Tooth Packing The amount of sample packed in and between the molar teeth after swallowing.
References: Cheerios = 3.5
Wheaties = 7.0

Particles(residuals) The amount of small pieces of sample remaining in mouth just after swallowing. This does not incorporate toothpacking and refers only to particulate matter on mouth surfaces other than in and between the molar teeth.
References: Cheerios = 3.0
Wheaties = 7.0

Shelf Life Pecan Evaluation

Panelists: Use 1 piece for evaluation. Please swallow at least one sample during evaluation.

FLAVOR:

Rancid An aromatic commonly associated with oxidized fat and oils.
Reference: Wesson Vegetable Oil = 2.5
Preparation: Microwave 1/3 cup of oil on high power for 2 1/2 minutes. Let cool and serve in individual covered cups

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