A Sensory Analysis of Raw Native, 'Kanza', and 'Pawnee' Pecans

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SUMMARY. **The purpose of this study is to evaluate the appearance, texture, color, and taste of two popular pecan (*Carya illinoinensis*) clones relative to native pecans in a blind sensory analysis. Subjects tasted the raw pecans acquired from the same farm and evaluated them using hedonic scores. Results suggest consumers prefer the two clones to natives, and most of this preference seems to be related to the pecan size. A crossmodal effect was detected whereby the subjects reported an improved flavor in whole native pecans compared with clones that were cut in half and were thus less visually appealing. Consequently, although a previous study showed that consumers prefer pecans in a hypothetical (nontasting) situation when they are labeled as a "native" as opposed to clones, when the pecans are actually eaten and there are no labels designating the pecan type, they prefer the clones.**

Pecan (*Carya illinoinensis*) production using clones rather than natives has a number of advantages. Clones produce a more consistent harvest, produce more and larger nuts that have thinner shells, and their disease resistance properties are known. For this reason, per pound of nut harvested, they are often less expensive to produce and even provide higher prices (Florkowski and Hubbard, 1994; Warren, 2018). Clones refer to pecans whose stump and roots are grown from a seed with varying genetics but with a top that is grafted onto the stump that is a clone of other pecan trees with the same genetics. Because these clones are chosen from the best-performing trees, they also provide superior harvests. Native pecans are grown entirely from seed with no grafting, and thus every native pecan tree contains different genetics. Although occasionally a single native tree may outproduce a clone in terms of nut size or consistency, usually natives produce inferior harvests.

However, a common notion for some in the pecan industry is that native pecans taste better. It is not unusual to hear sentiments akin to Worley (1994) who wrote, "Native or seedling nuts usually have excellent flavor due in part to a high oil content, and are frequently preferred by many users." This could be the case if clones are chosen mostly for their yield, and if the nuts are larger then perhaps it comes at the expense of oil content within the pecans, leading to an inferior taste. If this is true, pecan producers might consider segmenting their market, selling natives to consumers who emphasize taste and clones to those who prefer larger nuts.

If native pecans indeed taste better than clones, the higher expense of native pecan production might be justifiable, especially if this better taste is manifested in consumer demand. There is evidence that consumers prefer native pecans. Palma et al. (2015) demonstrated that in surveys, consumers prefer native pecans over improved pecans, where "improved" in their study refers to clones. However, this evidence comes from a hypothetical survey where subjects were presented only with written descriptions of the pecans—no tasting, no actual pecans to visualize. Subjects were asked to choose between various hypothetical pecans that differed by size (large or small), type ("native" or "improved"), and a number of other attributes. These choices are then used to measure the value consumers place on changes in each attribute, like large instead of small pecans or natives instead of clones. They found that consumers prefer both large over small pecans and natives over clones. In reality, natives tend to be smaller, and if they also have a better taste, then preferences for size and type may not be as easily separable as they are in hypothetical choice experiments. Blind taste tests can be used to help determine whether consumers prefer natives based on taste alone, absent of information about its type.

There is evidence that pecans with different genetics have different oil contents and that natives can display high amounts of certain oils relative to other clones (but lower amounts of other oils). For example, in study of pecans grown in Chihuahua, Mexico, native pecans had a higher oil content than 'Western Schley' but a lower content than 'Wichita'. Not only did the oil content differ across pecan types but the composition of the oil did as well; the oil from native pecans had higher amounts of linoleic acid but lower amounts of oleic acid (Rivera-Rangel et al., 2018).

Little sensory research involving taste tests have focused on pecans, and the research that has tends to exclude native pecans. Sensory research has demonstrated that the flavor of pecans can indeed depend on the pecan genetics. Two studies (Magnuson et al., 2016; Silva et al., 1995) showed that different clones have different flavor profiles, but the authors also remarked that environmental conditions probably played a larger role than genetics. The studies did not include native pecans and used a trained sensory panel of 6 to 12 individuals. Trained sensory analysts have a keener sense of taste than the ordinary consumer, and it is not clear whether ordinary consumers can even discern among different pecan types. Their decision to exclude natives is understandable. Given that all native pecan trees are different, it is difficult to gauge what the results would mean if they were included. 'Kanza' in Georgia has identical genetics as 'Kanza' in Oklahoma (assuming no genetic mutations), but two native pecan trees on the same farm may have a vastly different genetic profile, even if those two trees share the same parents. However, one trait shared by almost all native trees is that the nuts

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are smaller. If there is a relationship between nut size and taste, then sensory analysis might detect differences among natives and clones.

This is important because if consumers do not actually prefer the taste of native pecans and if they are made aware of this, then producers would be able to increase production of clones and decrease the production of native pecans to the benefit of consumers and the pecan industry. Thus we ask: do native pecans taste better than popular clones such as 'Kanza' and 'Pawnee'? Moreover, given the other possible differences in pecan attributes such as size and texture, how do natives and clones differ?

The purpose of this study is to evaluate the appearance, texture, color, and taste of two popular Oklahoma clones ('Kanza' and 'Pawnee') compared with native pecans in a blind sensory analysis. The objectives entail using blind taste tests to answer two specific questions. The first question is, how do consumers rate the appearance, texture, flavor, and overall satisfaction of native pecan varieties and 'Kanza' and 'Pawnee'? The second question is, what are the crossmodal sensory effects (where one sensory variable like appearance affects other sensory variables like taste/flavor) of pecan color and size on the evaluation of flavor and the overall eating experience of pecans?

