SENSORY PROFILES AND SEASONAL VARIATION OF BLACK WALNUT CULTIVARS
AND THE RELATIONSHIP BETWEEN SENSORY CHARACTERISTICS AND
CONSUMER ACCEPTANCE OF BLACK WALNUT GELATO

by

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Abstract

Black walnut (*Juglans nigra* L.) is a *Juglans* species native to the United States. Nuts are collected each fall from black walnut trees and the kernels are consumed in many food products like ice cream, candies, and baked goods. Flavor profiles of black walnut cultivars have been examined, but no studies have looked at the effect of growing season on flavor profile, and few studies have determined consumer acceptance of black walnut food products. The sensory profiles of 10 black walnut cultivars (Football, Vandersloot, Brown Nugget, Pounds, Sparks 127, Davidson, Sparrow, Neel, Emma K, and Tomboy) were evaluated using descriptive sensory analysis. A trained panel scored the intensity of 3 appearance, 7 aroma, 23 flavor, and 6 texture attributes. Results showed that the cultivars differed significantly ($P \leq 0.05$) on 11 of these attributes. The results from this study were also compared to results collected in 2011 of 7 black walnut cultivars. Two flavor attributes (black walnut ID and overall nutty) had an interaction effect of year and cultivar, while 7 attributes showed a main effect of year (brown, caramelized, floral/fruity, fruity,-dark piney, musty/dusty, and oily). In general, flavor attributes had higher intensities in 2011 than in 2013. Six of the black walnut cultivars were also incorporated into a gelato base and evaluated by both a trained panel and consumer panel. Trained panelists developed a lexicon for the gelato samples and scored the intensity of 18 flavor attributes. The gelato samples differed on 3 main flavor attributes: black walnut ID, overall nutty, and sour ($P \leq 0.05$). Based on consumer liking, there were 3 distinct clusters of consumers. One cluster preferred samples with a milder black walnut flavor, another preferred a more intense black walnut and overall nutty flavor, and the third cluster liked all of the samples. Results from this study indicate that growing season should be considered when determining flavor profile of agricultural products. These results can

also help guide growers in selecting cultivars that may produce a more consistent crop year after year, and cultivars that consumers find acceptable in food products.

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Chapter 1 - Literature Review

Nut Consumption Trends

Nut consumption has been increasing over the past few years. Mintel estimated that the nuts and trail mix segment will grow about 61% from 2013-2018, which means sales of about $10 billion (Mintel 2014). In 2013, the walnut crop alone was valued at $1.8 billion (Perez and Plattner 2014). This increase in nut consumption could be attributed to recent attention on the health benefits of nuts. In 2003, the United States Food and Drug Administration issued a qualified health claim for nuts that stated: "scientific evidence suggests that eating 1.5 ounces of nuts per day as a part of a healthy diet (low in cholesterol and saturated fat) may reduce the risk of heart disease" (FDA 2003; Robbins *et al.* 2011). The United States Department of Agriculture also stated in the 2010 Dietary Guidelines that "moderate evidence suggests that nuts and some tree nuts (including walnuts) can reduce the risk of cardiovascular disease when consumed within calorie needs as part of a nutritionally adequate diet" (USDA 2010; Robbins *et al.* 2011). These health claims may help increase nuts consumption and sales as people seek healthier food options.

Many consumers are aware of the nutritious properties of nuts, however, some consumers are still concerned about the amount of fat nuts contain. A survey conducted by Mintel (2012b) with almost 1,700 participants found that about 90% of consumers believe nuts are a good source of protein and a good source of energy; however, they also reported that 33% of consumers limit their consumption due to the fat content of nuts. The most commonly consumed nuts are peanuts, followed by almonds, cashews, pecans, and then walnuts (Table 1.1) (Mintel 2012b). This research by Mintel (2012b) demonstrates that there is room for growth in the walnut category, so walnut processors need to understand consumers' motivations for purchasing nuts. When purchasing black walnuts, researchers found that about 50% of respondents were influenced (either strongly

or very strongly) by nutrition or ease of preparation, 70% by taste, 66% by quality, and about 40% by growing location or price (Gold *et al.* 2004). This research showed that taste and quality are viewed as some of the most important factors of black walnuts.

Table 1.1 Average monthly household consumption of nut types in 2012 (Mintel 2012b)

Nut Type	Monthly Household Consumption
Peanuts	80%
Almonds	70%
Cashews	60%
Pecans	56%
Walnuts	50%
Pistachios	47%

Nuts are consumed in many ways, whether they are eaten alone, or included in products like trail mix, baked goods, or frozen dairy products. In a recent issue of Food Technology, the Institute of Food Technologists reported that about half of households add nuts to salads or use them as an entrée ingredient, while 38% add them to cereal, and about 31% add them to yogurt (Sloan 2012). One of the most common uses for black walnuts is as an inclusion in home baked goods; almost half of black walnut consumption takes place in the fall in baked goods, making them somewhat of a seasonal item (Hammons 1998). Black walnuts are also commonly found in ice cream with about 40% of commercial black walnuts going into ice cream production (Hammons 1998). Black walnut ice cream can be found year-round, so this has potential to stray away from the season category (Hammons 1998). In addition, black walnuts are included in many other food products including candies, salads, and entrées.

Gold *et al.* (2004) conducted a marketing study at the 2003 Missouri Chestnut Roast, a fall festival centered around chestnuts, to determine how familiar consumers are with chestnuts, eastern black walnuts, and pecans. Researchers found that, of 232 respondents, 58% consumed

black walnuts at least 2-6 times per year, 23% consumed them either weekly or monthly, and only 15% had never had black walnuts (Gold *et al.* 2004). In addition, forty-five percent of these respondents, who were from the Midwest, were interested in consuming black walnuts at restaurants, 38% were interested in buying semi-prepared products containing black walnuts, and 32% were interested in buying raw black walnuts (Gold *et al.* 2004).

Black Walnuts

Black walnut trees (*Juglans nigra* L.)*,* one of six *Juglans* species native to the United States, can be found growing across central and eastern United States, from Massachusetts to Northern Florida, stretching west as far as Texas and Minnesota (Reid 1990; Michler *et al.* 2007; Baughman and Vogt 2002). The high quality, dark colored wood of black walnut trees can be used in making furniture, cabinetry, interior woodwork, flooring, and gunstocks (Michler *et al.* 2007; Baughman and Vogt 2002; Dickerson 2002). Black walnut trees are also known for the unique nuts they produce. However, the nut crop is primarily harvested from the mid-portion of the black walnut tree's native range, from Ohio and Kentucky in the east, to Kansas and Nebraska in the west (W. Reid, pers. comm.).

Commercial Production of Black Walnuts

Commercial production of black walnuts is fairly limited, as there is only one commercial black walnut processor in the world: Hammons Products Company, located in Stockton, Missouri (Reid *et al.* 2009). Hammons has over 250 hulling stations in the Midwest, with most of their nut crop coming from native trees (wild black walnuts) and limited amounts coming from orchard trees (cultivar black walnuts) (Reid *et al.* 2009). Hammons estimates that U.S. consumers consume about 2 million pounds of black walnut kernels each year, many in ice cream and baked goods

(Hammons 1998; Hammons *et al*. 2004). About 26 million pounds of whole, hulled black walnuts (wet weight) are required to meet this demand (Hammons *et al*. 2004).

Byproducts of Black Walnut Production

Black walnuts are about 60% shell (wet weight), which makes it essential to use this byproduct of nut shelling (Hammons 1998). Black walnut shells can be ground into six different sizes and used in many industries (Hammons 1998); ground shells can be used for polishing and blast cleaning, water filtration, industrial tumbling and deburring, as a sealant in oil well drilling, and as an ingredient in cosmetics, soap, glue, explosives, and paint (Cavender 1973; Reid 1990; Michler *et al.* 2007).

Nutrition and Health Benefits of Black Walnuts

Black walnuts, like many nuts, have many health benefits that make them attractive to consumers. As shown in Table 1.2, black walnuts are low in saturated fats, high in polyunsaturated fat, fiber, and protein, and have no cholesterol (USDA).

Table 1.2 Nutritional Content of Black Walnuts (USDA)

Nutrient	Amount in 100g	Nutrient	Amount in 100g
Water	4.6 g	Iron	3.1 mg
Energy	619 kcal	Magnesium	201.0 mg
Protein	24.1 g	Phosphorus	513.0 mg
Total Fat	59.0 g	Potassium	523.0 mg
Monounsaturated Fat	15.0 g	Sodium	2.0 mg
Polyunsaturated Fat	36.0 g	Zinc	3.4 mg
Saturated Fat	1.0 g	Copper	1.4 mg
Cholesterol	0.0 mg	Selenium	17.0 µg
Total Carbohydrates	9.9 g	Manganese	3.9 mg
Dietary Fiber	6.8 g	Thiamin	0.06 mg
Sugars	1.0 g	Riboflavin	0.13 mg
Ash	2.5 g	Niacin	0.47 mg
Calcium	61.0 mg	Vitamin A	2.0 µg
Iron	3.1 mg	Vitamin C	1.7 mg

However, some research has shown that black walnuts may have fewer health benefits than English walnuts. Rorabaugh *et al.* (2011) found that black walnuts had fewer phenolic acids and flavonols than English walnuts, while English walnuts also demonstrated a better *in vitro* antioxidant capacity than black walnuts. However, a 28-day feeding study showed no difference in LDL (low density lipoprotein) resistance to oxidation between people who consumed English walnuts and those who consumed black walnuts (Rorabaugh *et al.* 2011). Fitschen *et al.* (2011) found that black walnut consumption decreased LDL levels in men more than English walnut consumption, in addition to decreasing total cholesterol levels in men (Fitschen *et al.* 2011). However, these effects were only seen in men, so there is still additional research that should be done to determine the specific health benefits of black walnuts.

Types of Black Walnut Trees

The same tree that is optimal for lumber is not optimal for nut production, so black walnut trees are either categorized as walnut timber trees or walnut orchard trees (Reid *et al.* 2009). In practice, black walnut wood products are harvested from forest grown trees, while nuts are collected from open grown wild trees or orchards of black walnut trees that have been grafted to cultivars selected for superior nut quality (Reid *et al.* 2009). Walnut timber trees are tall and straight, while walnut orchard trees are shorter, have a fuller canopy, and further spacing, as sunlight is crucial for nut production (Reid *et al.* 2009; Van Sambeek 1998). Orchard trees do not have high quality wood like timber trees and have a low timber value due to their short butt logs, large number of knots, and light-colored sapwood (Baughman and Vogt 2002).

Growing Conditions for Black Walnut Trees

Black walnut trees can have a height of 70-80 feet, a diameter of 2-4 feet, and mature around 150 years (Dickerson 2002); in optimal conditions, they can even grow as tall as 150 feet and have a diameter of 8 feet (Dickerson 2002). Black walnut trees start producing nuts at about 10 years old, and start yielding a decent size nut crop at around 30 years old (Baughman and Vogt 2002). Optimum growing conditions include deep, well-drained soil with a pH between 6.0 and 7.5 (Reid *et al.* 2009; Michler *et al.* 2007). Black walnut trees should not be planted in narrow valleys where there is minimal airflow, as cold air can sit in these valleys and cause frost damage to the trees (Baughman and Vogt 2002). Black walnut trees also produce a chemical, Juglone, which can be toxic to surrounding vegetation (Walnut Council 2011); for this reason, careful planning and consideration should occur before planting black walnut trees.

Factors Influencing Nut Production

Black walnut trees require space to grow; if not given enough space (25-30 feet), nut production can be limited due to negative effects of overcrowding on the tree canopy (Reid *et al.* 2009). Nut production is caused by carbohydrates made during photosynthesis (Van Sambeek 1998), so light penetration into the canopy, which is aided by a large canopy, is crucial for nut production. Nut production varies by tree, but generally, trees that have room to grown and have a large crown have larger nut crops than trees that have limited space to grow and small crowns (Baughman and Vogt 2002). In addition, some black walnut trees have spurs (short branches that grow off of the primary branches) (Reid *et al.* 2009); these additional branches help increase the number of nut bearing sites, and therefore increase nut production potential (Reid *et al.* 2004; Reid *et al.* 2009).

Cool temperatures can also be damaging to black walnut trees; after budbreak has begun, temperatures below 26°F can cause a loss of the tree's nut crop (Reid *et al.* 2004; Reid *et al.* 2009). Black walnut trees require at least 140 frost-free days per year, while at least 170 frost-free days is ideal (Baughman and Vogt 2002). Due to this limitation, it is important to plant cultivars that are suitable for specific areas; early-ripening cultivars should not be planted in long-season climates (areas with more than 210 frost-free days), and late-ripening cultivars should not be planted in cooler climates (areas with less than 180 frost-free days) (Reid *et al.* 2009). It is important to note that Reid *et al.* (2009) defines a frost-free day as one where the temperature is above 28°F. In addition to proper temperatures, sufficient rainfall is crucial for nut production. Lack of precipitation (at least 63.5 cm per year; optimal is 90 cm) can greatly affect nut quality and can also increase alternate bearing (Reid *et al.* 2009; Baughman and Vogt 2002).

Black Walnut Diseases and Pests

In addition to poor growing conditions, there are also some diseases that can harm black walnut trees and cause limited nut production. Anthracnose is a common leaf spotting disease that infects black walnut trees (Reid *et al.* 2009; Van Sambeek 1998). Anthracnose infects the leaves of black walnut trees causing early leaf drop, and limiting photosynthesis which is required for nut production (Reid *et al.* 2009; Van Sambeek 1998). The infection usually occurs in the spring and is accelerated by wet growing conditions, so trees should be treated with a fungicide as soon as pistillate (female) flowers are pollinated (Van Sambeek 1998; Reid *et al.* 2009). In addition to Anthracnose, caterpillars (fall webworm and walnut caterpillar), walnut aphids, walnut lace bugs and European Canker can also damage black walnuts trees (Dickerson 2002; Reid *et al.* 2009). To help combat insects, an insecticide can be mixed with the fungicide mentioned previously (Reid *et al.* 2009). In addition to damaging trees, there are some insects that harm nuts during ripening. Walnut Curculios lay their eggs inside the walnut fruit causing damage to the nut crop (Reid *et al.* 2009). Walnut husk flies also lay eggs inside softening husks of black walnut trees, which causes the husk to darken, in turn, staining the nutmeat black (Reid *et al.* 2009). To limit this, it is crucial to harvest black walnuts quickly or use an insecticide on walnuts just prior to ripening, so the husk flies don't have time to cause husk decay (Reid *et al.* 2009).

Black Walnut Kernels

There are two different types of black walnuts: wild black walnuts and cultivar black walnuts. Almost all of commercial black walnuts are harvested from wild trees (Hammons *et al.* 2004); wild black walnut kernels vary widely in factors like moisture content, percent yield, and quality (Hammons *et al.* 2004). Cultivar black walnuts are grown in orchards and tend to have higher percent yields than wild black walnuts (Reid *et al.* 2009; Reid *et al.* 2004). There are many

advantages to growing black walnut cultivars, for example higher yields and a more consistent

product. Many cultivars have an average nutmeat yield of at least 35%, while wild black walnuts

average closer to 17% nutmeat yield (Reid *et al*. 2004). This big difference in yield highlights the

benefits of cultivar black walnuts. In fact, new black walnut cultivars are not considered for

planting unless they yield at least 30% kernel (Reid *et al*. 2004). In addition, because of the vast

difference in yield, buying stations pay more for nuts harvested from black walnut cultivars

(Brawner and Warmund 2008).

There are over 750 black walnut cultivars that have been identified (Reid 1990). Still, the

most important characteristic of cultivars is the percent kernel yield (Michler *et al*. 2007). In

addition to percent kernel yield, there are other important factors to consider selecting cultivars,

which include: resistance to diseases, nut weight, leafing date, uniform fruit ripening, and low

alternate bearing tendency (Reid *et al*. 2009; Michler *et al*. 2007). It is important to note that

walnuts with thin outer shells and minimal internal convolutions have the highest yield, usually at

least 30% (Reid 1990). Cultivars which consistently produce an annual crop, are not prone to

alternate bearing (having a high yield one year, and a low yield the following year), have at least

30% kernel yield, and are spur-bearing are good cultivars to grow (Reid 1990; Reid *et al*. 2009).

Black Walnut Harvesting and Hulling

When it comes to ripening, black walnut trees can be grouped into three main groups: early-

, mid-, and late-season ripening period (Reid *et al.* 2009). It is important to understand the ripening

period, as different trees will have different optimal harvesting periods. For example, in central

Missouri, ripening dates for early cultivars are usually between September 1-14, mid-season

cultivars are between September 15-28, and late ripening cultivars are after September 28th (Reid *et al.* 2009). Table 1.3 shows some cultivars with their respective ripening times.

Table 1.3 Black Walnut Cultivars (Reid *et al.* 2009)

Cultivar	Leafing Date^	Spur Fruiting	Anthracnose Susceptibility	Nut Weight (g)	Percent Kernel	Alternate Bearing Tendency	Ripening Season*
Sparrow	15	No	Low	19	32	Medium	Early
Sparks 127	12	Yes	High	15	33	High	Early
Tomboy	7	No	Low	22	27	Medium	Early
Emma K	5	Yes	Medium	19	34	High	Mid
Football	6	Yes	High	22	29	High	Late

^ Leafing date = the number of days after Davidson, the earliest leafing cultivar
*Ripening dates for central Missouri: Early: Sept. 1-14; mid: Sept. 15-28; late: after Sept. 28

One method for determining if walnuts are ripe is called the "husk denting method." When a finger pressed into the husk leaves an indentation, it is an indication that the nuts are ripe and ready to harvest (Reid *et al.* 2009). Brawner and Warmund (2008) found that percent kernel fill is generally the greatest when almost all of the husks are dented using the husk denting method. When about half of the nuts on a tree are ripe, a tree shaker can be used to remove the nuts (Reid *et al.* 2009). However, it is more common for nuts to be picked from the ground after they have naturally fallen from the tree, than to be harvested by a tree shaker (Brawner and Warmund 2008); this is especially true for small scale producers (Reid *et al.* 2009). Nuts naturally fall to the ground between September and October (Baughman and Vogt 2002). It is important to pick the nuts off of the ground as soon as possible to prevent the kernel color from darkening too much (Reid *et al.* 2009).

Once the black walnuts are harvested, they must be hulled (removing the outer hull from the nut). Hulls are removed mechanically from the nuts, as the hulls do not easily or naturally separate from the nut (Brawner and Warmund 2008; Reid *et al.* 2004). Research has shown that the longer the husk stays on the nut, the darker the kernel color will be due alkaloids from the husk staining the nutmeat (Reid *et al.* 2009; Reid *et al.* 2004; Warmund 2008). Therefore, quick hulling is key to retain the light kernel color of high quality black walnuts.