Materials and methods

This study was conducted over a 3-year period, each year using pecans from the previous year's harvest that had been in cold storage, with all the pecans coming from the same Oklahoma farm. Samples of each pecan type were acquired from multiple trees. Subjects in the taste test were given three containers labeled only with a shape (square, circle, or triangle). Subjects were asked to participate in a blind taste test of 'Kanza', 'Pawnee', and native pecans, consumed in raw form. Each container contained two pecans, chosen mostly randomly. Selection of the pecans used was made by placing them in a container and shaking it, after which pecans were randomly chosen. So long as the pecan was not obviously inferior in some way, it was used. This was a subjective evaluation used only to eliminate blatantly defective pecans from the sample. If a pecan was broken in half or if it had a glaring discoloration like that from a fungus infection, it was not used. So long as a normal person would see the pecan and not conclude something was wrong with it, the randomly chosen pecan was used. Overall, the quality of the batch was high. Only a few of every 100 chosen pecans needed to be discarded.

The exact materials and methods used to achieve the aforementioned objectives evolved throughout the study, with the results of one taste test informing the design of subsequent tests. As such, in the methods section we sometimes briefly describe the results of one experiment to illustrate the motivation of the subsequent experiment. Although there were five taste-test experiments conducted over the 3-year period, four closely resembled one another, so the five experiments are described here as two different studies.

In all cases, the subjects participating were regular consumers, as opposed to trained sensory analysts. In most cases, the subjects were given a free meal in exchange for their participation, but they always participated in the taste test before given the free meal. The sample consisted of 42% male, 55% female, and 3% who did not select a specific gender. Ages from 18 to 78 years were represented, with half the sample being in the 18- to 30-year-old bracket. Only 11% indicated they rarely or never consume pecans. This study received Institutional Review Board approval at Oklahoma State University under application AG1632.

Study 1 design. The first taste test (study 1.a in Fig. 1) was conducted at an elementary school during a teacher workday. A free lunch was provided to 49 teachers in return for participating in the taste test before the lunch. The test was administered by providing each subject with a tray containing an unsalted cracker, water, pen, questionnaire, napkins, and a plate containing three containers. Each container contained one of the three pecan types: native, 'Kanza', or 'Pawnee'. Each container was identified only by a shape; the container with a square contained two 'Kanza' pecans, the triangle two 'Pawnee' pecans, and the circle two native pecans, although the subject did not know the relationship between the shapes and pecan varieties. The instructions required the subject to taste each pecan in the following order: triangle, circle, then square. Before tasting each pecan, however, they were asked to take a bite from the unsalted cracker and take a sip of water to cleanse their palate.

Before tasting each sample, the subject was asked to rate the appearance

Study 1	Randomization of pecan order?	Preparation of natives?	
1.a) 49 taste-tests at an elementary school in fall of 2016	No	All whole	*Hedonic scales for appearance, texture, flavor, and overall*
1.b) 47 tests in various focus groups in fall of 2016	No	All whole	
1.c) 99 tests in 1907 Meat Co. in December 2016	Yes	All cut in half	
1.d) 112 tests in 1907 Meat Co. restaurant in June 2017	Yes	Some whole, some cut in half	
Study 2			
2) 99 tests in 1907 Meat Co. in spring of 2018.	Yes	All whole	*Measures of pecans' color, length, and width. Hedonic scales for color, size, flavor, and overall*

Fig. 1. Randomization and preparation of pecans in sensory experiments. Hedonic scales pertain to how much subjects like each attribute (appearance, texture, flavor, and overall satisfaction on a 1 to 9 scale, where 1 = dislike extremely and 9 = like extremely). Length and width of pecans are objectives measures in inches, while color measures are subjective evaluations by the subjects on a 1 to 7 scale, where 1 = very light brown and 7 = very dark brown. 1907 Meat Co. is a restaurant located in Stillwater, OK.

of the pecans using a hedonic scale (Stone, 2012), where 1 = dislike extremely and 9 = like extremely. They then proceeded to taste the pecan and rate its texture, flavor, and overall eating equality using the same hedonic scale. A series of focus groups regarding pecans was also being conducted at the time, where the subjects completed the same taste test at the beginning of the session, producing 47 additional observations in study 1.b. That is, study 1.b is the same as 1.a except that it was conducted as part of a series of focus groups, whereas 1.a administered the taste tests but no focus groups.

As will be discussed shortly, the subjects gave higher hedonic scores to the clones relative to the native pecans for all four categories, including flavor. Although it could be that the native pecans actually do have an inferior flavor, it was also observed that the native pecans were considerably smaller in size, leading us to wonder whether the smaller size had a crossmodal effect whereby a less visually appealing pecan was also perceived to have a less appealing flavor. Such crossmodal effects are so prevalent in sensory studies (Spence, 2017) that one often assumes they are present unless evidence suggests otherwise.

A third test (1.c) was performed to determine whether the natives' flavor scores would be improved if 'Kanza' and 'Pawnee' pecans were of a smaller size. The idea was that perhaps the native pecans looked less appealing than the clones, causing an inferior perceived flavor. If there is such a relationship between appearance and reported flavor, then making the clones less visually appealing would increase the flavor scores for natives. This test was identical to 1.a except that it was conducted in the 1907 Meat Co. restaurant in Stillwater, OK, and the two clones were cut in half, making them smaller and irregularly shaped, which is presumably less visually appealing. As will be shown, this improved the perceived attractiveness, flavor, and overall eating satisfaction of the natives considerably, even though nothing about the natives had changed. It thus appeared that making the clones look less appealing improved the reported flavor of native pecans.

To further test the crossmodal relationship between the appearance and flavor scores, a fourth test (1.d) was conducted. The assignment of shapes to pecan types, and thus the order in which the varieties were tasted, were not randomized in the previous three tests because different groups of students assisted in the experiments, and the methods had to be kept simple to prevent confusion. This might present a bias if the order in which pecans are evaluated influences their scores. For the fourth test, only one trained assistant was used, allowing us to randomize the order in which the pecans were evaluated. Subjects were randomly allocated to one of six ordering treatments, with the treatments representing all the possible orders in which the three pecans can be evaluated. Also, the subjects were randomly assigned to one of two treatments: in one treatment, the clones were left whole, and in the other, the clones were cut in half. Once again, the data suggest that natives receive higher flavor scores when the clones are cut in half relative when they are left whole, suggesting that the appearance of pecans is a major driver of pecan flavor and overall likeability. As evidence increasingly pointed to a crossmodal effect between appearance and flavor, a second study was conducted using objective measures of the pecans' size and subjective methods of their color to study their impact on preferences

Study 2 design. To further explore the relationship between the appearance and reported flavor of pecans a second study was conducted. Much about the taste tests were the same. It was conducted at a similar location, using similar materials. Clones were never cut in half, and the pecan's color, length, and width were measured. Length and width were objectively measured using grid paper where one unit is equivalent to 1/8 inch (0.3175 cm). Color was measured using a subjective scale, where subjects indicate the brownness of the color on a scale of 1 = very light brown to 7 = very dark brown.

The questionnaire used first asks the subject to describe the color of the pecan in terms of very light to very dark brown. Then they were asked to provide hedonic scores indicating how much they like the pecans' color, size, flavor, and overall eating quality. Whereas study 1 elicited hedonic scores for appearance, texture, flavor, and overall eating quality, study 2 acquired scores for the color of the pecan and the size of the pecan, in addition to flavor and overall satisfaction.

Descriptive statistics of these length and width measurements, as well as subjective evaluations of color, are shown in Fig. 2. Measurements from a sample of 99 pecans of each type showed that natives are indeed smaller than the clones. 'Pawnee' was the largest in terms of both length and width. 'Kanza' was slightly longer than native pecans but 32% wider. All pecans were evaluated to be in the light brown range, with 'Pawnee' being the darkest and 'Kanza' being the lightest.

Empirical methods for study 1. The hedonic scores for study 1 are reported in discrete integers from 1 to 9, but the actual likeability of the pecan for person *i* and pecan type *j* (e.g., native, 'Kanza', 'Pawnee') in terms of attribute *k* (e.g., appearance, flavor) is assumed to be represented by a latent (meaning unobserved) and continuous variable U_{ijk}.

Referred to generically as utility, U_{ijk} is assumed to behave according to Eq. [1], where V_{ijk} is the deterministic portion of utility and ε_{ijk} is a stochastic error distributed according to the standardized logistic distribution. The ordered logit parameters were estimated by maximum likelihood (Greene and Hensher, 2010) using the ologit command in the

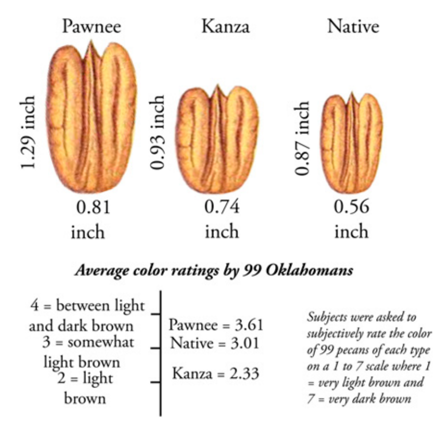

Fig. 2. Size and color differences among 'Pawnee', 'Kanza', and native pecans. The pecans were acquired from the same farm in 2018. Natives were acquired from multiple trees. Length and width measures are the average for the 99 pecans for each type; 1 inch = 2.54 cm.