After the nuts are hulled, they are washed in a 1,000 ppm chlorine solution that both disinfects and cleans the nuts, and then are air-dried (Reid *et al.* 2009). This process can also be used to help identify poorly-filled nuts which float to the top of the solution (Reid *et al.* 2009). It is estimated that at optimal conditions, an orchard could produce around 2,000 pounds of husked, air-dried nuts per acre (Reid *et al.* 2009).

Black Walnut Quality

Black walnut kernel quality is based on many factors including: kernel color, amount of kernel veins, and plumpness (Reid 1990; Reid *et al.* 2009; Hammons *et al*. 2004). High quality nuts are light in color (light brown/tan), have no kernel veins, no mottling (splotchy color patches) and have a firm texture (Reid 1990; Reid *et al.* 2009; Hammons *et al*. 2004). Size is not usually an indication of quality, as black walnuts are not generally sold as in-shell product (Reid *et al.* 2004). Table 1.4 shows industry sizing for black walnut pieces (Hammons Products Company).

Black walnuts are generally harvested at the same time, which means trees with long periods of ripening can produce kernels that are a wide variety of colors (Reid *et al.* 2004). Color is affected by the amount of time the husk says on the nut after it has matured; the longer the nut stays in the husk, the darker the kernel color will be (Chase 1941). In addition, the flavor of walnuts that are immediately hulled are milder and have a more pleasant flavor than walnuts that have a

delayed hulling (Chase 1941). The darker color and stronger flavors of darker colored nuts is due to alkaloids that are released from the husk and soak through the shell and onto the nut (Reid *et al.* 2004). Consumers associate darker kernel color with rancid flavor (Reid 1990).

Table 1.4 Black walnut nut piece sizing standards (Hammons Products Company)

Size Name	Nut Piece Size	U.S. Standard Sizes
Fancy Large	Larger than 5/16"	-
Large Medium	Range of 1/4" to 5/16"	More than 95% over #4 screen
Regular Medium	Range of 3/16" to 1/4"	At least 75% over #4 screen, and no more than 2% through #6 screen
Ice Cream Pieces	1/8" to 3/16"	At least 90% through #4 screen, and over #8 screen, trace through #8 screen
Small	1/8" to 3/16"	100% through #4 screen, at least 50% over #8 screen

Nut Sensory Properties

Descriptive Analysis of Various Nut Types

Descriptive analysis has been used to determine a wide range of nut flavor profiles. Studies have described the flavor profile of many different types of nuts. Sinesio *et al.* (2001) used descriptive analysis in three separate European laboratories (Italy, France, and Spain) to describe walnut (*Juglans Regia L.*) flavor profile. Civille *et al.* (2010) developed a lexicon (including appearance, aroma, flavor and texture attributes) for raw almond varieties for use in descriptive analysis panels. Warmund *et al.* (2011) used descriptive analysis to determine the texture and flavor of various chestnut cultivars and related it to the free sugar content of the chestnuts.

In addition to research that was done on individual nut types, research has also been done on common flavor attributes found in many different types of nuts. Miller *et al.* (2013) developed a lexicon for "nutty" attributes, and then validated the lexicon using a variety of samples that

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contained nutty flavor attributes. Researchers determined that five terms described the "nutty" attribute found in food products: overall nutty, nutty-buttery, nutty-beany, nutty-woody, and nutty-grain-like (Miller *et al.* 2013).

Research has also been done on the sensory differences between nuts grown in different regions. Tsantili *et al.* (2010) looked at the sensory, physical, and compositional characteristics of eight pistachio varieties from different origins. Young *et al.* (2005) used descriptive analysis to evaluate the flavor profile of peanuts from various production regions including: The United States, China, and Argentina, and conducted a consumer acceptance test with U.S. consumers. Researchers found that peanuts from each region had different flavor characteristics, and that U.S. consumers preferred peanuts from the U.S. (Young *et al.* 2005).

Some studies have also looked at the effect of both growing region and cultivar. Ng and Dunford (2009) used a trained sensory panel to evaluate seven peanut cultivars developed through conventional breeding to compare the flavor profile of peanut cultivars that were developed for the southwestern United States to existing cultivars in the same region. Ng and Dunford (2009) also looked at peanut composition (moisture, oil, protein, and sugar) and analyzed volatile compounds in the peanuts.

In addition, researchers also developed a lexicon for flavors that are affected by processing methods in different nuts. Johnsen *et al.* (1988) developed a lexicon for peanut flavor (*Arachis hypogea*, L. cultivar Florunner) that contained terms to describe flavor notes generated at different stages of the oxidation process, as well as other off-flavors. In the lexicon, researchers included terms that differentiated the different degrees of roast (light, medium, and dark roast), as different roast levels can be present in the same sample of nuts (Johnsen *et al.* 1988).

Descriptive Analysis of Black Walnut Kernels

Warmund *et al.* (2009b) used a descriptive sensory panel to evaluate the flavor profile of six black walnut cultivars (Emma K, Football, Jackson, Kwik Krop, Sparks 127, and Sparrow) and two Persian walnut cultivars (Chandler and Tulare). Researchers sorted the nuts based on color, and only used kernels with a medium skin color. Warmund *et al.* (2009b) found that the black walnut cultivars had different intensities of overall aroma, fruity, woody and sweet attributes; they had higher intensities of the musty flavor attribute, and had a fruity flavor that was not present in the Persian walnuts (Warmund *et al.* 2009b). The black walnuts also had higher overall aroma intensities and higher sweetness intensities than Persian walnuts (Warmund *et al.* 2009b).

Miller and Chambers (2013b) used descriptive analysis to determine the flavor profile of seven black walnut cultivars (Brown Nugget, Davidson, Emma K, Football, Sparks 127, Sparrow, and Tomboy). The authors developed a lexicon with flavor attributes which had more specific and detailed descriptor words than previous black walnut studies; for example, when describing nutty characteristics, there were four attributes listed: overall nutty, nutty-buttery, nutty-grain-like, and nutty woody (Miller and Chambers 2013b). Their results showed that a total of 13 flavor attributes were significantly different between the seven black walnut cultivars (Miller and Chambers 2013b); researchers found that the flavor profile of Emma K kernels differed greatly from the other cultivars; it had higher intensities for acrid, burnt, fruity-dark, musty/earthy, rancid, and bitter flavor attributes and had lower intensities of black walnut ID, overall nutty, nutty-grain-like, nutty buttery, floral/fruity, oily and overall sweet flavor attributes (Miller and Chambers 2013b). The other cultivars had similar flavor profiles, and are characterized by more black walnut ID, overall nutty and overall sweet flavor attributes (Miller and Chambers 2013b).

Impact of Kernel Color on Flavor Profile

Lee *et al.* (2011) studied the aromatic composition of black walnut kernels to determine differences in the aroma profile of different colored black walnut kernels. Overall, the lighter kernels had more volatile compounds than the medium and dark kernels (Lee *et al.* 2011). Furans, which were related overall nutty aroma, were present in higher concentrations in lighter kernels, while darker colored kernels had higher concentrations of aldehydes and alcohols, which are associated with rancid and acrid aromas (Lee *et al.* 2011). In addition, hexanal, which is associated with rancid and acrid aromas, was only found in dark- kernels (Lee *et al.* 2011).

Warmund *et al.* (2009a) evaluated the flavor of light, medium and dark colored black walnut kernels (wild black walnut kernels, and kernels from Sparks 127, Kwik Krop, and Emma K cultivars). Researchers found that 6 of the 18 flavor attributes were influenced by kernel color: burnt, musty/dusty, oily, woody, astringent, and sour (Warmund *et al.* 2009a); medium and dark colored kernels had a burnt flavor and higher intensities for musty/dusty and oily attributes, while light kernels had lower musty/dusty and oily intensities (Warmund *et al.* 2009a). It is also important to note that researchers noticed the Emma K flavor profile was more susceptible to delayed hulling then some of the other cultivars (Warmund *et al.* 2009a).

Warmund (2008) studied the effect of delayed hulling on kernel color of three different black walnut cultivars (Sparrow, Emma K, and Kwik Krop). Warmund (2008) collected walnuts on a weekly basis, hulling half of the walnuts immediately, and delaying hulling two weeks for the remaining half. The researchers used a handheld spectrophotometer to separate the kernels into three categories: light, medium, and dark colored kernels. Overall, Warmund (2008) found that delayed hulling can affect kernel color; however, the degree of these effects depends on cultivar. Researchers found that the Emma K cultivar showed the most changes due to delayed hulling (Warmund 2008).

Black Walnut Food Product Descriptive Research

Some research has looked at the flavor profile of black walnut food products. Matta *et al.* (2005) evaluated various black walnut syrups using a descriptive sensory panel. Syrup samples were made with varying levels of black walnut syrup (obtained by tapping black walnut trees) and cane sugar. Researchers also included a table syrup and a pure maple syrup in the study for comparison. A trained descriptive panel was used to develop a lexicon for the syrup samples which included the following flavor attributes: woody, brown, caramelized, burnt, sweet aromatics, sweet, astringent, bitter, musty/earthy, diacetyl, maple (non-natural) and maple (natural) (Matta *et al.* 2005). Overall, Researchers found that the walnut and maple syrups had similar flavor profiles with flavor attributes like: woody, nutty, maple, brown, musty/earthy, and burnt, which was more complex than that of the table syrup which was characterized by caramelized, sweet, sweet aromatics, and bitter flavor attributes (Matta *et al.* 2005).

Miller and Chambers (2013a) utilized a descriptive panel to determine the flavor profile of sugar cookies made with kernels from six different black walnut cultivars (Brown Nugget, Davidson, Emma K, Football, Sparks 127, and Sparrow). Overall, researchers found that the cookies were significantly different on nine of the twenty-five flavor attributes: black walnut ID, overall nutty, nutty-buttery, brown, toasted, acrid, rancid, overall sweet, and sweet (Miller and Chambers 2013a). Researchers found that the cookies made with Emma K kernels were associated with higher rancid and acrid flavor intensities, and were lower in black walnut ID, overall nutty, sweet, and overall sweet flavors (Miller and Chambers 2013a). The cookies made with Brown Nugget kernels were associated with toasted and brown attributes, while the cookies made with Davidson kernels had lower intensities of both brown and toasted attributes (Miller and Chambers 2013a). The Sparks 127, Sparrow, and Football cookies had similar flavor profiles in that they were associated with piney, leavening, and nutty-woody attributes (Miller and Chambers 2013a).

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Finally, the cookies made with Tomboy kernels were associated with higher overall sweet and sweet flavors (Miller and Chambers 2013a).

Seasonal Variation Research

Little research has been done on the effect of growing season on sensory properties of nut varieties. Heaton *et al.* (1975) studied three pecan cultivars throughout three consecutive growing seasons to determine differences in quality attributes at various harvesting times. Researchers found that pecan color darkened and was less uniform as harvest was delayed (Heaton *et al.* 1975). In addition, over the course of three years, the flavor, texture, and color of the different pecan varieties varied, which researchers attributed to differences in seasonal growing conditions (Heaton *et al.* 1975). Resurreccion and Heaton (1987) found similar results when looking at sensory properties of early harvested and traditionally harvested pecans; pecans harvested early had a lighter color and were not as firm as traditionally harvested pecans (Resurreccion and Heaton 1987). Consumers preferred the early harvested pecans, and were even willing to pay more for them (Resurreccion and Heaton 1987).

In addition to pecans, research has been done on how growing conditions/season can influence the flavor profile of other agricultural products. Bunning *et al.* (2010) researched the effect of seasonal variation on the sensory properties of five different lettuce cultivars. Overall, Bunning *et al.* (2010) found that cultivar influenced the flavor profile of the lettuce more than the growing conditions/seasonal variation. Schwieterman *et al.* (2014) looked at consumer acceptability of 35 strawberry cultivars over 2 growing seasons (12 harvest times). Researchers found that consumer acceptance was greater for early season strawberries than for later season samples for some cultivars, as consumers indicated strawberry flavor and sweetness decreased in the later season strawberries (Schwieterman *et al.* 2014). Schwieterman *et al.* (2014) attributed the

difference in liking scores to environmental factors (temperature prior to harvest) and the plant maturity. Franck *et al.* (2011) studied the effect of harvesting age and season on the texture and dry matter content of cassava root cultivars. Researchers found that the amount of rainfall before the time of harvest influenced the texture of the cassava root- rainfall before harvest lowered the mealiness of the boiled cassava roots (Franck *et al.* 2011). Researchers also found an interaction effect between cultivar and season for firmness of the cassava roots, but noted that the firmness of a few cultivars remained unchanged during the different seasons, showing that harvesting in the dry season is key to retaining quality cassava (Franck *et al.* 2011).

Consumer Research

Black Walnut Food Product Consumer Research

Matta *et al.* (2005) conducted a three consumer acceptance tests, in consecutive years, with table syrup, maple syrup, and black walnut syrups (made with various amounts of black walnut syrup and cane sugar). Two of the consumer tests contained table syrup; in both of these tests, consumers liked the table syrup significantly more than both the maple syrup and black walnut syrup (Matta *et al.* 2005). There were no significant differences in overall liking between the black walnut syrup and the maple syrup samples, so these results demonstrate that there may be a niche market for black walnut syrup, like pure maple syrup (Matta *et al.* 2005).

Miller and Chambers (2013a) conducted a consumer acceptance test with sugar cookies made with kernels from different black walnut cultivars (Brown Nugget, Davidson, Emma K, Football, Sparks 127, and Sparrow). Overall, Miller and Chambers (2013a) found that consumers were only able to distinguish differences in the black walnut flavor of the cookies; to consumers, cookies made with kernels from Football and Sparrow cultivars had the highest black walnut flavor

intensity, while cookies made with Emma K and Sparks 127 kernels had the lowest black walnut flavor intensity (Miller and Chambers 2013a). Despite these differences in black walnut flavor intensity between the cookies, there was no significant difference in overall liking of the different cookies. However, Miller and Chambers (2013a) found four clusters of black walnut consumers based on their acceptance ratings of the cookies. Cluster one (n=29) liked the Football cookie, and did not like the Emma K cookie; this cluster preferred cookies with higher intensities of black walnut ID and overall nutty flavors (Miller and Chambers 2013a). Clusters two (n=25) didn't like any of the cookies, cluster three (n=13) liked all of the cookies, and cluster 4 (n = 33) liked the Emma K cookie and did not like the Football cookie (Miller and Chambers 2013a). Miller and Chambers (2013a) suggested that the acrid flavor present in all of the cookies may be undesirable to consumers in cluster two who did not like any of the samples. The researchers also noted that most of the consumer clusters found the cookies made with Sparks 127 and Brown Nugget cultivars acceptable, so kernels from these cultivars may be more suitable for inclusion in cookies (Miller and Chambers 2013a).

Variety Seeking Tendency

A major limiting factor regarding black walnut sales is lack of familiarity with the nut (Hammons 1998). Because there is only one black walnut processor, and a limited amount of nuts produced, many consumers have never tried or even heard of black walnuts. Therefore, it is important to understand factors that would influence consumers' decision to try or purchase black walnuts. Variety seeking tendency, or intrinsic desire for variety, is important to understand, as it may affect a consumers' motivation for food choice and therefore could be an important criterion to understand when determining consumer segmentation (Van Trijp and Steenkamp 1992). Van Trijp and Steenkamp (1992) developed a scale (VARSEEK) to measure this intrinsic desire for

variety in foods; the scale consists of 8 statements (Table 1.5) that consumers rate on a five-point scale from 1 = completely disagree to 5 = completely agree. Based on their VARSEEK scores, consumers are given a variety seeking score (calculated by reversing the score for question 7 and then adding all responses), and are then segmented into three different groups: low variety seeker (score of 25 and below), medium variety seeker (score of 26-34), and high variety seeker (score of 35 and above), as suggested by Van Trijp and Steenkamp (1992).

Table 1.5 Variety Seeking Scale (VARSEEK) developed by Van Trijp and Steenkamp (1992)

1. When I eat out, I like to try the most unusual items, even if I am not sure I would like them.
2. While preparing foods or snacks, I like to try out new recipes.
3. I think it is fun to try out food items one is not familiar with.
4. I am eager to know what kind of foods people from other countries eat.
5. I like to eat exotic foods.
6. Items on the menu that I am unfamiliar with make me curious.
7. I prefer to eat food products I am used to.
8. I am curious about food products I am not familiar with.

*(Rated on a 5-point Likert scale where 1 = completely disagree; 5 = completely agree)

Several studies have used the VARSEEK scale to relate the variety seeking tendency of consumers to their food choice. Van Trijp *et al.* (1992) determined consumers' desire for variety in spreads (margarine and butter) and cheese. Consumers who had a higher variety seeking scores showed more purchase variation; this was demonstrated more clearly in the cheese results than in the spread results. Van Trijp *et al.* (1992) attributed these findings to a greater sensory variation in cheese than in spreads, and therefore suggested that variety seeking behavior is found more for foods that have a high level of sensory variation (Van Trijp *et al.* 1992). This is a possible reason for why other studies were unable to relate variety seeking tendency and overall liking. Anderson *et al.* (2014) looked at the influence of VARSEEK scores on overall liking of pomegranate juice,

but found that consumer acceptability was not determined by the VARSEEK scores. In addition, Lähteenmäki and Van Trijp (1995) were not able to relate variety seeking tendency to sandwich liking.

Gelato Research

Gelato, Italian style ice cream, is made in smaller batch sizes than ice cream, has little to no overrun, has less fat, and is served at a warmer temperature than traditional ice cream. Based on U.S. standards, ice cream must contain at least 10% milkfat, 20% total milk solids (TMS), and must weigh a minimum of 0.54 kg per liter (Clarke 2012; Marshall *et al.* 2003). A quality gelato is 58-68% water and 32-42% total solids (14-24% sugars, 3-10% fat, 7-12% skim milk solids, and 0.35-0.5% other solids) (Carpigiani Group 2010b). The amount of milkfat in gelato can vary up to 18%, but 6% is common (Marshall and Goff 2003; Marshall *et al.* 2003). Gelato also contains less air than ice cream (overrun of gourmet ice cream is 60-80%, while overrun of gelato is 25-40%) (Carpigiani Group 2008), is served right after production, and has a warmer serving temperature than ice cream (Ferrari 2005); gelato is served between -12 and -16°C (Carpigiani Group 2010a), while ice cream is served between -14 to -12°C (NFRA 2009).