STATA software package (StataCorp, College Station, TX).

$$U_{ijk} = V_{ijk} + \varepsilon_{ijk} = \beta_{1k}(KANZA_{ijk}) + \beta_{2k}(PAWNEE_{ijk}) + \beta_{3k}(TREATMENT_{ijk}) + \beta_{4k}(KANZA_{ijk}) \times (TREATMENT_{ijk}) + \beta_{5k}(PAWNEE_{ijk}) \times (TREATMENT_{ijk}) + \beta_{6k}(NORANDOM_{ijk}) + \varepsilon_{ijk} \quad [1]$$

The variables are as follows. *KANZA* (*PAWNEE*) are indicator variables that equal one if pecan j is a 'Kanza' ('Pawnee') and zero otherwise. If pecan j is sampled in a context where the 'Kanza' and 'Pawnee' pecans are cut in half, then the *TREATMENT* indicator variable equals one. Recall that in study 1.d (Fig. 1), the order in which the pecans are sampled is randomized, so that there is no ordering bias present for these 112 observations. To account for any ordering bias in tests 1.a to 1.c the indicator variable *NORANDOM* equals 1 if the observation was from study 1.a, 1.b, or 1.c, and zero otherwise. Although this is included primarily to account for possible ordering effects, note that it will also capture other differences in study 1.d from 1.a, 1.b, and 1.c, such as the weather. Some normalization is required for the parameters to be estimated, so the deterministic portion of utility for native pecans, when *TREATMENT* = *NORANDOM* = 0, is normalized to equal zero.

Preferences for clones relative to native pecans are then evaluated by predicting the average utility for each pecan type. Consider the predicted utility for 'Kanza', and recall that the utility for natives are normalized to zero for the cases where all clones are whole. The coefficient β_{1k} indicates how hedonic scores for 'Kanza' differ relative to natives for the kth attribute. If positive and statistically significant, and if $k = 1$ refers to appearance, then the subjects on average report a higher likeability for the appearance of 'Kanza' relative to natives. If $k = 3$ refers to flavor, then 'Kanza' has a more likeable flavor relative to natives.

This is for the case where *TREATMENT* = 0, meaning the clones are whole. If the clones are cut in half, meaning *TREATMENT* = 1, then the predicted utility for natives now becomes β_{3k}. If β_{3k} is positive and statistically significant, then cutting the clones in half then increases the predicted score for natives. Whether 'Kanza' is preferred to natives when 'Kanza' pecans are cut in half (recall natives are never halved) can then be tested by testing the null hypothesis $\beta_{1k} + \beta_{4k} = 0$ relative to the alternative hypothesis that it is positive.

$$\text{Predicted utility for 'Kanza'} = \beta_{1k} + \beta_{4k}(TREATMENT_{ijk}) + \beta_{3k}(TREATMENT_{ijk}) \quad [2]$$

$$\text{Predicted utility for 'Pawnee'} = \beta_{2k} + \beta_{5k}(TREATMENT_{ijk}) + \beta_{3k}(TREATMENT_{ijk}) \quad [3]$$

$$\text{Predicted utility for natives} = \beta_{3k}(TREATMENT_{ijk}) \quad [4]$$

Empirical methods for study 2. The second study uses measurements of the pecans' color, length, and width to investigate the role of appearance in taste perceptions. The first study suggests that pecan appearance is a major driver of pecan preferences. If appearance is the only driver, then information on the size and color of the nut might contain all the information needed to predict hedonic scores. This is tested by first specifying a model where the width, height, and color of the pecan are the only attributes explaining hedonic scores, as shown below. In Eq. [5], the variables *WIDTHPECAN* and *HEIGHTPECAN* are the actual width and height of the pecans, respectively, where a value of eight equals 1 inch (2.54 cm). The variable *COLORPECAN* is the subjective evaluation of the brownness of the pecan by the subject on a scale of 1 = very light brown to 7 = very dark brown.

$$\text{Model 1: } U_{ijk} = V_{ijk} + \varepsilon_{ijk} = \beta_{1k}(WIDTHPECAN_{ijk}) + \beta_{2k}(HEIGHTPECAN_{ijk}) + \beta_{3k}(COLORPECAN_{ijk}) + \varepsilon_{ijk} \quad [5]$$

Model 1 has the potential problem of multicollinearity between the width and height of the nuts. Longer nuts also tend to be wider, so pecan width and height are correlated (correlation = 0.68). This means that information on the width also contains information on the height, and so estimations might not be able to separate the effects of width vs. height. Model 2a thus creates one size variable *AREAPECAN* which equals *WIDTHPECAN* × *HEIGHTPECAN*.

$$\text{Model 2a: } U_{ijk} = V_{ijk} + \varepsilon_{ijk} = \beta_{1k}(AREAPECAN_{ijk}) + \beta_{2k}(COLORPECAN_{ijk}) + \varepsilon_{ijk} \quad [6]$$

Pecans are not rectangles, so their area is only approximated by multiplying length and width. In case this is a poor approximation, Model 2b uses only the single variable *WIDTHTPECAN* without *WIDTHPECAN,*

$$\text{Model 2b: } V_{ijk} + \varepsilon_{ijk} = \beta_{1k}(WIDTHPECAN_{ijk}) + \beta_{2k}(COLORPECAN_{ijk}) + \varepsilon_{ijk} \quad [7]$$

As shown in Fig. 2, there are distinct differences in the size of the three pecan varieties. Although the actual size of each type varies across individual nuts, any one 'Pawnee' is usually larger than any one 'Kanza', and any one 'Kanza' is usually larger than any one native. For example, 3 SD below the mean of the area of 'Pawnee' is larger than 3 SD above the mean of the area of the native, testifying that 'Pawnee' is virtually always larger than a native. Thus, information on the pecan type already contains information on the pecan size, and so Model 3 is specified to capture this.

$$\text{Model 3: } U_{ijk} = V_{ijk} + \varepsilon_{ijk} = \beta_{1k}(KANZA_{ijk}) + \beta_{2k}(PAWNEE_{ijk}) + \varepsilon_{ijk} \quad [8]$$

If pecan flavor is affected only by the pecan size and each type contributes no unique flavors, then adding information on the pecan size to Eq. [8] should have no additional information. To test this we specify Model 4 as well.

$$\text{Model 4:} U_{ijk} = V_{ijk} + \varepsilon_{ijk} = \beta_{1k}(AREAPECAN_{ijk}) + \beta_{2k}(COLORPECAN_{ijk}) + \beta_{3k}(KANZA_{ijk}) + \beta_{4k}(PAWNEE_{ijk}) + \varepsilon_{ijk} \quad [9]$$

Estimates of the four models are used to describe how preferences for pecans vary with size measurements, color measurements, and information on pecan type. The main hypothesis test concerns Model 4 applied to overall satisfaction. If the size of the pecan is the only determinant of pecan preferences, then for overall satisfaction, 1) β_{1k} will be statistically significant and β_{3k} and β_{4k} will not; 2) β_{1k} will be insignificant and β_{3k} and β_{4k} will be statistically significant; or 3) all three variables will be statistically insignificant due to multicollinearity. However, if β_{1k}, β_{3k}, and β_{4k} are all statistically significant, then both the size of the pecan and the pecan type provide information on the eating experience provided, and there are differences in the pecans' type other than size and color.

Results

Study 1 results

There were subjects in study 1 and 99 subjects in study 2. If participants were under age 18 years, their observation was omitted from the analysis (the recruiting material explicitly stated subjects had to be over the age of 18, but four people younger than 18 either did not notice this or participated anyway). Any observations that were incomplete were also omitted. This resulted in 294 subjects in study 1 and 99 subjects in study 2.

The model estimates for study 1 are shown in Table 1. Although the coefficients measure the unobserved latent utility and are thus difficult to interpret, a positive coefficient indicates a higher hedonic score, meaning a more likeable evaluation of the attribute. A negative coefficient indicates the opposite, meaning a less likeable pecan. Of course, only coefficients with probability values <0.05 should be taken seriously; all other coefficients are interpreted to be, in reality, zero. All coefficients are statistically significant except the *NORANDOM* variable, suggesting that there is no ordering bias for tests 1.a, 1.b, and 1.c. The significance of the other coefficients suggests differences between the pecan varieties across all four attributes, and that sensory perceptions change even for natives when 'Kanza' and 'Pawnee' pecans are cut in half.

For all four attributes—appearance, texture, flavor, and overall satisfaction—the coefficients for 'Kanza' and 'Pawnee' are statistically significant and positive, indicating that the subjects preferred the two pecan clones over native pecans on all four dimensions. The coefficient for *PAWNEE* is larger than *KANZA* for appearance, suggesting that 'Pawnee' is favored in terms of appearance. The coefficient for *KANZA* is greater than *PAWNEE* for the remaining three attributes, suggesting that 'Kanza' has a superior flavor. However, likelihood ratio tests (see Table 2) for the null hypothesis that $\beta_{1k} - \beta_{2k} = 0$ cannot be rejected at the 5% level across all attributes. Thus, 'Kanza' and 'Pawnee' are superior to natives, but subjects are indifferent between the two clones.

The coefficient for *TREATMENT* is statistically significant and positive for all attributes, indicating that natives receive higher likeability ratings when they are being compared with the halved clones. The fact that native pecans are given a higher likeability rating for their appearance compared with the halved clones suggests that the hedonic scores being measured are not absolute appraisals but are influenced by contrasting them with nuts of varying appearances. Also, the fact that native pecans have a higher rating for texture and flavor when the clones are halved

Table 1. Ordered logit model estimates for study 1 showing the relationship between pecan type and experimental treatment and the concomitant ratings of pecan appearance, texture, flavor, and overall satisfaction.

	Attribute			
	Appearance	Texture	Flavor	Overall satisfaction
Variable	Parameter estimate (*P*)			
$\beta_{1k}(KANZA_{ijk})^z$	1.795 (0.00)	0.826 (0.00)	0.897 (0.00)	1.192 (0.00)
$\beta_{2k}(PAWNEE_{ijk})$	2.145 (0.00)	0.526 (0.01)	0.623 (0.00)	0.944 (0.00)
$\beta_{3k}(TREATMENT_{ijk})$	0.768 (0.00)	0.394 (0.06)	0.797 (0.00)	0.812 (0.00)
$\beta_{4k}(KANZA_{ijk})(TREATMENT_{ijk})$	–1.119 (0.00)	–0.811 (0.01)	–1.262 (0.00)	–1.163 (0.00)
$\beta_{5k}(PAWNEE_{ijk})(TREATMENT_{ijk})$	–1.050 (0.00)	–0.619 (0.04)	–1.067 (0.00)	–1.013 (0.00)
$\beta_{6k}(NORANDOM_{ijk})$	–0.088 (0.49)	0.036 (0.78)	–0.223 (0.08)	–0.167 (0.19)

[z]Threshold parameters for ordered logit model are omitted. The dependent variable in the ordered logit model is the hedonice score (1 = dislike extremely, 7 = like extremely) for each of the four traits listed in the first row. The explanatory variables in the first column denote the pecan variety, a treatment variable for whether the clones are cut in half, and an indicator variable for whether the order of the pecans are randomized.