Thompson *et al.* (2009) studied the sensory profile differences between Italian gelato and U.S. ice cream, as there are many compositional differences between the two products. The researchers found that the Italian gelato samples were similar to high-end U.S. ice cream samples, however, the gelato had few to no off-flavors, and had a "truer" flavor than the ice cream samples (more natural flavors and higher quality ingredients) (Thompson *et al.* 2009). In addition, the Italian gelato samples had a dense, smooth texture, while the U.S. ice cream samples were more firm, most likely due to a combination of serving temperature and overrun in U.S. ice cream production (Thompson *et al.* 2009).

Research Objectives

Studies have looked at the flavor profile of black walnuts, and the differences in the flavor profiles of black walnut kernels with varying skin colors. However, it is important to understand how growing season or conditions influence the flavor profile of black walnuts. As seen in other studies on agricultural food products, growing season and conditions can impact flavor profile. In addition, limited research has been done on the flavor profile and consumer acceptance of black walnut food products. This is another important area to study, as black walnuts are commonly consumed in in products like ice cream and baked goods due to their unique flavor profile. This research was conducted to understand the following objectives: (1) a) the sensory profile, including appearance, aroma, flavor, and texture, of 10 black walnut cultivars (Davidson, Sparrow, Neel, Emma K, Tomboy, Football, Vandersloot, Brown Nugget, Pounds, and Sparks 127) and b) the effects of growing season on flavor profile of black walnut cultivars (Emma K, Brown Nugget, Sparrow, Football, Tomboy, Sparks 127, and Davidson); (2) a) the flavor profile of gelato made with six different black walnut cultivars (Davidson, Emma K, Football, Pounds, Sparks 127, and Vandersloot), b) consumer liking and acceptability of the different gelati, and c) if there are associations between consumer acceptability of the gelati and variety seeking tendencies.

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Chapter 2 - Sensory Profiles and Seasonal Variation
of Black Walnut Cultivars

Abstract

Ten black walnut cultivars (Davidson, Sparrow, Neel, Emma K, Tomboy, Football, Vandersloot, Brown Nugget, Pounds, and Sparks 127) were evaluated by a trained sensory panel to determine the sensory profile (appearance, aroma, flavor, and texture) of nut kernels extracted from each cultivar. The panel rated the intensity of 3 appearance, 7 aroma, 23 flavor, and 6 texture attributes for each sample. Results show that cultivars are significantly different on 3 appearance (skin color, nutmeat color, and kernel roughness), 1 aroma (black walnut ID), 5 flavor (black walnut ID, overall nutty, banana-like, piney, and rancid), and 2 texture attributes (surface roughness and hardness). Seven of these black walnut cultivars (Emma K, Brown Nugget, Sparrow, Football, Tomboy, Sparks 127, and Davidson) were compared to results collected in 2011, to determine differences in the flavor profile between growing seasons. A trained panel developed a lexicon for the black walnut kernels and scored the intensity of 22 flavor attributes for each sample. Results showed two flavor attributes (black walnut ID and overall nutty) had an interaction effect of year and cultivar, while seven attributes showed a main effect of year (brown, caramelized, floral/fruity, fruity-dark, piney, musty/dusty, and oily). In general, flavor attributes had higher intensities in 2011 than in 2013. These results suggest that seasonal variation may influence flavor profile more than cultivar. They also indicate that seasonal variation is a critical factor to consider when determining flavor profile of agricultural products, and highlights the importance of having representative samples for testing. Thus, using samples from only one growing season when testing agricultural products may not provide adequate information for the long term.

Introduction

Black walnut (*Juglans nigra L.*) is a North-American hardwood tree valued for producing high quality, dark colored wood used in making furniture, cabinetry, interior woodwork, flooring, and gunstocks (Baughman and Vogt 2002; Dickerson 2002; Michler *et al.* 2007). The tree also produces edible nuts. In practice, black walnut wood products are harvested from forest grown trees, while nuts are collected from open grown wild trees or orchards of black walnut trees that have been grafted to cultivars selected for superior nut quality (Reid *et al.* 2009). Walnut orchard trees are shorter, have a fuller canopy, and are spaced farther apart than the timber trees, as sunlight is crucial for nut production (Reid *et al.* 2009; Van Sambeek 1998). In 1998, Hammons (1998) estimated that U.S. consumers consume about 2 million pounds of black walnut kernels annually in food products. Black walnut trees can be found growing across central and eastern United States, from Massachusetts to Northern Florida, stretching west as far as Texas and Minnesota (Reid 1990; Michler *et al.* 2007; Baughman and Vogt 2002). However, the nut crop is primarily harvested from the mid-portion of the black walnut tree's native range, from Ohio and Kentucky in the east, to Kansas and Nebraska in the west (W. Reid, pers. comm.).

There are over 750 black walnut cultivars that have been identified (Reid 1990). These cultivars can be classified as either ripening in early-, mid-, or late-season (Reid *et al.* 2009). However, even though cultivars ripen at different rates, the black walnuts are usually harvested at the same time (Reid *et al.* 2004). There is no standard for black walnut quality, however, research has shown that delayed harvesting and hulling can have negative effects on kernel color (Warmund 2008), which in turn can lead to unpleasant flavor notes. High quality nuts tend to be light in color (light brown to tan), have no kernel veins, and have a firm texture (Reid 1990; Hammons *et al.* 2004; Reid *et al.* 2009).

There is only one commercial black walnut processor in the world: Hammons Products Company, located in Stockton, Missouri (Reid *et al.* 2009). Hammons processes around 26 million pounds (wet weight) of whole, hulled black walnuts every year, which equates to about 2 million pounds of black walnut kernels (Hammons *et al.* 2004).

Many studies have looked at the flavor profile of black walnut kernels (Miller and Chambers 2013b; Warmund *et al.* 2009b), different factors that influence black walnut kernel flavor profile like time of harvest/hull and skin color (Lee *et al.* 2011; Warmund *et al.* 2009a; Warmund 2008), and sensory characteristics and consumer acceptance of black walnut food products (Matta *et al.* 2005; Miller and Chambers 2013a). However, no research has looked at the effect of growing season on black walnut flavor profile. With many environmental factors influencing nut production, yield, and quality, it is important to understand the effects of growing season on the flavor profile of black walnuts; understanding this can help growers identify how the flavor profile of black walnut kernels changes from year to year, and may help them select cultivars that may be more resistant to seasonal changes. Studies have looked at black walnut flavor profile, but they have not looked at the entire sensory profile of black walnuts (including aroma, appearance, and texture attributes). However, some studies have determined the sensory profile of other nut varieties. Civille *et al.* 2010 developed an almond lexicon, Guerrero *et al.* 2000 studied the sensory profile of different walnut varieties, Sinesio *et al.* 2001 determined the sensory properties of walnut varieties using three different trained panels, Warmund *et al.* 2011 determined the sensory properties (texture and flavor) of chestnut cultivars, and Tsantili *et al.* 2010 studied the physical sensory differences between pistachio varieties.

The objectives of this study were to (1) determine the sensory profile, including appearance, aroma, flavor, and texture, of nut kernels from 10 black walnut cultivars (Davidson,

Sparrow, Neel, Emma K, Tomboy, Football, Vandersloot, Brown Nugget, Pounds, and Sparks 127) and (2) determine the effects of growing season on flavor profile of black walnut cultivars (Emma K, Brown Nugget, Sparrow, Football, Tomboy, Sparks 127, and Davidson).

Materials and Methods

Black Walnut Samples

Ten black walnut cultivars were obtained (9 kilograms per cultivar, in-shell) from an orchard near Joplin, MO, USA. Cultivars obtained included: Davidson, Sparrow, Neel, Emma K, Tomboy, Football, Vandersloot, Brown Nugget, Pounds (formerly Pounds II), and Sparks 127. Shelling was done at the Kansas State University Sensory Analysis Center in November 2013. A Duke Walnut Cracker (Duke Company, West Point, MS, USA) and Channel Lock pliers, model 436 (Channel Lock Inc., Meadville, PA, USA) were used to obtain the nut meat. After shelling, the nuts were chopped into 1 cm pieces and vacuum packaged using a FoodSaver vacuum sealer (Sunbeam Products, Boca Raton, FL, USA) in 3.8 liter FoodSaver bags (Sunbeam Products, Boca Raton, FL, USA). The chopped black walnuts were stored under frozen conditions (-26°C ± 1°C) until evaluation. The nuts were stored for no longer than two months before evaluation.

Sample Preparation

The afternoon prior to evaluation, the black walnut samples were removed from the freezer and allowed to thaw at room temperature (23°C ± 1°C). The morning of evaluation, ten grams of chopped nut pieces were placed in colorless, odorless 3 oz. plastic cups with a lid (Solo Cup Company, Lake Forest, IL, USA); these samples were used for flavor and texture evaluation. Seven grams of chopped nut pieces were placed in a medium snifter and covered with a watch glass to use for aroma evaluation. Four whole walnut kernels were placed in a 3 oz. clear, plastic cup (Solo Cup Company, Lake Forest, IL, USA) for appearance evaluation; these samples were placed under ambient lighting in the back of the evaluation room. The cups and snifters were labeled with random, three-digit blinding codes.

Panelists

Six highly trained panelists (five female and one male) from the Kansas State Sensory Analysis Center (Manhattan, KS, USA) were selected as panelists for the descriptive panel. All six panelists participated in a black walnut kernel and black walnut sugar cookie descriptive panel in 2011 (Miller and Chambers 2013a) and had over 2,000 hours of testing experience with a wide variety of products. In addition to previous training, the panelists also received orientation on the black walnut kernels they were evaluating.

Orientation and Lexicon Development

Two, 90 minute orientation sessions were utilized to determine appearance, aroma, flavor, and texture attributes for the black walnut kernel ballot. Panelists were provided with an initial lexicon that included all of the flavor attributes from the black walnut kernel research conducted by Miller and Chambers (2013b) in 2011 and additional terms for aroma, flavor, and texture from other previous nut studies (Sinesio *et al.* 2001; Civille *et al*. 2010; Tsantili *et al.* 2010; Young *et al.* 2005; Ng and Dunford 2009; Johnsen *et al.* 1988). Panelists identified an additional flavor attribute present in the 2013 black walnut samples that was not on the ballot produced by Miller and Chambers (2013b): Banana-like. Attributes were grouped on the ballot, by order of prominence, by appearance, aroma, flavor, and texture (Appendix B). A total of three appearance attributes, eight aroma attributes, twenty-three flavor attributes, and six texture attributes were identified for the ballot. During orientation, panelists were provided with references that served as anchor points on the scale. Table 2.1 contains a complete list of attributes, definitions, and references.

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Table 2.1 Black walnut kernel attributes, references, and definitions

Attribute	Definition	References
APPEARANCE		
Skin Color	A visual evaluation of the color intensity of the skin on the exterior of the kernel.	Porter Paint Chip 6844-2 = 4.0 (ap) Porter Paint Chip 6767-2 = 8.0 (ap) Porter Paint Chip 6684-1 = 12.0 (ap)
Internal Color	A visual evaluation of the color intensity of the internal nutmeat color of the kernel (nutmeat).	Porter Paint Chip 6188-2 = 2.0 (ap) Porter Paint Chip 6189-2 = 5.0 (ap) Porter Paint Chip 6190-2 = 7.0 (ap)
Roughness/wrinkling	A visual evaluation of the uneven texture of the surface of the product.	Picture A= 2.0 (ap) Picture B = 4.0 (ap) Picture C = 8.0 (ap)
AROMA		
Black Walnut ID	The aromatics commonly associated with black walnuts 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 Black Walnut pieces = 10.0 (a) <u>Preparation:</u> Measure out 1 tbsp. of various cultivars into a food processor and blend for 30 seconds. Put 1 teaspoon in a medium snifter, cover.
Caramelized	A round, full-bodied, medium brown aromatic.	C&H Golden Brown Sugar = 7.5 (a) <u>Preparation:</u> Serve 1 teaspoon of brown sugar in a medium snifter, cover.

Brown	A rich, full aromatic impressions always characterized with some degree of darkness generally associated with attributes (i.e. toasted, nutty, sweet).	Sethness AP 100 Caramel Color (Full Strength) = 13.0 (a) Preparation: Place ½ teaspoon caramel color in a medium snifter, cover.
Fruity-Dark	The sweet, brown honey/caramel-like aromatics commonly associated with dark fruits such as raisins and prunes that have been cooked.	1/4 cup Sun Maid raisins, 1/3 cup dried Ocean Spray cranberries and ¼ cup of Sun Maid prunes, and 3/4 cup of water = 7.0 (a) Preparation: Mix raisins, dried cranberries and prunes (chopped). Add ¾ cup of de-ionized water and cook in microwave on high for 2 minutes. Put 1 tsp of cooked fruit with at least 1 piece of the chopped prune in medium snifters, cover with watch glass.
Banana-Like	Sweet, floral, fruity, candy-like aromatics commonly associated with banana flavored candies.	HyVee Circus Peanut Candy = 10.0 (a) Preparation: Chop candy peanut in half and place in medium snifter, cover.
Musty/Dusty	Dry, dirt-like aromatic associated with dry, brown soil.	Potato peel (covered) = 5.0 (a) Preparation: Put 1.0 gram potato peel in a medium snifter, cover.
Musty/Earthy	Humus-like aromatics that may or may not include damp soil, decaying vegetation, or cellar like characteristics.	Sliced Button mushroom = 8.5 (a) Preparation: Place 3 slices in a medium snifter, cover.

Woody	The sweet, brown, musty, dark, dry aromatics associated with the bark of a tree.	Sigma-Aldrich Cedarwood Oil, Virginia = 6.5 (a) Preparation: Place one drop oil on a cotton ball in a medium snifter, cover.

FLAVOR

Black Walnut ID	The aromatics commonly associated with black walnuts 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 black walnut pieces = 12.0 (f) Preparation: Measure out 1 tablespoon 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.	Gold Medal whole wheat flour = 4.5 (f) Kretschmer wheat germ = 7.5 (f) Mixture of Diamond slivered almonds and Kroger chopped hazelnuts = 7.5 (f) Preparation: Puree the almonds and hazelnuts separately in blenders for 45 seconds on high speed. Combine equal amounts of chopped nuts. Serve in 1 oz. cups.
Nutty-Woody	A nutty aromatic characterized by the presence of woodiness, increased musty/dustiness, brown, astringent and bitter.	Diamond pecan halves = 7.5 (f) Diamond shelled walnuts = 7.5 (f)
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 (f) Kretschmer wheat germ = 7.5 (f)

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 (f)
Brown	A rich, full aromatic impressions always characterized with some degree of darkness generally associated with attributes (i.e. toasted, nutty, sweet).	Bush's Best Pinto Beans (Canned) = 5.0 (f) Preparation: Drain beans and rinse with de-ionized water. Serve in 1 oz. cups. Kretschmer wheat germ = 7.5 (f) Sethness AP 100 Caramel Color = 13.0 (a) Preparation: Place 1/2 teaspoon caramel color in a medium snifter, cover.
Caramelized	A round, full-bodied, medium brown aromatic.	C&H Golden Brown Sugar = 9.0 (f) Preparation: Serve 1 teaspoon of brown sugar in a medium snifter, cover.
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 (f)
Burnt	A dark, brown, somewhat sharp, over-baked grain aromatic.	Alf's Natural Nutrition puffed red wheat cereal = 3.0 (f)
Floral/Fruity	Sweet, light, aromatics impression associated with flowers and fruits.	Welch's White Grape Juice = 5.0 (f) Preparation: Dilute 1 part juice with one part water.

Fruity-Dark	The sweet, brown honey/caramel-like aromatics commonly associated with dark fruits such as raisins and prunes that have been cooked.	1/4 cup Sun Maid raisins, 1/3 cup dried Ocean Spray cranberries and ¼ cup of Sun Maid prunes, and 3/4 cup of water = 5.0 (f)
		Preparation: Mix raisins, dried cranberries and prunes (chopped). Add ¾ cup of de-ionized water and cook in microwave on high for 2 minutes. Pour juice into 1 ounce cups, cover with lid. Put 1 tsp of cooked fruit with at least 1 piece of the chopped prune in medium snifters, cover with watch glass.
Banana-Like	Sweet, floral, fruity, candy-like aromatics commonly associated with banana flavored candies.	HyVee circus peanut candy = 10.0 (f)
		Preparation: Cut peanut in quarters and serve 4 pieces in a 1 oz cup.
Piney	A slight resinous aromatic associated with fresh green pine needles.	Kroger pine nuts = 6.0 (f)
Musty/Dusty	Dry, dirt-like aromatic associated with dry, brown soil.	Potato peel (covered) = 5.0 (a)
		Preparation: Put 1.0 gram potato peel in a medium snifter, cover.
Musty/Earthy	Humus-like aromatics that may or may not include damp soil, decaying vegetation, or cellar like characteristics.	Sliced Button mushroom = 8.5 (a), 10.5 (f)
		Preparation: Place 3 slices in a medium snifter, cover. Serve chopped mushroom in 1 oz cups.

Woody	The sweet, brown, musty, dark, dry aromatics associated with the bark of a tree.	Diamond shelled walnuts = 4.0 (f)
		Sigma-Aldrich Cedarwood Oil, Virginia = 6.5 (a)
		Preparation: Place one drop oil on a cotton ball in a medium snifter, cover.
Overall Sweet	An aromatic associated with the impression of sweet substances.	Post Shredded Wheat = 1.5 (f)
		General Mills Wheaties = 3.0 (f)
		Lorna Doone cookie = 4.5 (f)
Oily	The light aromatics associated with vegetable oil such as corn or soybean oil.	Kroger slivered and blanched almonds = 4.0 (f)
		HyVee dry roasted and salted macadamia nuts = 9.0 (f)
Rancid	An aromatic commonly associated with oxidized fat and oils.	Wesson vegetable oil = 2.5 (f)
		Preparation: Microwave 1/3 cup of oil on high power for 2 1/2 minutes. Let cool and serve in 1 oz. covered cups.
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 (f)
		0.050% Alum solution = 2.5 (f)
		0.075% Alum solution = 3.5 (f)
		0.10% Alum solution = 5.0 (f)
Bitter	A fundamental taste factor of which caffeine is typical.	0.010% Caffeine Solution = 2.0 (f)
		0.020% Caffeine Solution = 3.5 (f)

0.035% Caffeine Solution = 5.0 (f)

Sour	A fundamental taste factor of which citric acid is typical.	0.015% Citric acid solution = 1.5 (f) 0.025% Citric acid solution = 2.5 (f)
Sweet	A fundamental taste factor of which sucrose is typical.	1.0% Sucrose solution = 1.0 (f)

TEXTURE

Surface Roughness	The amount of indentations/bumps and surface abrasions which can be perceived by gently manipulating one piece between the palate and the tongue.	General Mills Cheerios (one piece) = 5.0 (t) General Mills Wheaties (one piece) = 9.0 (t) Nabisco Triscuit (1/4 cracker) = 11.0 (t)
Hardness	The force required to bite completely through the sample with molar teeth. Evaluate on first bite down with the molars.	Cheerios (one piece) = 5.5 (t) Wheaties (one piece) = 7.5 (t) Kroger Dry Roasted Slightly Salted Peanuts = 8.5 (half peanut, cut side down) (t)
Initial Crispness	The intensity of audible noise at first chew with molars.	General Mills Cheerios = 8.0 (t) General Mills Wheaties = 10.5 (t)
Fracturability	The force with which the sample ruptures. Evaluate on first bite down with the molars.	General Mills Cheerios (one piece) = 4.0 (t) General Mills Wheaties (one piece) = 7.5 (t)

Tooth Packing	The amount of sample packed in and between the molar teeth after swallowing.	General Mills Cheerios = 3.5 (t) General Mills Wheaties = 7.0 (t)
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.	General Mills Cheerios = 3.0 (t) General Mills Wheaties = 7.0 (t)

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Test Design and Sample Evaluation

Each black walnut sample was evaluated, in triplicate, using a descriptive sensory method used by Ledeker *et al.* (2012) and Miller and Chambers (2013b). Panelists rated the intensity of 3 appearance, 7 aroma, 23 flavor, and 6 texture attributes on a 15 point scale with 0.5 increments, where 0 = not present and 15 = highest possible intensity. Panelists were provided with references for appearance, aroma, flavor and texture attributes (Appendix A). Panelists received ten grams of black walnut kernel pieces in a 3 oz. clear, plastic cup with a clear lid (Solo Cup Company, Lake Forest, IL, USA) labeled with a random, 3-digit code. Panelists used one nut piece at a time for evaluation, and were encouraged to swallow at least one bite of every sample.

To cleanse their palate between samples, panelists were given 0.64 cm carrot medallions, 0.64 cm skinless cucumber slices, and 1.3 cm mozzarella cheese cubes (low moisture, part skim; Kroger Company, Cincinnati, OH, USA). They were also provided with soft-bristled toothbrushes (Kroger Company, Cincinnati, OH, USA) to help remove particles from their teeth.

A modified William's Latin Square design (Kuehl 2000) was used to serve the samples (Appendix G). Each cultivar was evaluated, in triplicate, by the trained panel. Evaluation sessions lasted 120 minutes, with a 10 minute break in the middle of each session. The evaluation process took a total of 6 days, with panelists evaluating 6-7 samples per day.

Statistical Analysis

Analysis of variance (ANOVA) was used, at the 5% significance level, to test for significance between attributes across the ten cultivars in 2013. Fisher's Least Significant Difference post-hoc means separation was used, at the 5% significance level, to determine statistical significance between black walnut kernels from different cultivars. Analysis was

performed using SAS 9.3 statistical software (SAS Institute Inc., Cary, NC, USA), PROC GLIMMIX. Appendix I contains all codes. Principal components analysis (PCA) biplots were created using XLSTAT (Addinsoft, New York, NY, USA).

To determine seasonal variation, analysis of variance (ANOVA) was performed, at the 5% significant level, on the means from both growing seasons (2011 and 2013). The seven overlapping cultivars were used in this analysis (Emma K, Brown Nugget, Sparrow, Football, Tomboy, Sparks 127, and Davidson). In addition, only flavor attributes were included in this analysis (excluding the banana-like flavor attribute that was only found in the 2013 samples), as flavor attributes were the only attributes studied in 2011. Miller and Chambers (2013b) had seven panelists evaluate the 2011 black walnut samples; because six panelists were used in the 2013 black walnut evaluation, the overlapping panelists' data was used, and the seventh panelist's data from 2011 was not used in the comparison of data from the two different growing seasons. Analysis of variance (ANOVA) was used to test the significance of the flavor attributes across cultivars at the 5% significance level. Fisher's protected Least Significant Difference (LSD) post-hoc means separation was used at the 5% significance level to determine significance. Analysis was performed using PROC MIXED on SAS® statistical software (version 9.3, SAS Institute Inc., Cary, NC, USA).

Results

Sensory Profiles of Cultivars

Miller and Chambers (2013b) found that black walnut kernels produced in 2011 differed on 13 of 22 flavor attributes (black walnut ID, overall nutty, nutty-grain-like, nutty-buttery, acrid, burnt, floral/fruity, fruity-dark, musty/earthy, overall sweet, oily, rancid, and bitter). The Emma K nut meats were significantly lower in attributes like black walnut ID, overall nutty, nutty-buttery, and floral/fruity than the rest of the cultivars (Miller and Chambers 2013b); Emma K was also significantly higher in acrid, burnt, fruity-dark, musty/earthy, rancid, and bitter flavor attributes than the rest of the cultivars (Miller and Chambers 2013b). The other six cultivars (Brown Nugget, Football, Davidson, Sparks 127, Sparrow, and Tomboy) had similar flavor profiles.

The black walnut kernels produced in 2013 differed on 5 of 23 flavor attributes (black walnut ID, overall nutty, banana-like, piney, and rancid) (Table 2.2). Sparrow nut meats had the highest black walnut ID flavor, while Vandersloot kernels had the lowest black walnut ID flavor and piney flavor. Tomboy kernels had the highest overall nutty flavor, while Davidson kernels had the lowest. Banana-like flavor was highest in Sparrow nut meats, and lowest in Vandersloot. Finally, rancid flavor was highest in Davidson and Neel kernels, while there was no rancid flavor in kernels from the Brown Nugget, Emma K, Football, Pounds, Sparks 127, and Sparrow cultivars.

In addition to evaluating flavor attributes, the panel in 2013 also evaluated appearance, aroma, and texture. The panel found that the 10 cultivars differed on 3 appearance, 1 aroma, and 2 texture attributes (Table 2.2). The Emma K and Davidson kernels had the darkest skin color, while Football kernels had the lightest skin color. Davidson kernels also had the highest kernel roughness, while Football, Tomboy, and Emma K had the lowest kernel roughness. Neel and Pounds cultivars yielded the darkest nutmeat color, while Sparks 127 and Tomboy had the lightest

nutmeat color. Pounds, Sparrow, and Tomboy had the highest black walnut ID aroma, while Vandersloot, Davidson, and Emma K had the lowest black walnut ID aroma. Sparks 127 had the highest surface roughness and highest kernel hardness, while Football had the lowest surface roughness, and Vandersloot had the lowest kernel hardness.

Two Principal Components Analysis (PCA) biplots were also created with the data from the 2013 cultivars (Figure 2.1 and 2.2). Figure 2.1, a PCA biplot with aroma and flavor attributes that accounts for 58% of the variation, shows that the Tomboy, Sparks 127, Brown Nugget, Sparrow, and Football kernels had higher black walnut ID and overall nutty flavor (in addition to nutty-woody, nutty-buttery, and nutty-grain-like), banana-like flavor, sweet flavor, and piney flavor. The Neel and Pounds kernels had less black walnut ID and overall nutty flavor than the previous cultivars, and had slightly more fruity-dark, banana-like, and black walnut ID aroma. Kernels from the Vandersloot cultivar had lower black walnut ID aroma and flavor, overall nutty flavor, banana-like flavor, and higher oily, bitter, sour, and musty/earthy flavors. The Emma K and Davidson kernels seem to have less black walnut ID, fruity-dark, banana-like, and caramelized aromas, and more brown flavor.

Figure 2.2, a PCA biplot with appearance and texture attributes that accounts for 73% of the total variation, shows that Sparks 127 kernels were characterized by a higher initial crispness, fracturability, hardness, and tooth packing. Neel, Pounds, and Vandersloot kernels had a darker nutmeat color and lower hardness and initial crispness than most of the other cultivars. The Tomboy and Football cultivars had lower kernel roughness and surface roughness and had a lighter skin color. The Davidson kernels had a darker skin color, and more surface and kernel roughness. The Emma K and Brown Nugget cultivars also appear to have less kernel and surface roughness.

Table 2.2 Mean intensity scores of appearance, aroma, flavor and texture attributes in 2013 black walnut samples

					Attribute						
Cultivar	Skin Color (ap)	Nutmeat Color (ap)	Kernel Roughness (ap)	Black Walnut ID (a)	Black Walnut ID (f)	Overall Nutty (f)	Banana-Like (f)	Piney (f)	Rancid (f)	Surface Roughness (t)	Hardness (t)
Brown Nugget	7.83^{AB}	4.42^{BC}	2.92^{CDE}	9.28^{AB}	11.53^{AB}	7.25^{ABC}	1.64^{AB}	1.64^{AB}	0.00^{C}	2.94^{BC}	5.72^{AB}
Davidson	8.72^{A}	4.11^{CD}	3.89^{A}	8.39^{C}	10.39^{CD}	6.50^{E}	1.42^{BC}	1.75^{A}	0.42^{A}	3.31^{AB}	5.56^{ABC}
Emma K	8.56^{A}	4.47^{BC}	2.58^{E}	7.89^{C}	11.06^{ABC}	7.06^{BC}	1.69^{AB}	1.69^{A}	0.00^{C}	2.89^{BC}	5.36^{BCD}
Football	4.89^{F}	4.53^{BC}	2.47^{E}	8.69^{BC}	11.31^{AB}	7.14^{ABC}	1.75^{AB}	1.92^{A}	0.00^{C}	2.78^{C}	5.17^{CD}
Neel	6.75^{CD}	5.28^{A}	2.72^{DE}	9.53^{AB}	10.94^{BC}	6.94^{CD}	1.50^{ABC}	1.92^{A}	0.22^{AB}	2.89^{BC}	5.28^{BCD}
Pounds	6.22^{DE}	5.44^{A}	3.17^{BCD}	10.00^{A}	11.14^{ABC}	7.06^{BC}	1.56^{AB}	1.89^{A}	0.00^{C}	2.86^{BC}	5.22^{CD}
Sparks 127	7.86^{AB}	3.61^{D}	3.28^{BC}	9.42^{AB}	11.61^{AB}	7.28^{ABC}	1.58^{AB}	1.72^{A}	0.00^{C}	3.56^{A}	5.86^{A}
Sparrow	5.89^{DEF}	4.39^{BC}	3.47^{AB}	9.69^{A}	11.89^{A}	7.39^{AB}	1.78^{A}	1.78^{A}	0.00^{C}	3.11^{ABC}	5.47^{ABC}
Tomboy	5.58^{EF}	3.42^{D}	2.47^{E}	9.86^{A}	11.69^{AB}	7.56^{A}	1.72^{AB}	1.94^{A}	0.11^{BC}	2.86^{BC}	5.56^{ABC}
Vandersloot	7.50^{BC}	4.89^{AB}	3.22^{BCD}	8.17^{C}	9.89^{D}	6.58^{DE}	1.19^{C}	1.33^{B}	0.14^{BC}	3.19^{ABC}	4.92^{D}

Scores were based on a 15 point scale with 0.5 increments, where 0 = not present and 15 = highest possible intensity

+ (ap) = appearance; (a) = aroma; (f) = flavor; (t) = texture

^Mean liking scores sharing the same superscript within a column are not significantly different (P≤0.05)
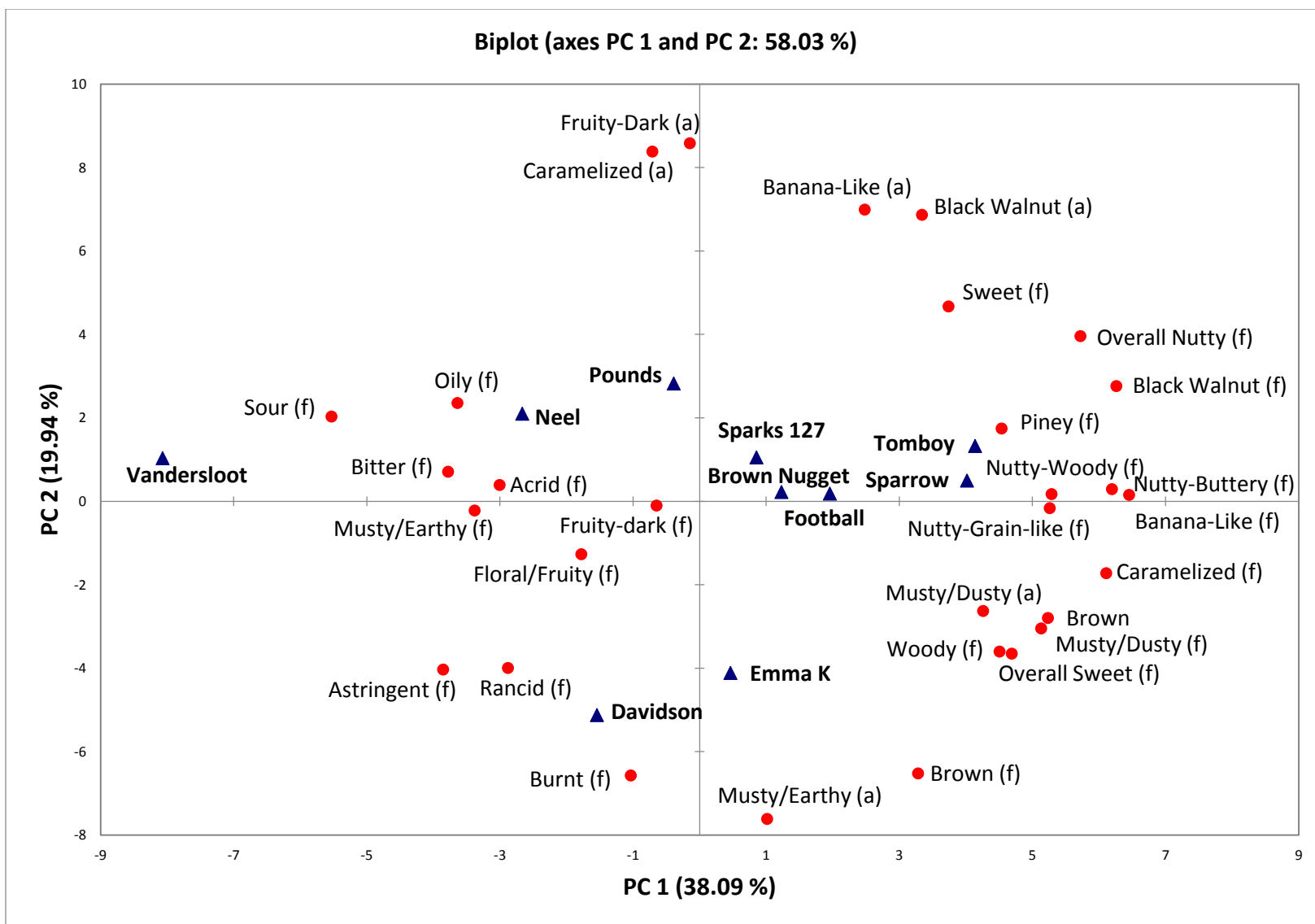
Figure 2.1 Principal components analysis (PCA) biplot showing principal components 1 and 2 for the 10 black walnut cultivars from 2013 and the aroma and flavor attributes. *(a) indicates aroma; (f) indicates flavor
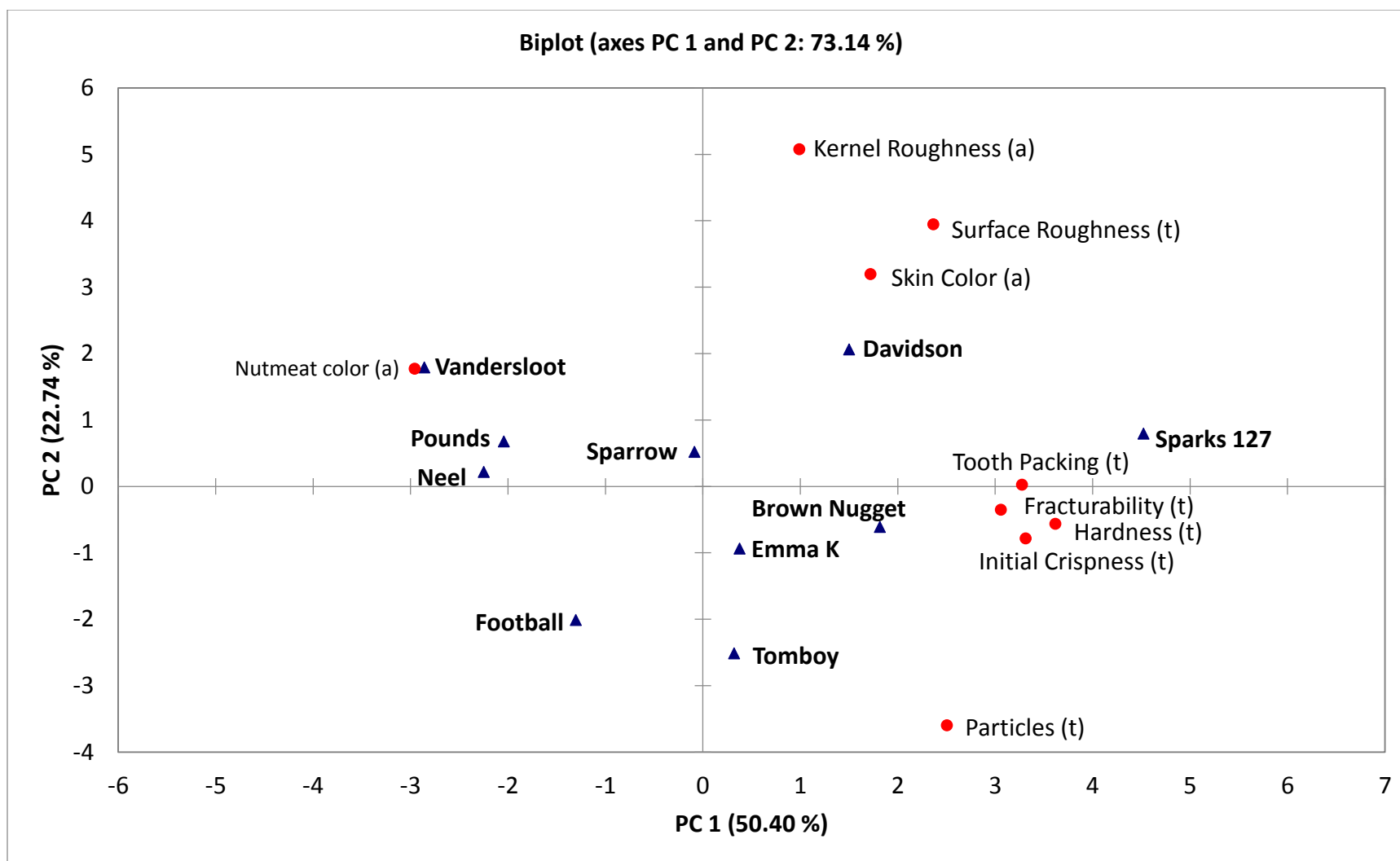
Figure 2.2 Principal components analysis (PCA) biplot showing principal components 1 and 2 for the 10 black walnut cultivars from 2013 and the appearance and texture attributes. *(a) indicates appearance; (t) indicates texture

Seasonal Variation Research

An interaction effect was found between year and cultivar for 11 of the 22 flavor attributes (Black walnut ID, overall nutty, nutty-grain-like, nutty-buttery, acrid, burnt, floral/fruity, fruity-dark, musty/earthy, overall sweet, and rancid). However, almost half of these interactions (black walnut ID, overall nutty, acrid, and rancid) were caused by a single sample from 2011, Emma K, which most likely was non-representative of the cultivar due to crop overload (too many nuts on the tree can lead to poor kernel formation and dark colored kernels), or due to late harvesting or hulling. Miller and Chambers (2013b) described the Emma K sample as having a darker skin color and being more shrivelled/wrinkled than the other six cultivars. Miller and Chambers (2013b) also found that the Emma K samples had higher intensities of acrid, rancid, bitter, musty/earthy, burnt, and fruity-dark notes, which is also an indication of late harvesting or hulling; Warmund (2008) found that delayed hulling caused kernels to have darker colors and increased undesirable flavors (acrid, rancid, and bitter). Because of this, the Emma K cultivar was removed from the analysis.