Table 2. Hypothesis tests for study 1 determining preferences for pecan type.

	Attribute			
Null hypothesis[z]	Appearance	Texture	Flavor	Overall satisfaction
$\beta_{1k} - \beta_{2k} = 0$	Fail to reject	Fail to reject	Fail to reject	Fail to reject
$\beta_{1k} + \beta_{4k} = 0$	Reject	Fail to reject	Fail to reject	Fail to reject
$\beta_{2k} + \beta_{5k} = 0$	Reject	Fail to reject	Reject	Fail to reject
$\beta_{1k} + \beta_{4k} - \beta_{2k} - \beta_{5k} = 0$	Reject	Fail to reject	Fail to reject	Fail to reject

[z]Tests are conducted using likelihood ratio tests to compare ordered logit estimates with and without the parameter restrictions. The null is rejected if the probability value is <0.05, making the probability of a Type I error less than 5%. The coefficients in the table refer to the estimates shown in Table 1.

suggests a crossmodal effect whereby an improved appearance produces a more likeable eating experience.

The coefficients for (*KANZA*)(*TREATMENT*) and (*PAWNEE*)(*TREATMENT*) are statistically significant and negative for all attributes, meaning the clones receive less favorable ratings when they are halved. This is not surprising for appearance, but why would they have a worse flavor when halved? As before, this might be a crossmodal effect, but another reason might be that subjects are consuming fewer total pecans and thus experience less flavor. When comparing whole pecans, the subjects prefer the clones to the natives, but what about when the clones are halved? The likeability of the 'Kanza' relative to the native pecans when the 'Kanza' is halved can be assessed by the value of $\beta_{1k} + \beta_{4k}$; if positive, 'Kanza' is preferred to natives. Table 2 shows that the null hypothesis $\beta_{1k} + \beta_{4k} = 0$ is rejected at the 5% level for appearance, and because the value of the estimates $\beta_{1k} + \beta_{4k}$ is 1.795 – 1.119 = 0.676, the appearance of 'Kanza' pecans is superior to that of natives even when the 'Kanza' are halved. The same can be said for 'Pawnee' relative to natives. Even though the clones are smaller, they are still wider, so perhaps wideness is preferred to subjects even if they have an unusual shape. In regard to texture and overall satisfaction, when the clones are halved, statistical tests show that the subjects are indifferent between the three pecan types in terms of overall satisfaction. However, when the 'Pawnee' are halved and the natives are not, the natives are deemed to display a superior flavor.

Next consider how 'Kanza' and 'Pawnee' compare with one another when they are both halved. For example, if the value of $\beta_{1k} + \beta_{4k} - \beta_{2k} - \beta_{5k}$ is positive then they prefer the 'Kanza', and if negative they prefer the 'Pawnee'. As Table 2 shows, the null hypothesis that this expression is zero is only rejected in terms of appearance, and for appearance, the value is negative, indicating the appearance of the 'Pawnee' is preferred, presumably due to its larger size.

For readers with less experience interpreting ordered logit models, Fig. 3 provides a more aesthetically pleasing illustration of the results. These are the average hedonic scores for each of the three pecan types in the two treatments. They are the simple averages and not a prediction from the ordered logit model. Notice first that all of the scores are in the "like" side of the hedonic scale, meaning that, on average, the subjects like all three pecan types. Second, notice how the appearance of natives improves considerably when they are compared with halved clones, whereas the average score for the appearance of 'Pawnee' is virtually unchanged and the 'Kanza' appearance falls somewhat. Third, observe how the texture, flavor, and overall likeability improves for natives when the clones are halved. When the clones are whole the native has the lowest flavor rating but attains the highest flavor rating when the clones are halved. Finally, consider how the subjects overall prefer 'Kanza' to 'Pawnee' and the 'Pawnee' to natives when the clones are whole, but when the clones are halved, the scores are virtually indistinguishable. These results further illustrate the finding that the appearance of a pecan is not only important to the consumer, but it also impacts their evaluation of other attributes of the pecans.