After removing Emma K, the non-representative sample, two flavor attributes (black walnut ID and overall nutty) had an interaction effect of year and cultivar, while seven attributes showed a main effect of year (brown, caramelized, floral/fruity, fruity-dark, piney, musty/dusty, and oily). No main effects of cultivar were found.

Two flavor attributes had an interaction effect of year and cultivar (Table 2.3). Flavor attributes like black walnut ID and overall nutty, main flavor attributes of black walnuts, varied depending on year and cultivar, further supporting the idea that growing season influences flavor profile of black walnuts. However, it does appear that the change in intensity was less than 1 (on a 15-point scale) for these attributes, so these effects may be small. Additional research should be done to determine the seasonal variation over many growing seasons.

Table 2.3 Mean intensity scores of flavor attributes with a year and cultivar interaction effect

| | Flavor Attribute | | | |
| | Black Walnut ID | | Overall Nutty | |
Cultivar	2011	2013	2011	2013
Brown Nugget	11.22	11.53	7.11	7.25
Davidson	11.31	10.39	7.36	6.50
Football	11.28	11.31	7.11	7.14
Sparks 127	11.22	11.61	7.08	7.28
Sparrow	11.36	11.89	7.11	7.39
Tomboy	11.42	11.69	7.19	7.56

Seven flavor attributes had a main effect of year (Table 2.4). A majority of the flavor attributes that had a main effect of year (brown, caramelized, floral/fruity, piney, and musty/dusty) had higher intensities in 2011 than in 2013. However, the fruity-dark and oily flavor attributes had higher intensities in 2013 than in 2011. These results suggest that growing season/year may influence flavor profile more than cultivar, as there were seven attributes with a main effect of year and no attributes with a main effect of cultivar.

Table 2.4 Mean intensity scores of flavor attributes with a main effect of year

					Flavor Attribute								
	Brown		Caramelized		Floral/Fruity		Fruity-Dark		Piney		Musty/Dusty		Oily	
Cultivar	2011	2013	2011	2013	2011	2013	2011	2013	2011	2013	2011	2013	2011	2013
Brown Nugget	4.08	2.33	1.83	1.25	1.58	0.61	0.36	1.58	2.39	1.64	2.50	1.25	3.54	5.86
Davidson	4.08	2.72	1.94	1.08	1.64	0.50	0.39	1.72	2.39	1.75	2.42	1.22	3.58	5.64
Football	4.31	2.22	1.83	1.19	1.50	0.58	0.53	1.28	2.47	1.92	2.56	1.11	3.64	5.86
Sparks 127	4.19	2.39	1.94	1.14	1.44	0.31	0.36	1.56	2.53	1.72	2.61	1.14	3.64	5.25
Sparrow	4.22	2.50	1.81	1.36	1.56	0.67	0.50	1.67	2.72	1.78	2.47	1.33	3.56	5.81
Tomboy	4.14	2.58	1.81	1.33	1.64	0.53	0.25	1.86	2.44	1.94	2.61	1.19	3.61	5.69

In addition to the year and cultivar interaction effects and the main effects of year found, there was also a flavor attribute found in the 2013 samples that was not present in the 2011 samples: banana-like. This attribute was present at intensities just above the threshold level (Table 2.2). Davidson, which was also lower in black walnut ID and overall nutty flavors, had lower intensities of banana-like flavor. Football, which was characterized as having higher intensities of black walnut ID flavor, had a higher intensity of banana-like flavor.

Discussion

No studies were found on black walnut texture characteristics; however, research by Civille *et al.* (2010) found that almond varieties had more differences in chew-down and residual attributes than surface and first chew attributes, and were not very variable on appearance and aroma. Our research found that black walnut varieties were significantly different on skin color and nutmeat color, in addition to surface roughness, hardness, and black walnut ID aroma. Warmund *et al.* (2011) found that chestnut cultivars were significantly different on initial firmness, and dissolvability, while our research also found that kernels of black walnut cultivars had significantly different hardness ratings (hardness was evaluated on the first bite). The sensory panel in a study conducted by Tsantili *et al.* (2010) found no significant differences in kernel color, whereas our research found that there was a significant difference in kernel color of different black walnut cultivars. Guerrero *et al.* (2000) found significant differences in many of the texture and appearance attributes of English walnut cultivars including: skin color, internal color, and adhesiveness, which is similar to results found in our study which show significant differences in skin color and nutmeat color of black walnut cultivars.

There are many factors that can influence the production and quality of black walnuts. One of the main environmental factors that can influence nut production is rainfall. For optimal nut production and quality, black walnut trees require at least 63.5 cm of rain, with optimal amounts closer to 89 cm (Baughman and Vogt 2002). The annual precipitation in 2011 was 99 cm and 113 cm in 2013 (Midwestern Regional Climate Center). While the annual precipitation amounts in both years are both above the optimal amount of 89 cm, the rainfall during key kernel filling time (July to August) was strikingly different between the two years. In 2011, the average precipitation during these months was 8.3 cm, while in 2013, the average precipitation in these months was 20.1

cm (Midwestern Regional Climate Center). This major difference in rainfall during kernel filling in the 2011 and 2013 growing seasons could have influenced the kernel quality and flavor; it could be a reason for why there were main effects of year, and no main effects of cultivar.

In addition, previous studies have found that harvest and hull time is an important factor in obtaining optimal nut quality. Warmund (2008) found that delayed hulling affected kernel color; the severity of the effect was dependent on cultivar. Warmund *et al.* (2009a) found that dark colored kernels had higher intensities of burnt, musty/dusty, oily, woody and astringent attributes. Lee *et al.* (2011) found that darker colored kernels had higher concentrations of aldehydes and alcohols, which are associated with rancid and acrid aromas, and hexanal, which is associated with acrid, rancid, and musty/earthy attributes. In addition, Lee *et al.* (2011) found that light colored kernels had higher concentrations of Furans, which are associated with the overall nutty aroma, a more desirable aroma characteristic. The Emma K cultivar from 2011 appeared to have been harvested/hulled late, because of its dark skin color and higher intensities of acrid, burnt, fruity-dark, musty/earthy, rancid, and bitter attributes. In 2013, the Emma K cultivar had a lighter skin color, so it appeared that it was harvested/hulled at a more appropriate time. This shows the importance of harvesting and hulling black walnuts at proper times, as delayed harvesting and hulling may cause different flavor profiles in black walnuts.

The results of this study, which indicate that growing season/growing conditions influences flavor profile more than cultivar, are also similar to several previous studies on seasonal variation of agricultural products. Heaton *et al.* (1975) found that pecan color darkened and was less uniform as harvest was delayed, and texture, color and flavor profile of pecan varieties varied due to seasonal growing conditions. In addition, Resurreccion and Heaton (1987) found that consumers were willing to pay more for early harvested pecans, which were lighter in color and less firm than

traditionally harvested pecans. Finally, Schwieterman *et al.* (2014) found that consumers had higher acceptance ratings for strawberries harvested earlier in the growing season than later in the growing season. These studies show that environmental growing conditions and growing season can affect the sensory properties of agricultural food products, as this research has also demonstrated.

There are a few limitations to this study. The panelists may have some unintentional shifts from year to year, so it is important to monitor their performance, on occasion, and ensure they understand all references. The authors tried to minimize this by using the same panelists and references from the 2011 study, and holding two orientation sessions for panelists to ensure they understood the references and the scale. In addition, the black walnut ID reference that was used both years was inconsistent, as it was composed of the black walnuts kernels from that specific growing season. In 2011, it contained an Emma K sample that was not representative of the cultivar, and in 2013 it contained 10 cultivars instead of only 7, in addition to containing an Emma K sample that was lighter in color than the previous study, which is shown to have different flavor attributes than the sample used in 2011. In future studies, it may help to get a black walnut extract or a reference that will be more consistent from year to year to use as the black walnut ID reference.

This study demonstrated that further research should be done to investigate the effect of growing season on flavor profile of black walnuts, in particular, looking at cultivars that may produce a more consistent flavor profile from year to year and are more robust to seasonal changes, for example amount of rainfall during the kernel filling months, or late harvesting and hulling.

Conclusion

The sensory profiles of black walnut kernels from 10 walnut cultivars in 2013 differ on 3 appearance (skin color, nutmeat color, and kernel roughness), 1 aroma (black walnut ID), 5 flavor (black walnut ID, overall nutty, banana-like, piney, and rancid), and 2 texture attributes (surface roughness and hardness). Vadnersloot kernels tended to have milder flavor attributes and aromas, while Sparrow kernels had the most black walnut ID and banana-like flavor, Tomboy kernels had the highest overall nutty flavor, and Davidson kernels had the most rancid flavor. Emma K and Davidosn kernels had the darkest skin color, while Football kernels had the lightest skin color. Davidson kernels also had the most kernel roughness, and Sparks 127 kernels had the highest surface roughness and hardness. Seven different black walnut cultivars (Emma K, Brown Nugget, Sparrow, Football, Tomboy, Sparks 127, and Davidson), from two different growing seasons (2011 and 2013), were evaluated by a trained sensory panel. After determining that Emma K was a non-representative sample in 2011, it was removed from analysis. The remaining six cultivars showed an interaction effect between year and cultivar for two flavor attributes (black walnut ID and overall nutty), and showed a main effect of year for seven flavor attributes (brown, caramelized, floral/fruity, fruity-dark, piney, musty/dusty, and oily). No flavor attributes had a main effect of cultivar. In general, flavor attributes had higher intensities in 2011 than in 2013. These results suggest that seasonal variation may influence flavor profile more than cultivar. Seasonal variation (in this case, growth year) is a critical factor to consider when determining flavor profile of agricultural products and highlights the importance of having representative samples for testing. Using samples from only one growing season may not provide adequate information for the long term when testing agricultural products.

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Chapter 3 - Sensory Characteristics and Consumer Acceptance of Black Walnut Gelato

Abstract

Black walnuts kernels are a common ingredient in baked goods and ice cream products. Although a limited number of studies have evaluated the flavor profile and consumer acceptance of black walnut food products, no investigations have been conducted to define the sensory profiles of black walnut ice cream/gelato--one of the most common ways black walnut kernels are consumed. In this study, we determined the sensory characteristics and consumer acceptance of gelato made with six different black walnut cultivars: Davidson, Emma K, Football, Pounds, Sparks 127, and Vandersloot. The descriptive sensory panel found that the gelato samples differed on three main flavor attributes: black walnut ID, overall nutty, and sour ($P \leq 0.05$). The gelato samples were also evaluated by 103 consumers who were acceptors of black walnuts (either consume or willing to consume black walnuts). Consumers evaluated the gelato samples for overall liking, overall flavor liking, flavor intensity, black walnut flavor liking, and black walnut flavor intensity. Based on the consumer liking data, there were three distinct clusters of consumers that differed in their acceptance of gelato made with each of the six black walnut cultivars. One cluster of consumers (n=29) preferred gelato samples with a milder black walnut flavor, while another (n=20) preferred gelato samples with more intense black walnut and overall nutty flavor. The third cluster of consumers (n=54) liked all of the gelato samples. Overall, black walnut kernels from the Pounds and Sparks 127 cultivars were accepted by all consumers indicating that these may be good cultivars to include in consumer products.

Introduction

Black walnut (*Juglans nigra L.*) is a North American hardwood tree valued for producing high quality wood used in making furniture, cabinetry, interior woodwork, flooring, and gunstocks (Baughman and Vogt 2002; Dickerson 2002; Michler *et al.* 2007). The tree also produces an edible nut. In practice, black walnut wood products are harvested from forest grown trees, while nuts are collected from open grown wild trees or orchards of black walnut trees that have been grafted to cultivars selected for superior nut quality (Reid *et al.* 2009). In 1998, Hammons (1998) estimated that US consumers consume about 2 million pounds of black walnut kernels annually in food products. Black walnut trees can be found growing across central and eastern United States, from Massachusetts to Northern Florida, stretching west as far as Texas and Minnesota (Reid 1990; Michler *et al.* 2007; Baughman and Vogt 2002). However, the nut crop is primarily harvested from the mid-portion of the black walnut tree's native range, from Ohio and Kentucky in the east, to Kansas and Nebraska in the west (W. Reid, pers. comm.).

There are over 750 black walnut cultivars that have been identified (Reid 1990). Many black walnut cultivars yield at least 35% kernel, with researchers attempting to develop cultivars that will produce nuts with 40% kernel (Reid *et al.* 2004). There is no standard for black walnut quality, however, research has shown that delayed harvesting and hulling can have negative effects on kernel color (Warmund 2008), which in turn leads to unpleasant flavor notes. High quality nuts tend to be light in color (light brown to tan), have no kernel veins, and have a firm texture (Reid 1990; Hammons *et al.* 2004; Reid *et al.* 2009).

There is only one commercial black walnut processor in the world: Hammons Products Company, located in Stockton, Missouri (Reid *et al.* 2009). Hammons processes around 26 million pounds (wet weight) of whole, hulled black walnuts every year, which equates to about 2 million

black walnut kernels (Hammons *et al.* 2004); about 40% of these commercial black walnut kernels go into ice cream production (Hammons 1998).

Many studies have looked at the flavor profile of black walnut kernels (Miller and Chambers 2013b; Warmund *et al.* 2009b), and different factors that influence black walnut kernel flavor profile (Lee *et al.* 2011; Warmund *et al.* 2009a; Warmund 2008). However, due to their unique flavor, black walnuts are not commonly consumed alone, and are consumed in products like ice cream/gelato, baked goods, and candies. Little research has been done on the sensory characteristics of black walnut food products. Matta *et al.* (2005) determined the flavor profile and consumer acceptance of various black walnut syrups and Miller and Chambers (2013a) determined the flavor profile and consumer acceptance of sugar cookies made with six different black walnut cultivars.

In addition to determining consumer acceptance of food products, it is also important to understand consumers' motivations for food choice and how it can affect their overall liking of certain products. Van Trijp and Steenkamp (1992) developed a variety seeking scale (VARSEEK) to determine a person's intrinsic desire to try different foods. Due to the unique flavor profile of black walnuts, and their limited availability, it is important to understand how a consumer's variety seeking tendency influences their acceptance of black walnuts.

Gaining an understanding of consumer liking and acceptance of black walnut gelati made with kernels extracted from several cultivars will help guide black walnut growers and ice cream/gelato producers in selecting black walnut cultivars that are acceptable and liked by consumers. The objectives of this study were to (1) determine the flavor profile of gelato made with six different black walnut cultivars (Davidson, Emma K, Football, Pounds, Sparks 127, and Vandersloot), (2) understand consumer liking and acceptability of the different gelati, and (3)

understand if there are associations between consumer acceptability of the gelati and variety seeking tendencies.

Materials and Methods

Black Walnut Samples

Ten black walnut cultivars were obtained (9 kilograms per cultivar, in-shell) from an orchard near Joplin, MO, USA. Cultivars obtained include: Davidson, Sparrow, Neel, Emma K, Tomboy, Football, Vandersloot, Brown Nugget, Pounds (formerly Pounds II), and Sparks 127. Shelling was done at the Kansas State University Sensory Analysis Center in November 2013. A Duke Walnut Cracker (Duke Company, West Point, MS, USA) and Channel Lock pliers, model 436 (Channel Lock Inc., Meadville, PA, USA) were used to extract the nutmeat from the shells. After shelling, the nutmeats were vacuum packed using a FoodSaver vacuum sealer (Sunbeam Products, Boca Raton, FL, USA) in 3.8 liter FoodSaver bags (Sunbeam Products, Boca Raton, FL, USA). The samples were stored, for no longer than two months, under frozen conditions (-26°C ± 1°C) until evaluation.

When all of the shelling was complete, nuts were chopped, using an Oxo Good Grips® hand chopper (OXO, New York City, NY, USA). The nut pieces were then sifted through a #4 sieve- 4.75mm (W.S. Tyler® Industrial Group, Mentor, OH, USA) and vacuum packaged using a FoodSaver vacuum sealer (Sunbeam Products, Boca Raton, FL, USA) in 3.8 liter FoodSaver bags (Sunbeam Products, Boca Raton, FL, USA) until incorporation into gelato.

Black Walnut Gelato Samples and Preparation

Based on descriptive analysis results of the ten walnut cultivars obtained, six cultivars, which were deemed representative of all ten cultivars obtained using Principal Components Analysis (PCA), were chosen to be incorporated into gelato. The cultivars include: Davidson,

Emma K, Football, Pounds, Sparks 127, and Vandersloot. The afternoon prior to gelato production, the black walnut nutmeat pieces were removed from the freezer and placed at room temperature to thaw. A white gelato base mix recipe (Carpigiani Group 2010a) was used for the gelato base mix (Table 3.1). The researchers substituted nonfat dry milk (Walmart, Bentonville, AR, USA) for skim powdered milk due to availability, and added all of the heavy whipping cream (The Kroger Company, Cincinnati, OH, USA) and dextrose (donated by Archer Daniels Midland Company, Chicago, IL, USA) to the base mix, instead of adding additional amounts to each individual gelato batch.

To make the white base mix, the whole milk (4% milk fat)(The Kroger Company, Cincinnati, OH, USA) was added to the Carpigiani Pastomaster 60 RTX (Carpigiani, Bologna, Italy) and the machine was started (machine settings: Ice cream mix workings, high pasteurization (85°C ± 1°C)). When the milk temperature reached 40°C ± 1°C, the dry ingredients (nonfat dry milk (Walmart, Bentonville, AR, USA), sucrose (California and Hawaiian Sugar Company, Crockett, CA, USA), dextrose (donated by Archer Daniels Midland Company, Chicago, IL, USA), and Diamant Base 50 (PreGel America, Concord, NC, USA)) were added to the milk. This mixture was heated to 85°C ± 1°C, and then the cooling process started. When the mixture cooled to 65°C ± 1°C, the heavy whipping cream (The Kroger Company, Cincinnati, OH, USA) was added. Once the mixture reached 4°C ± 1°C, the base mixture was allowed to age for 24 hours at 3°C ± 1°C.

Once the base had aged 24 hours, single batches of gelato were prepared (Carpigiani Group 2010a). For each batch, 3,500 grams of the base mix was added to the Carpigiani LB 302 RTX batch freezer (Carpigiani, Bologna, Italy). Using the Excellent Ice Cream production type setting, the base mix was frozen (for approximately 8 minutes) and then dispensed into metal gelato trays (that had been tempered in the freezer). Three thousand grams of this frozen base mix was

measured into a bowl and 200 g of chopped black walnuts were folded in for thirty seconds using a rubber spatula. The mixture was then poured into a metal gelato tray (that had been tempered in the freezer), covered with cling wrap (The Glad Products Company, Oakland, CA, USA), and placed in a blast freezer (-34°C ± 1°C) for two hours. This process was repeated until all gelato batches were made. All gelato trays were stored in the freezer at -18°C ± 1°C until evaluation. The researchers made a new base mix for each replication, and ensured that the gelato was three days old for every tasting.

Table 3.1 White gelato base mix formula (Carpigiani Group 2010a)

Ingredient	Quantity (g)
Whole Milk (4% fat)	16,000
Skim Powdered Milk	475
Heavy Whipping Cream (35% fat)	5,967
Sucrose	3,257
Dextrose (Dry Glucose)	1,484
Base 50	785

Descriptive Analysis

Panelists

Six highly trained panelists (five female and one male) from the Kansas State University Sensory Analysis Center (Manhattan, KS, USA) were selected as panelists for the descriptive panel. All six panelists participated in a black walnut kernel and black walnut sugar cookie descriptive panel in 2011 and had over 2,000 hours of testing experience with a wide variety of products. In addition to previous training, the panelists also received orientation on the black walnut products they were evaluating.

Orientation and Lexicon Development

One 90 minute orientation session was utilized to determine flavor attributes for the black walnut gelato ballot. Panelists were provided with an initial lexicon that included flavor attributes from the black walnut kernel research (in Chapter 2) and previous gelato research (Thompson *et al.* 2009). Panelists identified flavor attributes present in the gelato samples, and arranged the ballot so that more prominent attributes were first, while less prominent attributes were at the end of the ballot. A total of 18 flavor attributes were identified for the ballot (Appendix A and B). During orientation, panelists were also provided with references for anchor points on the scale of each flavor attribute. Panelists tasted/smelled the references to ensure they were suitable for use in evaluating the black walnut gelato. Table 3.2 contains a complete list of attributes, definitions, and references.

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Table 3.2 Flavor attributes, definitions, and references for black walnut gelato

Attribute	Definition	References
Overall Dairy	A general term for the aromatics associated with products made from cow's milk.	Dillon's skim milk = 5.0 (f) Dillon's 1% milk = 6.5 (f) Dillon's 2% milk = 8.0 (f) Dillon's whole milk = 9.0 (f) Preparation: Serve in a 1 oz cup.
Dairy Fat	The oily aromatics reminiscent of milk or dairy fat.	Dillon's whole milk = 3.0 (f) Dillon's Half and Half = 6.0 (f) Dillon's heavy whipping cream = 9.0 (f) Preparation: Serve in a 1 oz cup.
Dairy Cooked	Slightly browned, slightly caramelized cooked notes reminiscent of heated dairy products.	Heated Dillon's whole milk = 5.0 (f) Preparation: Heat one cup of Dillon's Vitamin D whole milk in the microwave on high power for 4 minutes. Serve in 1 oz cups.
Black Walnut ID	The aromatics commonly associated with black walnuts 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 black walnut pieces = 12.0 (f) Preparation: Measure out 1 tablespoon of all black walnut cultivars into a food processor and blend for 30 seconds. Serve ground nut mixture in 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	Gold Medal whole wheat flour = 4.5 (f) Kretschmer wheat germ = 7.5 (f)

	are: sweet, oily, light brown, slightly musty and/or buttery, earthy, woody, astringent, bitter, etc. Examples: nuts, wheat germ, certain whole grains.	Diamond shelled walnuts = 8.0 (f)
Brown	A rich, full aromatic impressions always characterized with some degree of darkness generally associated with attributes (i.e. toasted, nutty, sweet).	Kretschmer wheat germ = 7.5 (f)
Floral/Fruity	Sweet, light, aromatics impression associated with flowers and fruits.	Welch's white grape juice = 5.0 (f) Preparation: Dilute 1 part juice with one part water. Serve in 1 oz cups.
Banana-Like	Sweet, floral, fruity, candy-like aromatics commonly associated with banana flavored candies.	McCormick imitation banana extract in milk = 5.0 (f) Preparation: Mix 1/8 teaspoon of McCormick imitation banana extract in 1 cup of Dillon's whole milk. Serve in 1 oz cups.
Piney	A slight resinous aromatic associated with fresh green pine needles.	Kroger pine nuts = 6.0 (f) Preparation: Serve in 1 oz cups.
Musty/Dusty	Dry, dirt-like aromatic associated with dry, brown soil.	Potato peel (covered) = 5.0 (a) Preparation: Put 1.0 gram potato peel in a medium snifter, cover.
Musty/Earthy	Humus-like aromatics that may or may not include damp soil, decaying vegetation, or cellar like characteristics.	Sliced Button mushrooms = 8.5 (a), 10.5 (f)

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		Preparation: Place 3 mushroom slices in a medium snifter, over. Serve chopped mushrooms in a 1 oz cups.
Woody	The sweet, brown, musty, dark, dry aromatics associated with the bark of a tree.	Diamond shelled walnuts = 4.0 (f)
		Sigma-Aldrich Cedarwood oil, Virginia = 6.5 (a)
		Preparation: Serve walnuts in 1 oz cups. Place on drop of oil on a cotton ball in a medium snifter, cover.
Overall Sweet	An aromatic associated with the impression of sweet substances.	Highland whipping cream = 5.0 (f)
		Pepperidge Farm Bordeaux cookie = 9.5 (f)
		Preparation: Serve whipping cream in 1 oz cups. Serve cookies in a Ziploc bag.
Oily	An aromatic associated with vegetable oil or nut oil such as corn or soybean oil.	Kroger slivered and blanched almonds = 4.0 (f)
		HyVee dry roasted and salted Macadamia nuts = 9.0 (f)
		Preparation: Serve in 1 oz cups.
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 (f)
		0.050% Alum solution = 2.5 (f)
		0.075% Alum solution = 3.5 (f)
		0.100% Alum solution = 5.0 (f)
Bitter	A fundamental taste factor of which citric acid 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 (f)
		0.025% Citric acid solution = 2.5 (f)
Sweet	A fundamental taste factor of which sucrose is typical.	4.0% Sucrose solution = 4.0 (f)
		6.0% Sucrose solution = 6.0 (f)
		8.0% Sucrose solution = 8.0 (f)

Test Design and Sample Evaluation

Each gelato sample was evaluated, in triplicate, using a descriptive sensory analysis method used by Ledeker *et al.* (2012) and Miller and Chambers (2013b). Panelists rated the intensity of eighteen flavor attributes (Table 3.2) on a 15 point scale with 0.5 increments, where 0 = not present and 15 = highest possible intensity. Panelists were provided with references for flavor and aroma attributes. Panelists received two scoops of gelato (Pampered Chef medium scoop #2540 (The Pampered Chef®, Addison, IL, USA)) in a Styrofoam bowl (8S-J20) (The Solo® Foodservice, Lake Forest, IL, USA) labeled with a random 3-digit code. Gelato samples were served out of a gelato display case set at -12°C ± 1°C (Model E1420S01NV, Excellence Industries, Tampa, FL, USA) that was located in the evaluation room. Panelists evaluated six samples per day, for a total of three days (one replication per day). Samples were served every eighteen minutes, with a ten minute break after the third sample (Appendix G). Panelists were provided with hot water and unsalted saltine crackers (Kroger, Cincinnati, OH, USA) to cleanse their palate between samples.

A series of William's Latin Squares designs (Kuehl 2000) were used to determine gelato serving order; this design ensures that each sample is seen in each position. Panelist was used as one blocking factor, and sample position as the other (Appendix G). Three William's Latin Squares designs were used, one per day, for a total of three replicates. The designs were created using SAS® statistical software (version 9.3, SAS Institute Inc., Cary, NC, USA).

Statistical Analysis

Analysis of variance (ANOVA) at the 5% significance level was used to test the significance of each of the flavor attributes across the gelati made with different black walnut cultivars. Fisher's Least Significant Difference (LSD) post-hoc means separation was used to

determine significant differences between samples at the 5% significance level. This analysis was performed using SAS® statistical software, PROC GLIMMIX (version 9.3, SAS Institute Inc., Cary, NC, USA). See Appendix I for codes.

Consumer Analysis

Consumers

Consumers were recruited from the Manhattan, Kansas area via the Kansas State University Sensory Analysis consumer database. Participants first completed an online screening survey to ensure they were eligible for the study (Appendix C); the initial screening was done using Compusense at-hand® software (Compusense, Inc. Guelph, Ontario, Canada). Screening criteria included: at least 18 years old, no know food allergies, no immediate family members working for a market research firm, advertising firm, or a food manufacturing company, have not participated in a consumer research study in the past three months, eat nuts at least once every 2-3 months, and were willing to eat black walnuts in ice cream/gelato. All consumers were scheduled using the Compusense at-hand® software (Compusense, Inc. Guelph, Ontario, Canada) scheduler, and received a confirmation email and reminder email regarding their participation.

Test Design and Sample Evaluation

Compusense at-hand® (Compusense, Inc. Guelph, Ontario, Canada) was used to create a test design that was blocked by groups of 6, for a total of 120 consumers. See Appendix H for complete design.

Consumer panels were held over a two-day period, with each consumer coming to one session. A moderator guide was read to the panelists at the start of each session which stated the purpose and procedures of the study (Appendix D). Then, each panelist signed an electronic consent form stating they agreed to participate in the study, but could withdraw at any time

(Appendix E). Participants were served one scoop of gelato at a time (sequential monadic design) and evaluated all six gelato samples. Participants were provided a new spoon for each sample. Unsalted crackers and water were provided to each participant to help cleanse their palate between samples, along with an expectoration cup. Each session lasted approximately 60 minutes.

Tablet computers equipped with Compusense at-hand® (Compusense, Inc. Guelph, Ontario, Canada) were used to collect data. Panelists rated their overall liking, overall flavor liking, and black walnut flavor liking of each sample on a hedonic nine-point scale (1 = dislike extremely; 9 = like extremely), and overall flavor intensity, and black walnut flavor intensity of each sample on a hedonic nine-point scale (1 = not at all flavorful; 9 = extremely flavorful). Participants were also provided a space where they could write any additional comments about what they liked or disliked about each sample. At the end of the questionnaire, panelists were asked demographic questions, and a series of eight agreement statements on the VARSEEK scale, a 5 point scale (1= Disagree completely; 5= Agree completely), to determine their variety seeking tendency (Van Trijp and Steenkamp 1992). The agreement statements included: (1) When I eat out, I like to try the most unusual items, even if I am not sure I would like them, (2) While preparing foods or snacks, I like to try out new recipes, (3) I think it is fun to try out food items one is not familiar with, (4) I am eager to know what kinds of foods people from other countries eat, (5) I like to eat exotic foods, (6) Items on the menu that I am unfamiliar with make me curios, (7) I prefer to eat food products that I am used to, (8) I am curious about food products I am not familiar with (Van Trijp and Steenkamp 1992). Consumers were grouped into, three groups based on their overall score: low variety seeker (score ≤ 25), medium variety seeker (score 26-34), and high variety seeker (score ≥ 35). When consumers finished the session, they were compensated $10 for their participation. The consumer ballot can be found in Appendix F.

Statistical Analysis

Statistical analysis was performed using SAS ® statistical software (version 9.3, SAS Institute Inc., Cary, NC, USA). Analysis of Variance (ANOVA) at the 5% significance level was used to determine if significant differences exist between the gelati samples made with different black walnut cultivars. Fisher's protected LSD post-hoc means were used to determine the significant differences across the liking and intensity scores at the 5% significance level. See Appendix I for all codes.

The *k*-means nonhierarchical clustering method was used for determining clusters/sub-groups of consumers using the Fastclus procedure in SAS ® statistical software (version 9.3, SAS Institute Inc., Cary, NC, USA). The *k*-means nonhierarchical clustering method was chosen because it has been shown to be a superior classification method as compared to Ward's nonhierarchical clustering method (Cherdchu and Chambers 2013). ANOVA and Fisher's LSD post-hoc means separation at the 5% significance level was used to determine significant differences in liking and intensity scores across clusters and across variety seeking levels using PROC GLM in SAS® statistical software (version 9.3, SAS Institute Inc., Cary, NC, USA.).

Partial least squares regression (PLS) was performed to help identify relationships between the descriptive flavor profile (X-matrix) and consumer acceptability (Y-matrix) of the black walnut gelato. Plots were made in Unscrambler (The Unscrambler Trial Version, Camo Software AS, Oslo, Norway) and recreated using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA).

Results

Descriptive Evaluation

Overall, some of the main flavor attributes found in black walnut gelato were: overall dairy, dairy fat, overall sweet, black walnut ID, overall nutty, and sweet flavor attributes (Table 3.3). In gelato, Vandersloot kernels were significantly lower than Football kernels in black walnut ID and overall nutty attributes ($P \leq 0.05$). Although previous studies have not evaluated black walnut kernels from the Vandersloot cultivar, they have shown similar patterns of cultivars having lower intensity flavor attributes. Miller and Chambers (2013a) found that cookies made with Emma K nut meats were significantly lower in both black walnut ID and overall nutty flavors than other black walnut cookies.

Gelato made with Football kernels was significantly higher in black walnut ID when compared to gelato made with Vandersloot kernels, and it was significantly higher in overall nutty flavor when compared to gelato made with kernels of Vandersloot, Sparks 127, and Emma K. Miller and Chambers (2013a) found that cookies made with the Emma K kernels were significantly lower in overall nutty flavor than other cultivars, which is the opposite of results found in this study. Gelato made with Davidson and Pounds nut meats were not significantly different from any of the cultivars in black walnut ID and overall nutty flavor ($P \leq 0.05$). Warmund *et al.* (2009a) found that both black walnut and overall nutty flavor attributes had an interaction effect of cultivar and kernel color, so the discrepancies between the gelato and cookie studies may be due to this interaction effect. Lee *et al.* (2011) found that darker colored kernels contain hexanal, which is associated with acrid, rancid, and musty/earthy aromas. The Emma K cookies were associated with acrid, rancid and musty/earthy notes (Miller and Chambers 2013a), which indicates the kernels may have been darker in color in 2011 than in 2013. This difference in kernel color could be

attributed to different harvesting or hulling times; Warmund (2008) attributes darker kernel color

to delayed hulling, which tends to increase undesirable flavors (rancid, acrid and bitter).

Table 3.3 Mean intensity scores and separation for black walnut gelato flavor attributes

Attribute	Cultivar					
	Davidson	**Emma K**	**Football**	**Pounds**	**Sparks 127**	**Vandersloot**
Overall Dairy	7.61	7.92	7.72	7.67	7.69	7.80
Dairy Fat	6.39	6.47	6.33	6.17	6.47	6.53
Dairy Cooked	0.47	0.58	0.33	0.42	0.47	0.44
Black Walnut ID	5.72^{AB}	5.67^{AB}	6.22^{A}	5.69^{AB}	5.61^{AB}	5.14^{B}
Overall Nutty	5.83^{AB}	5.69^{B}	6.28^{A}	5.78^{AB}	5.61^{B}	5.36^{B}
Brown	2.97	2.81	3.36	2.97	3.08	3.00
Floral/Fruity	2.03	1.92	2.06	2.28	2.17	2.11
Banana	2.19	1.72	2.11	2.42	1.89	1.75
Piney	2.72	2.39	2.44	2.44	2.36	2.17
Musty/Dusty	0.06	0.08	0.08	0.17	0.00	0.06
Musty/Earthy	2.61	2.44	2.56	2.47	2.47	2.19
Woody	2.42	2.56	2.50	2.56	2.44	2.42
Overall Sweet	5.92	5.97	5.89	6.25	6.22	6.22
Oily	2.56	2.33	2.44	2.50	2.36	2.36
Astringent	2.31	2.22	2.28	2.19	2.11	2.36
Bitter	2.03	2.06	1.94	1.94	1.89	1.97
Sour	1.56^{A}	1.56^{A}	1.42^{AB}	1.53^{A}	1.33^{B}	1.43^{AB}
Sweet	5.17	5.25	5.06	5.28	5.22	5.36

*Scores were based on a 15 point scale with 0.5 increments, where 0 = not present and 15 = highest possible intensity
^Mean liking scores sharing the same superscript within a row are not significantly different (P≤0.05)

Consumer Acceptance

A total of 103 consumers evaluated the six gelato samples. Table 3.4 shows demographic information about these participants. About 59% of the participants said they consume nuts at least once per week, while about 50% said they consumed black walnuts at least once every 2-3 months, and 20% never consume black walnuts (Table 3.5). The most common form of black walnut

consumption for the participants was in cookies/cakes, followed by granola bars/trail mix, candy/fudge/confectionary, and ice cream/gelato (Table 3.5). This data is similar to data collected by Gold *et al.* (2004); of 232 people surveyed, 15% had never heard of black walnuts, and 58% consumed black walnuts at least 2-6 times per year. With about 40% of commercial black walnuts going into ice cream production (Hammons 1998), it is no surprise that about 38% of participants consumed black walnuts in ice cream/gelato.