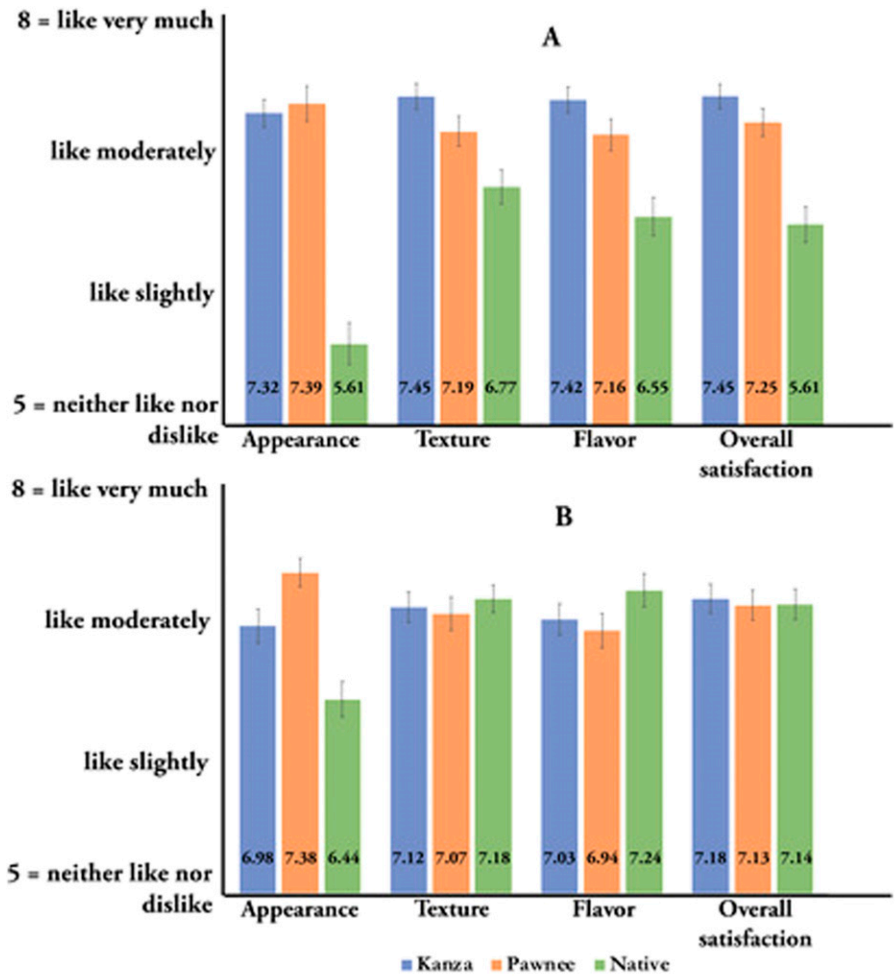

Fig. 3. Average hedonic scores for raw clones ('Kanza' and 'Pawnee') and native pecans when (A) clones (and natives) are whole and (B) clones (but not natives) are halved. Hedonic scores pertain to how much subjects like each attribute (appearance, texture, flavor, and overall satisfaction on a 1 to 9 scale where 1 = dislike extremely and 9 = like extremely. Scores reported in the figure are averages. On the basis of sample sizes of 150 whole and 144 halved clones and 294 natives. Error bars refer to the ± 1 SE (standard error of the average score).

Study 2 results

There were a total of 99 participants in study 2, with no participants under age 18 and no incomplete observations within the data. The model estimates for study 2 are shown in Table 3. Four models are estimated, and each model considered different explanatory variables associated with the three pecan varieties and four attributes: color, size, flavor, and overall satisfaction.

Model 1. The first model contains three variables: *WIDTHPECAN*, *HEIGHTPECAN*, and *COLORPECAN*. Recall that the height and width of each pecan sample was measured before administering the survey to the participants, and the color of each pecan sample was determined by the survey participant. For all four attributes, the coefficients for *COLORPECAN* are insignificant, indicating that the color of a pecan does not influence the sensory evaluations of attributes. The coefficients for *HEIGHTPECAN* were insignificant for all attributes except size, suggesting that the height of a pecan only influences subjects' pecan size preference. For all four attributes, the coefficients for *WIDTHPECAN* are significant, indicating that the width of a pecan influences subjects' preferences of color, size, flavor, and overall satisfaction.

The estimates show pecan width matters, but height does not. However, a wider pecan may also tend to be a taller pecan, such that width is a proxy for height. If this is the case, then the model may not be able to tease apart the impact of width vs. height, implying that one matters but the other one does not, even though in reality both may matter.

Models 2a and 2b. If width and height are both reasonable proxies for size, it may be best to combine them into one size variable. With this in mind, Model 2a contains two variables: *AREAPECAN* and *COLORPECAN*. The area of each pecan sample was calculated by multiplying the measured height and width of the pecan, and the color of each pecan sample was determined by the survey participant. For all four attributes, the coefficients for *COLORPECAN* are insignificant, whereas the coefficients for *AREAPECAN* are significant. Similar to the first model, the second model indicates that the color of a pecan does not influence subjects' sensory evaluations, but size does. Model 2b replaces the area of the pecan with its width and finds similar results.

Model 3. The three varieties all have distinct size and color characteristics. It might be that information on the type explains the important details about the pecan size and color, such that once the type is known, the length and width measurements do not provide any additional useful information. Thus, the third model contains two variables, *KANZA* and *PAWNEE*, allowing the model to estimate preferences based on distinct pecan type characteristics. The two variables represent 'Kanza' and 'Pawnee', and if the pecan being evaluated is a native, then both of the variables are zero. Both the *KANZA* and *PAWNEE* variables have positive and significant coefficients for size and overall satisfaction. Because the utility of native is normalized to equal zero, the coefficients for *KANZA* and *PAWNEE* represent how much more subjects prefer those clones over the natives. This shows that compared with native varieties, 'Kanza' and 'Pawnee' are preferred in their size and considered superior overall to natives.

Model 4. The fourth model contains four variables: *AREAPECAN*, *COLORPECAN*, *KANZA*, and *PAWNEE*. Across all attributes the coefficients for *COLORPECAN* are insignificant. Whether the pecan being evaluated is a 'Kanza', 'Pawnee', or a native does not influence

Table 3. Ordered logit model estimates for study 2 showing the relationship among pecan type, size, and color and the concomitant ratings of pecan appearance, texture, flavor, and overall satisfaction.