Table 3.4 Consumer Demographics

Gender	Frequency (%)	Age	Frequency (%)
Male	25.24%	**18-24**	20.39%
Female	74.76%	**25-35**	34.95%
		36-45	9.71%
		46-55	13.59%
		56-65	18.45%
		66 or older	2.91%

N=103

Table 3.5 Consumer frequency and form of black walnut consumption of black

Frequency of Consumption	Frequency (%)	Form of Consumption	Frequency (%)
2 or more times a week	2.91%	Alone/by themselves	26.21%
About once a week	6.80%	Ice cream/gelato	37.86%
About once every month	17.48%	Cookies/cake	58.25%
About every 2-3 months	22.33%	Granola bars/trail mix	44.66%
About every 6 months	32.04%	Candy/fudge/confectionary	41.75%
Never	18.45%	Other	7.77%

N=103

There were no significant differences in the overall liking, overall flavor liking, overall flavor intensity, and black walnut flavor liking scores for the different types of black walnut gelato

at the 5% significance level (Table 3.6). There was a significant difference in black walnut flavor intensity scores at the 5% significance level; Vandersloot kernels had lower intensities of black walnut flavor (mean scores of 5.62), while Davidson nut meats had the highest black walnut flavor intensity (mean score of 6.50). Miller and Chambers (2013a) also found no significant difference in overall liking of black walnut cookies. Consumer clusters based on overall liking were expected for this study, however, as Miller et al. (2013a) found clusters of consumers based on liking scores for the black walnut sugar cookies.

Table 3.6 Consumer frequency and form of black walnut consumption of black

	Davidson	Emma K	Football	Pounds	Sparks 127	Vandersloot
Overall Liking	6.86	6.93	6.91	7.02	7.01	7.24
Overall Flavor Liking	6.65	6.79	6.86	6.74	6.92	7.15
Overall Flavor Intensity	6.34	6.05	6.23	6.30	6.40	6.15
Black Walnut Flavor Liking	6.33	6.59	6.50	6.44	6.64	6.87
Black Walnut Flavor Intensity	6.50^A	6.03^{AB}	5.94^{AB}	6.08^{AB}	6.15^{AB}	5.62^B

N=103
*Scores were based on a 9-point hedonic scale
^Mean liking scores sharing the same superscript within a row are not significantly different (P≤0.05)

Clusters of Consumers

Additional analysis was performed on the overall liking scores to determine if consumer segments/clusters existed. Three sub-groups/clusters of consumers were found (Table 3.7 and 3.8). The first cluster contained 29 consumers. The consumers in this cluster liked the Vandersloot gelato the best, and liked Emma K, Football, and Davidson the least. This group seemed to like the 'milder flavor' of Vandersloot, as it had the lowest black walnut ID intensity. This cluster consisted of mainly younger consumers (69% were between the ages of 18-35, while only 3.5%

were over 55 years old). The second sub-group/cluster contained 20 consumers. These consumers liked Football the best, and Vandersloot, Davidson, and Sparks 127 the least. Gelati made with the Football cultivar had the highest intensity of black walnut ID and overall nutty flavor, while Vandersloot had the lowest; Davidson was also high in overall nutty. Therefore, it was determined that this group of consumers prefers the intense black walnut ID flavor. The third and largest sub-group consisted of 54 consumers. These consumers liked all of the gelati. This cluster liked Football the least, but it still had a high overall liking score (mean score of 7.41). Consumers in this cluster were generally older (28% were 56 years old or older; 30% were between the ages of 18-35). Like Miller and Chambers (2013a), researchers found a cluster of consumers who liked all of the gelato samples, a cluster that liked the Football sample the best, and a cluster that liked the Emma K sample the least. However, unlike the study conducted by Miller and Chambers (2013a) where researchers found a cluster of consumers who didn't like any of the black walnut sugar cookie samples, this study did not find a cluster of consumers that disliked all of the black walnut gelato samples. In the open-ended comments, many participants said the samples were good/delicious, had a nice flavor balance, and had a good black walnut flavor, while some participants also said the samples had an unappealing aftertaste. In addition, many participants said the gelato made with Pounds and Vandersloot kernels had a mild black walnut flavor, which was not mentioned as frequently for the other samples.

Table 3.7 Demographic data of all consumers and consumer clusters

	Gender %		Age %					
Consumers	**Female**	**Male**	**18-24**	**25-35**	**36-45**	**46-55**	**56-65**	**66+**
All	74.76	25.24	20.39	34.95	9.71	13.59	18.45	2.91
Cluster 1	79.31	20.69	24.14	44.83	17.24	10.34	3.45	0.00
Cluster 2	75.00	25.00	15.00	35.00	15.00	5.00	25.00	5.00
Cluster 3	72.22	27.78	20.37	29.63	3.70	18.52	24.07	3.70

* All (n=103); cluster 1 (n=29); cluster 2 (n=20); cluster 3 (n=54)

Table 3.8 Overall liking scores and means separation of black walnut gelato for consumer clusters

Consumers	Cultivar					
	Davidson	**Emma K**	**Football**	**Pounds**	**Sparks 127**	**Vandersloot**
Cluster 1	5.79^{EFGH}	5.48^{H}	5.48^{GH}	6.24^{DEF}	6.38^{DE}	7.24^{BC}
Cluster 2	5.75^{EFGH}	6.90^{CD}	7.65^{AB}	6.40^{DE}	6.15^{EFG}	5.65^{FGH}
Cluster 3	7.85^{A}	7.72^{AB}	7.41^{BC}	7.67^{AB}	7.67^{AB}	7.83^{A}

N=103
*Scores were based on a 9-point hedonic scale
^Mean liking scores sharing the same superscript within a row are not significantly different (P≤0.05)

When examining the cluster demographics (Table 3.7), it appears that age may be related to overall liking; consumers in cluster one preferred the Vandersloot gelato, which had a lower black walnut ID intensity, and liked the Emma K gelato the least, which was characterized as having a higher intensity of black walnut ID than Vandersloot gelato; almost 70% of the consumers in this cluster were 35 years old or younger. The other two clusters seemed to have more of an even distribution of age ranges; both clusters had about 50% that were 35 years old and younger, and between 35-45% that were over the age of 46. From this demographic data, it appears as though younger consumers may prefer the gelato samples that have lower intensities of black walnut ID. Gender, however, did not seem to play a factor, because all three clusters had a similar gender distribution (between 72-79% female and 21-28% male). From these clusters, it is also clear that some people prefer the lower black walnut ID intensity (cluster 1), others liked the higher intensity black walnut ID (cluster 2), and a majority liked all black walnut ID intensities (cluster 3).

Our research showed that all cultivars may be suitable for incorporation into gelato. In each cluster, none of the gelati scored below a 5.48 (mean score; 5 = I neither like nor dislike and 6 = I slightly like) on a 9 (1 = dislike extremely, 9 = like extremely) point hedonic scale. Pounds and

Sparks 127 are cultivars that were not disliked by any cluster, so they may be a suitable compromise for all consumer clusters. Additional research should be conducted on the influence of growing season on cultivar flavor profiles, as unpublished preliminary research conducted by Lynch and Koppel (unpublished data, 2014) suggests that growing season may influence flavor profile more than cultivar. Similar results are also demonstrated in other studies, which show that time of harvest/hull and kernel color can influence the flavor profile of black walnuts (Warmund *et al.* 2009a; Lee *et al.* 2011; Warmund 2008).

Variety Seeking Categories

Based on their VARSEEK scores, consumers were segmented into three different groups: low variety seeker (score of 25 and below), medium variety seeker (score of 26-34), and high variety seeker (score of 35 and above), as suggested by Van Trijp and Steenkamp (1992).

There were no significant differences in overall liking between the different types of variety seeking consumers. There was, however, a significant difference in the overall liking scores within the same variety seeking segment. The data shows that liking scores are not influenced by if a participant is a high variety seeking individual, but points to that fact that other demographic factors may play a bigger role.

It was expected that consumers in the high variety seeking segment would have higher overall liking scores for the black walnut gelato samples since black walnuts have a unique flavor profile and limited availability. However, previous researchers have also been unable to relate variety seeking tendencies and liking scores. Anderson *et al.* (2014) looked at the influence of VARSEEK scores on overall liking of pomegranate juice, but found that consumer acceptance was not determined by the VARSEEK scores. In addition, Lähteenmäki and Van Trijp (1995) found no relationship between variety seeking tendency and sandwich liking. However, results

from a study by Van Trijp *et al.* (1992) suggested that food products need to have a high level of sensory variation in order to see a relationship between liking and variety seeking tendency. The descriptive data only shows three flavor attributes that are significantly different between the black walnut gelato samples, which may not be enough sensory variation to see a variety seeking pattern.

Relating Descriptive Analysis to Consumer Evaluation

A PLS regression map was created to relate the flavor profile to consumer acceptability of black walnut gelato (Figure 3.1). Overall, 53% of the descriptive sensory data explained eighty-four percent 84% of the consumer liking data across dimensions 1 and 2.

The preference map indicates that consumers in cluster 1 (liked Vandersloot the most, and Emma K, Football, and Davidson the least) may tend to like samples that have more dairy fat, overall dairy, and overall sweet notes. This makes sense because consumers in cluster 1 did not like the stronger black walnut ID flavor of the Emma K, Football, and Davidson gelati, so it appears they liked the milder samples with more dairy and sweet notes, and less black walnut flavor. The preference map indicates cluster 2 associated more with brown, black walnut ID, and overall nutty flavor attributes; consumers in cluster 2 liked the Football gelato, and disliked the Davidson, Sparks 127, and Vandersloot gelati. The Football gelato is characterized by higher intensities of black walnut ID and overall nutty, while the Vandersloot is characterized by lower intensities of these attributes; Sparks 127 is also characterized by a lower intensity of overall nutty. Finally, the preference map indicated that cluster 3 generally liked all gelato samples, as it was positioned in the center of the plot.

Overall, a majority of the consumers liked all of the black walnut gelato samples (cluster 3), however, there were small groups of consumers that either liked or disliked the stronger black walnut ID and overall nutty flavors.
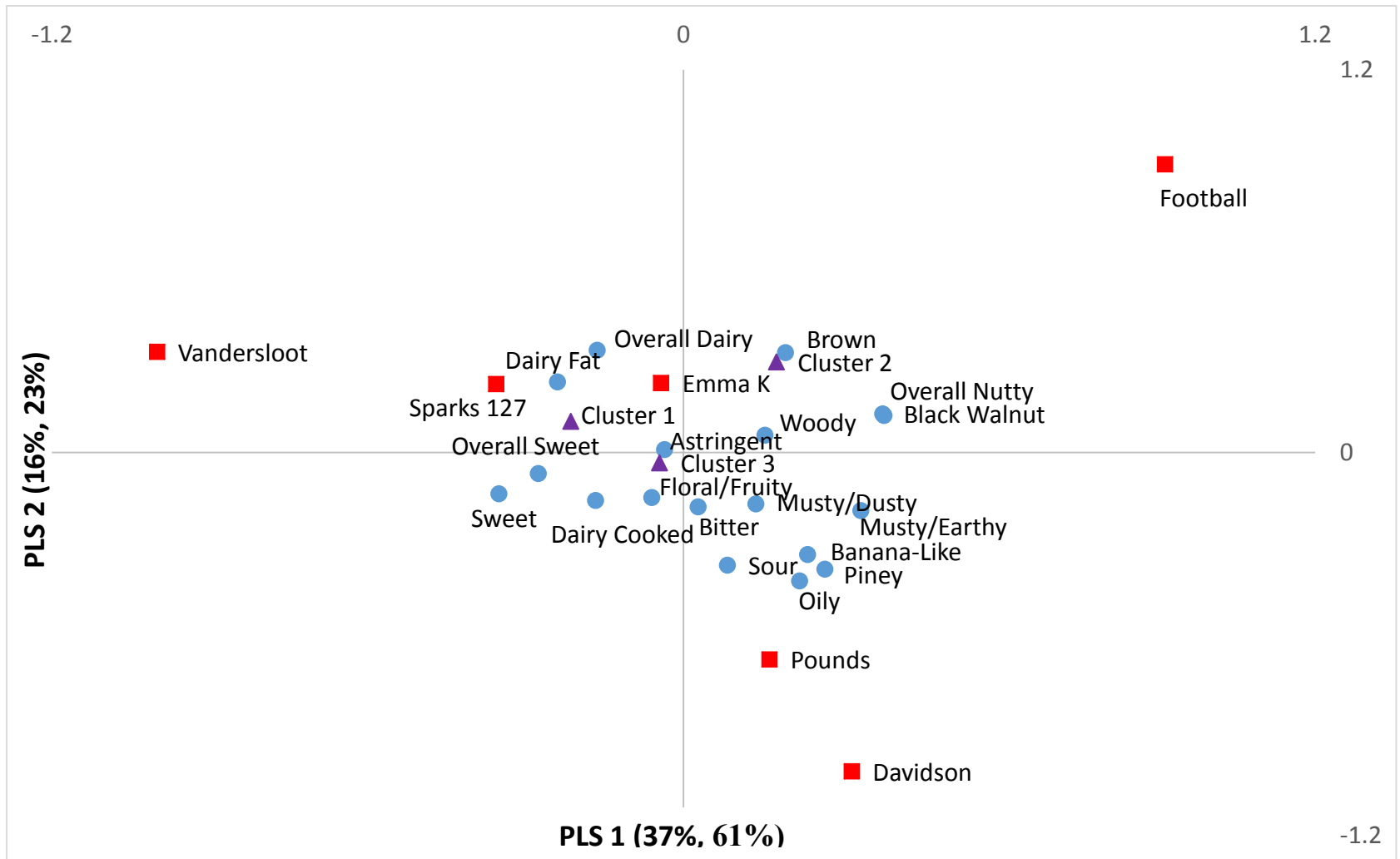
Figure 3.1 Partial Least Squares Regression (PLSR) map of consumer clusters, descriptive attributes, and black walnut gelato samples

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Discussion

Overall, researchers found that both Pounds and Sparks 127 cultivars were accepted by all consumer clusters. However, as previous research has shown, black walnut kernel flavor can be influenced by many factors including: kernel color and time of harvest and hull (Lee *et al.* 2011; Warmund *et al.* 2009a; Warmund 2008). Therefore, it may be important for growers to focus on kernel quality and color rather than on cultivar. When comparing the black walnut gelato results to previous research on black walnut cookies (Miller and Chambers 2013a), there were more flavor attributes in the cookies that were significantly different between samples; Miller and Chambers (2013a) found 9 of 25 flavor attributes were significantly different between cookies made with different black walnut kernels, while this this study only found 3 of 18 flavor attributes that were significantly different between gelato samples made with different black walnut kernels. Both the black walnut sugar cookies and black walnut gelato samples differed on black walnut ID and overall nutty flavor. In gelato, Football kernels had more black walnut ID flavor than Vandersloot gelato, and more overall nutty flavor than Vandersloot, Sparks 127, and Emma K gelato, while in sugar cookies, Emma K had was significantly lower in both black walnut ID and overall nutty flavor than all the other cultivars.

In addition, consumer preferences for a specific cultivar were not consistent between years, indicating that variation between growing seasons may play a bigger role than cultivar type. It is important to note that Brown Nugget and Sparrow cultivars were included in the black walnut sugar cookie consumer study, while these cultivars were not included in the gelato study (Pounds and Vandersloot cultivars were included instead). However, in both studies, there were no significant differences in overall acceptability of the black walnut products, there were, however, significant differences in black walnut flavor intensities of both sets of samples. There is still no

overlap in the results from either study, which is another indication that seasonal variation may influence flavor profile, and therefore, consumer acceptance. This research is important for black walnut growers and processors to understand, as it shows that it is more important to focus on kernel quality and obtaining kernels of optimal kernel color, than it is to focus on cultivar type.

These findings showed there are additional opportunities to study consumer acceptance of black walnuts and black walnut food products. Studies have determined the effect of kernel color on the flavor profile of black walnuts, however, research has not looked at consumer acceptance of different colored kernels. In addition, the amount of walnuts in both the gelato samples and the black walnut sugar cookie samples (Miller and Chambers 2013a) remained constant for all samples. Additional research should look at optimal inclusion amount for black walnut pieces in black walnut consumer products, as consumers only noticed a difference in black walnut flavor intensity between samples, which for gelato, appeared to be a factor in overall liking scores.

Conclusions

Black walnut kernels extracted from six different black walnut cultivars (Football, Sparks 127, Pounds, Vandersloot, Emma K, and Davidson) were incorporated into a white gelato base and evaluated by both a descriptive and consumer panel. The black walnut gelati were significantly different on three of the eighteen flavor attributes: black walnut ID, overall nutty, and sour. Gelato made with kernels from the Football cultivar was significantly higher in black walnut ID flavor, while gelato made with Vandersloot kernels was significantly lower in black walnut ID flavor. Gelato made with Football nut meats was also significantly higher in overall nutty flavor than Vandersloot gelato. Gelato made with Sparks 127 was significantly lower in sour flavor than gelato made with Davidson, Emma K, or Pounds kernels. A consumer acceptance test was performed on all six black walnut gelato samples. Three significant clusters with differing gelato preferences were found. The results indicate that nut kernels from Pounds and Sparks 127 cultivars were accepted by all consumers, and therefore, may be good cultivars to include in consumer products.

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Appendix A - Black Walnut Reference and Definition Sheets For Descriptive Analysis

Black Walnut Nutmeat Evaluation

Technicians: *Serve 10 grams (1 cm nut pieces) for evaluation.*
Panelists: *Use 1 piece for evaluation. Please swallow at least one sample during evaluation.*

APPEARANCE

Skin Color: A visual evaluation of the color intensity of the skin on the exterior of the kernel.
           Reference: Porter Paint Chip 6844-2 = 4.0
                           Porter Paint Chip 6767-2= 8.0
                           Porter Paint Chip 6684-1 = 12.0

Internal color: A visual evaluation of the color intensity of the internal nutmeat color of the kernel (nutmeat)
           Reference: Porter Paint Chip 6188-2 = 2.0
                           Porter Paint Chip 6189-2= 5.0
                           Porter Paint Chip 6190-2= 7.0

Roughness/wrinkling, visual: A visual evaluation of the uneven texture of the surface of the product
           Reference: Picture A= 2.0
                           Picture B = 4.0
                           Picture C = 8.0

AROMA

Black Walnut ID: The aromatics commonly associated with black walnuts 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.
           Reference: Ground Black Walnut pieces = 10.0 (a)
           Preparation: Measure out 1 tbsp. of various cultivars into a food processor and blend for 30 seconds. Put 1 teaspoon in medium snifter, cover.