	Attribute			
	Color	Size	Flavor	Overall satisfaction
Variable[z]	Parameter estimate (*P*)			
Model 1				
$\beta_{1k}(\boldsymbol{WIDTHPECAN_{ijk}})$[y]	0.3585 (0.02)	0.9333 (0.0000)	0.3922 (0.01)	0.4730 (0.00)
$\beta_{2k}(\boldsymbol{HEIGHTPECAN_{ijk}})$	–0.0586 (0.52)	0.4509 (0.0000)	0.0119 (0.90)	0.1501 (0.10)
$\beta_{3k}(\boldsymbol{COLORPECAN_{ijk}})$[x]	–0.1183 (0.17)	0.00845 (0.92)	–0.0699 (0.45)	–0.1272 (0.14)
Model 2a				
$\beta_{1k}(\boldsymbol{AREAPECAN_{ijk}})$	0.0139 (0.04)	0.0927 (0.00)	0.0228 (0.00)	0.0398 (0.00)
$\beta_{2k}(\boldsymbol{COLORPECAN_{ijk}})$	–0.1485 (0.07)	–0.0339 (0.68)	–0.1080 (0.19)	–0.1546 (0.06)
Model 2b				
$\beta_{1k}(\boldsymbol{WIDTHPECAN_{ijk}})$	0.2907 (0.01)	1.3651 (0.00)	0.4066 (0.00)	0.6531 (0.00)
$\beta_{2k}(\boldsymbol{COLORPECAN_{ijk}})$	–0.1330 (0.11)	0.1572 (0.06)	–0.0661 (0.43)	–0.0808 (0.33)
Model 3				
$\beta_{1k}(\boldsymbol{KANZA_{ijk}})$[w]	0.6546 (0.01)	1.6609 (0.00)	0.4691 (0.06)	0.7610 (0.00)
$\beta_{2k}(\boldsymbol{PAWNEE_{ijk}})$[w]	0.4819 (0.06)	3.4098 (0.00)	0.6300 (0.01)	1.2414 (0.00)
Model 4				
$\beta_{1k}(\boldsymbol{AREAPECAN_{ijk}})$	0.0124 (0.44)	0.0718 (0.00)	0.0463 (0.00)	0.0584 (0.00)
$\beta_{2k}(\boldsymbol{COLORPECAN_{ijk}})$	–0.1095 (0.21)	0.00723 (0.94)	–0.0752 (0.39)	–0.1199 (0.18)
$\beta_{3k}(\boldsymbol{KANZA_{ijk}})$	0.4426 (0.19)	0.7424 (0.03)	–0.2032 (0.55)	–0.0838 (0.80)
$\beta_{4k}(\boldsymbol{PAWNEE_{ijk}})$	0.1087 (0.86)	0.9514 (0.13)	–0.9937 (0.11)	–0.7805 (0.21)

[z]The dependent variable in the ordered logit model is the hedonice score (1 = dislike extremely, 7 = like extremely) for each of the four traits listed in the first row. The explanatory variables in the first column denote the pecan variety and the width, height, and area = width × height of the pecan.
[y]All area measurements are in units of 1/8 inch (0.3175 cm).
[x]Color is determined by the subject according to a 1 to 7 scale, where 1 = very light brown and 7 = very dark brown.
[w]*KANZA* and *PAWNEE* are indicator variables designating the pecan type. If both *KANZA* and *PAWNEE* are zero, the pecan is a native.

preferences. The most significant variable observed in the model is *AREA-PECAN*, indicating that the larger the pecan, the more it is preferred by subjects when considering the size, flavor, and overall satisfaction attributes. This model shows that the size of a pecan is the only attribute that really matters, not the type—apart from the impact of type on size, meaning if a native happens to be the same size as a 'Pawnee', the two pecans are equally preferred.

Discussion

Native pecans are not the preferred pecan in blind taste tests compared with 'Kanza' and 'Pawnee'. Furthermore, although both 'Kanza' and 'Pawnee' are preferred over natives, both clones are liked about the same. The data suggest that appearance is the most influential attribute when considering consumer preferences, with 'Kanza' and 'Pawnee' being more visually appealing. When considering different characteristics of pecan appearance, it is the size of the pecan, not the color, that matters the most to the consumer. Specifically, the larger a pecan is in size, the more satisfied the consumer is overall, and its width seems to matter more than its height. Of course, these results only hold for pecans in the raw form, for these particular types of pecans grown on this one farm, in settings without labels identifying the pecans, and for the subjects included in this study. We recommend future researchers to consider cutting the pecan types into small pieces and have subjects taste each type by the spoonful as a way of completely isolating taste separate from pecan size and amount eaten during the tasting.

These results should not be interpreted as contradicting Palma et al. (2015); instead, the two studies combined have important implications for pecan producers. On the production side, clones tend to produce a more consistent product at a lower cost. On the consumer side, clones also produce a superior nut. However, as Palma et al. (2015) demonstrated, consumers like the name "native" over "improved" varieties, and seemingly small attributes like names can influence not only anticipated but also actual reported taste. Thus, unless a farm's marketing plan involves labeling pecans as "natives," when establishing a new orchard, many orchards may find it best if the farm uses clones similar in appearance and taste to the 'Kanza' and 'Pawnee'. However, even if native pecans have no advantage in blind taste tests, they might still be perceived as better tasting if consumers are told they are natives.

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