Caramelized: A round, full-bodied, medium brown aromatic.
           Reference: C&H Golden Brown Sugar = 7.5 (a)
           Preparation: Serve 1 teaspoon of brown sugar in a medium snifter, cover.

Brown: A rich, full aromatic impressions always characterized with some degree of
               darkness generally associated with attributes (i.e. toasted, nutty, sweet)
               Reference: Sethness AP 100 Caramel Color (Full Strength) = 13.0 (a)
               Preparation: Place ½ teaspoon caramel color in a medium snifter, cover.

Fruity-dark: The sweet, brown honey/caramel-like aromatics commonly associated with dark
               fruits such as raisins and prunes that have been cooked.
               Reference: 1/4 cup Sun Maid raisins, 1/3 cup dried Ocean Spray
                               cranberries and ¼ cup of Sun Maid prunes, and 3/4 cup of
                               water = 7.0 (a).
               Preparation: Mix raisins, dried cranberries and prunes (chopped). Add
                               ¾ cup of de-ionized water and cook in microwave on high
                               for 2 minutes. Put 1 tsp of cooked fruit with at least 1 piece
                               of the chopped prune in medium snifters, cover with watch
                               glass.

Banana-Like: Sweet, floral, fruity, candy-like aromatics commonly associated with banana
               flavored candies.
               Reference: HyVee Circus Peanut Candy = 10.0 (a)
               Preparation: Chop candy peanut in half and place in medium snifter,
                               cover.

Musty/Dusty: Dry, dirt-like aromatic associated with dry, brown soil.
               Reference: Potato Peel (covered) = 5.0 (a)
               Preparation: Put 1.0 gram potato peel in a medium snifter, cover.

Musty/Earthy: Humus-like aromatics that may or may not include damp soil, decaying
               vegetation, or cellar like characteristics.
               Reference: Sliced Button mushroom = 8.5 (a)
               Preparation: Place 3 slices in a medium snifter, cover.

Woody: The sweet, brown, musty, dark, dry aromatics associated with the bark of a tree.
               Reference: Sigma-Aldrich Cedarwood Oil, Virginia = 6.5 (aroma)
               Preparation: Place one drop oil on a cotton ball in a medium snifter,
                               cover.

FLAVOR

Black Walnut ID: The aromatics commonly associated with black walnuts 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.
                  Reference: Ground Black Walnut pieces = 12.0 (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.
Reference: 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.
Reference: Diamond Pecan Halves = 7.5 (flavor)
Diamond Shelled Walnuts = 7.5 (flavor)
Preparation: Serve pecans and walnuts in 1 oz cups.

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.
Reference: HyVee Dry Roasted and Salted Macadamia Nuts = 5.0 (flavor)
reparation: Serve macadamia nuts in a 1 oz cup.

Brown: A rich, full aromatic impressions always characterized with some degree of darkness generally associated with attributes (i.e. toasted, nutty, sweet).
Reference: Bush's Best Pinto Beans (Canned) = 5.0 (flavor)
Kretschmer Wheat Germ = 7.5 (flavor)
Preparation: Drain beans and rinse with de-ionized water. Serve in 1 oz. cups.
Place ½ teaspoon caramel color in a medium snifter, cover.

Caramelized: A round, full-bodied, medium brown aromatic.
Reference: C&H Golden Brown Sugar = 9.0 (flavor)
Preparation: Serve 1 teaspoon of brown sugar in a medium snifter, cover.

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)

Floral/Fruity:　Sweet, light, aromatics impression associated with flowers and fruits.
　　　　　　　Reference:　　Welch's White Grape Juice = 5.0 (flavor)
　　　　　　　Preparation:　Dilute 1 part juice with one part water.

Fruity-dark:　The sweet, brown honey/caramel-like aromatics commonly associated with dark fruits such as raisins and prunes that have been cooked.
　　　　　　　Reference:　　1/4 cup Sun Maid raisins, 1/3 cup dried Ocean Spray cranberries and ¼ cup of Sun Maid prunes, and 3/4 cup of water = 5.0 (f).
　　　　　　　Preparation:　Mix raisins, dried cranberries and prunes (chopped). Add ¾ cup of de-ionized water and cook in microwave on high for 2 minutes. Pour juice into 1 ounce cups, cover with lid. Put 1 tsp of cooked fruit with at least 1 piece of the chopped prune in medium snifters, cover with watch glass.

Banana-Like:　Sweet, floral, fruity, candy-like aromatics commonly associated with banana flavored candies.
　　　　　　　Reference:　　HyVee Circus Peanut Candy = 10.0 (f)
　　　　　　　Preparation: Cut peanut in quarters and serve 4 pieces in a 1 oz cup.

Piney:　　　　A slight resinous aromatic associated with fresh green pine needles.
　　　　　　　Reference:　　Kroger Pine Nuts = 6.0 (fl)

Musty/Dusty:　Dry, dirt-like aromatic associated with dry, brown soil.
　　　　　　　Reference:　　Potato Peel (covered) = 5.0 (a)
　　　　　　　Preparation:　Put 1.0 gram potato peel in a medium snifter, cover.

Musty/Earthy:　Humus-like aromatics that may or may not include damp soil, decaying vegetation, or cellar like characteristics.
　　　　　　　Reference:　　Sliced Button mushroom = 8.5 (a), 10.5 (f)
　　　　　　　Preparation:　 Place 3 slices in a medium snifter, cover.
　　　　　　　　　　　　　　Serve chopped mushroom in 1 oz cups.

Woody:　　　The sweet, brown, musty, dark, dry aromatics associated with the bark of a tree.
　　　　　　　Reference:　　Diamond Shelled Walnuts = 4.0 (flavor)
　　　　　　　　　　　　　　Sigma-Aldrich Cedarwood Oil, Virginia = 6.5 (aroma)
　　　　　　　Preparation:　Serve walnuts in a 1 oz cup.
　　　　　　　　　　　　　　Place one drop oil on a cotton ball in a medium snifter, cover.

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)
Preparation: Serve macadamia nuts in a 1 oz cup.

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.

Astringent: A feeling of a puckering or a tingling sensation on the surface and/or edge of the tongue and mouth.
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

Take one bite through the whole nut. Assess firmness, then chew the same bite and assess dissolvability.

Except where indicated otherwise, use 4 pieces of Cheerios and 4 "penny size" Wheaties flakes.

Surface Roughness: The amount of indentations/bumps and surface abrasions which can be perceived by gently manipulating one piece between the palate and the tongue.
Reference: Cheerios (one piece) = 5.0
                    Wheaties (one piece) = 9.0
                    Nabisco Triscuit (1/4 cracker) = 11.0

Hardness: The force required to bite completely through the sample with molar teeth.
                            Evaluate on first bite down with the molars.
                            Reference: Cheerios (one piece) = 5.5
                                          Wheaties (one piece) = 7.5
                                          Kroger Dry Roasted Slightly Salted Peanuts =8.5 (half
                                          peanut with cut side down)

Initial Crispness: The intensity of audible noise at first chew with molars.
                            Reference: Cheerios = 8.0
                                          Wheaties = 10.5

Fracturability: The force with which the sample ruptures. Evaluate on first bite down
                            with the molars.
                            Reference: Cheerios (one piece) = 4.0
                                          Wheaties (one piece) = 7.5

Tooth Packing: The amount of sample packed in and between the molar teeth after
                            swallowing.
                            Reference: 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.
                            Reference: Cheerios = 3.0
                                          Wheaties = 7.0

Black Walnut Gelato Evaluation

Technicians: Place gelato in display case 2 hours prior to evaluation.
Panelists: Use 1 bite for evaluation. Please swallow at least one sample
during evaluation.
Cleanout: Water, crackers

FLAVOR

Overall Dairy: A general term for the aromatics associated with products made from cow's milk.
>   Reference: Dillon's skim milk = 5.0 (flavor)
>   Dillon's 1% milk = 6.5 (flavor)
>   Dillon's 2% milk = 8.0 (flavor)
>   Dillon's whole milk = 9.0 (flavor)
>   Preparation: Serve in a 1 oz cup.

Dairy Fat: The oily aromatics reminiscent of milk or dairy fat.
>   Reference: Dillon's whole milk = 3.0 (flavor)
>   Dillon's Half and Half = 6.0 (flavor)
>   Dillon's Heavy Whipping Cream = 9.0 (flavor)
>   Preparation: Serve in a 1 oz cup.

Dairy Cooked: Slightly browned, slightly caramelized cooked notes reminiscent of heated dairy products.
>   Reference: Heated whole milk = 5.0 (flavor)
>   Preparation: Heat one cup Dillon's Vitamin D whole milk in the
>   microwave on high power for 4 minutes. Serve in 1oz cups.

Black Walnut ID: The aromatics commonly associated with black walnuts 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.
>   Reference: Ground Black Walnut pieces = 12.0 (flavor)
>   Preparation: Measure out 1 tbsp. of various cultivars into a food processor and
>   blend for 30 seconds. Serve in 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.

Reference: Gold Medal Whole Wheat Flour = 4.5 (flavor)
                    Kretschmer Wheat Germ = 7.5 (flavor)
                    Diamond Shelled Walnuts = 8.0 (flavor)
Preparation: Serve in 1 oz cups.

Brown: A rich, full aromatic impressions always characterized with some degree of darkness generally associated with attributes (i.e. toasted, nutty, sweet).
                    Reference: Kretschmer Wheat Germ = 7.5 (flavor)
                    Preparation: Serve in 1 oz. cups.

Floral/Fruity: Sweet, light, aromatics impression associated with flowers and fruits.
                    Reference: Welch's White Grape Juice = 5.0 (flavor)
                    Preparation: Dilute 1 part juice with one part water. Serve in 1 oz cups.

Banana-Like: Sweet, floral, fruity, candy-like aromatics commonly associated with banana flavored candies.
                    Reference: McCormick Imitation Banana extract in milk = 5.0 (flavor)
                    Preparation: Mix 1/8 teaspoon of McCormick Imitation Banana extract in 1 cup of Dillon's whole milk. Serve in 1 oz cups.

Piney: A slight resinous aromatic associated with fresh green pine needles.
                    Reference: Kroger Pine Nuts = 6.0 (flavor)
                    Preparation: Serve in 1 oz cups.

Musty/Dusty: Dry, dirt-like aromatic associated with dry, brown soil.
                    Reference: Potato Peel (covered) = 5.0 (aroma)
                    Preparation: Put 1.0 gram potato peel in a medium snifter, cover.

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)
                    Preparation: Place 3 slices in a medium snifter, cover.
                                        Serve chopped mushroom in 1 oz cups.

Woody: The sweet, brown, musty, dark, dry aromatics associated with the bark of a tree.
                    Reference: Diamond Shelled Walnuts = 4.0 (flavor)
                                        Sigma-Aldrich Cedarwood Oil, Virginia = 6.5 (aroma)
                    Preparation: Serve walnuts in a 1 oz cup.
                                        Place one drop oil on a cotton ball in a medium snifter, cover.

Overall Sweet: An aromatic associated with the impression of sweet substances.

Reference:	Highland Whipping Cream = 5.0 (flavor)
	Pepperidge Farm Bordeaux Cookie = 9.5 (flavor)
Preparation:	Serve whipping cream in 1 oz cups. Serve cookies in a Ziploc bag.

Oily: The light aromatics associated with vegetable oil or nut oil such as corn or soybean oil.

Reference:	Kroger Slivered and Blanched Almonds = 4.0 (flavor)
Preparation:	Serve macadamia nuts in a 1 oz cup.

Astringent: A feeling of a puckering or a tingling sensation on the surface and/or edge of the tongue and mouth.

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:	4% Sucrose Solution = 4.0
	6% Sucrose Solution = 6.0
	8% Sucrose Solution = 8.0

Appendix B - Black Walnut Descriptive Analysis Ballots

Black Walnut Kernel Evaluation

Panelist _____   **Sample** _____   **Date**
_____

APPEARANCE

Skin Color 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

Nutmeat Color 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

Kernel Roughness 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

AROMA

Black Walnut 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

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

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

Fruity-Dark 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

Banana-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

Musty/Dusty 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

FLAVOR

Black Walnut 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

Floral/Fruity   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

Fruity-Dark   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

Banana-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

Piney   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/Dusty   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

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

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

Surface Roughness 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

Hardness   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

Initial Crispness 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

Fracturability   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

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

Black Walnut Gelato Evaluation

Panelist _____   Sample _____   Date

_____

<u>FLAVOR</u>

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

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

Dairy Cooked   0 0.5 1 1.5 2 2.5 3 3.5 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 **<u>13</u>** 13.5 14 14.5 15

Black Walnut 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 **<u>12</u>** 12.5 13 13.5 14 14.5 15

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

Floral/Fruity   0 0.5 1 1.5 2 2.5 3 3.5 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

Banana-Like   0 0.5 1 1.5 2 2.5 3 3.5 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

Piney   0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 **<u>6</u>** 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/Dusty   0 0.5 1 1.5 2 2.5 3 3.5 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

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 **<u>8.5</u>** 9 9.5 10 **<u>10.5</u>** 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 **<u>4</u>** 4.5 5 **<u>5.5</u>** 6 **<u>6.5</u>** 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

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

Appendix C - Consumer Study Screening Ballot

Please circle or place an 'X' in front of each appropriate response:

1.   What is your gender: **Male**   **Female**
(Want even distribution of gender)

2.   What is your age?
Under 18   **18-24**   **25-35**   **36-45**   **46-55**   **56-65**   **Over 65**
(Terminate if under 18 years old. Want an even distribution)

3.   Do you have any known food allergies or dietary restrictions?   **YES**   **NO**
(Terminate if select 'Yes')

4.   Do you or anyone in your household work for any of the following? Please select all that apply.

An advertising agency, public relations or media company   **(Terminate if select)**
Marketing or market research firm or department   **(Terminate if select)**
A food or beverage manufacturer, distributor, or processor   **(Terminate if select)**
A restaurant, café or food service company   **(Terminate if select)**
I don't know   **(Terminate if select)**
None of the above

5.   When was the last time, if ever, you have participated in any type of product testing or market research?
In the past month   **(Terminate if select)**
In the past 2 months **(Terminate if select)**
In the past 3 months **(Terminate if select)**
In the past 6 months
6 months or more ago
I have never participated in a consumer research study

_____

6.   Which of the following foods do you eat? (Circle all that apply)

Beans
Nuts
Yogurt
Rice
Cereal
None of the above
(Must select nuts to continue)

7. You said that you eat nuts. How often do you eat nuts of any kind?

Everyday	At least once every 1-2 weeks	At least once a month	Once every 2-3 months	Once every 6 months	Never
				Terminate	**Terminate**

7.   Which of the following nuts/legumes are you willing to try? Please select all that apply.

Peanuts   Black Walnuts   Cashews   Almonds   Walnuts   Pecans
(Must select Black Walnuts to continue)

8.   In Which of the following food categories would you be willing to taste nuts? Please select all that apply.

Pastries   Ice cream/gelato   Pasta or Rice Dishes   Salad   Meat Dishes
(Must select ice cream/gelato to continue)

We are recruiting people in a Black Walnut Gelato study. We would need you to participate on either May 6th or 7th. The study will take approximately 1 hour to complete. Are you willing to participate in this study?   **YES   NO**
(Terminate if select 'No')

Appendix D - Consumer Study Moderator Guide

Hello. My name is _____. On behalf of The Sensory Analysis Center, I would like to thank you for your participation in this study. This session will last approximately 60 minutes. You will receive $10 for your time and opinions at the completion of the session.

You should have a consent form in front of you. Please read and sign this if you haven't already done so.

You will be asked to answer questions pertaining to your liking and intensity of various aspects of black walnut gelato samples. Each sample will be evaluated one at a time. When you receive a sample, please check to make sure that the code on the cup matches the one on the screen. Taste each sample as many times as needed to evaluate each sample.

Please make sure that you have answered each question before moving on to the next sample.

After evaluating the samples, there is a short demographic questionnaire.

There are several things you need to remember as you participate today.

- Please silence your cell phones.
- Be honest in answering the questions. There is no right or wrong answers to any of the questions.
- Do not discuss your answers with your neighbors. We want to know your own opinion.
- Take your time considering each sample - your input is very important to us.
- If you have any questions during the session, please raise your hand.
- There will be short periods of wait time in between serving of the samples. Please sit quietly during that time.
- Please take a bite of cracker and a sip of water between samples. Raise your hand if you need more crackers or water.
- The results of this study are confidential. Please do not discuss what you have tested with anyone outside this room.
- Make sure that you answer all of the questions. Please double check all responses when you are done to make sure all questions have been answered.

After you have completed the study, you may leave the room quietly to receive your payment.

Thank you again for your time and opinions.

Appendix E - Consumer Study Informed Consent Form

Sensory Analysis Center

Kansas State University

Ice Hall 136

Manhattan, KS 66502

1. I, (print your name) _____, agree to participate as a panelist for research at the Kansas State University Sensory Analysis Center.

2. I understand that the purpose of this research is to participate in a taste test evaluating six samples of black walnut gelato.

3. I understand that if I have any food allergies I should not participate in the study.

4. For this test, I will receive $10 when I complete this 60 minute study.

5. I understand that my performance as an individual will be treated as research data and will in no way be associated with me for identification purposes, thereby assuring confidentiality of my performance and responses.

6. I understand that I do not have to participate in research, and that if I choose not to participate, there will be no penalty.

7. I understand that I may withdraw from this research at any time.

8. If I have any questions concerning this study, I understand that I may contact Catherine Lynch, 136 Ice Hall, Kansas State University, Manhattan, KS at 785-532-0144, or Kadri Koppel at 785-532-0163.

9. If I have questions about my rights as a consumer or about the manner in which this research was conducted, I may contact Rick Scheidt, Chair, Committee on Research Involving Human Subjects, at 203 Fairchild Hall, or Gerald Jaax, Associate Vice-provost for Research, 1 Fairchild Hall (785-532-2334).

I understand the above statements (Participant must sign):

_____

Signature   **Date**

Appendix F - Black Walnut Gelato Consumer Ballot

Date: _____   **Panelist #** _____

Sample: ____

Mark an X in the box that best represents your answer.
Please taste the sample and answer the following questions, tasting as many times as needed to evaluate it.

1. How much do you **like or dislike** this sample **OVERALL**?

Dislike
Extremely ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Like
Extremely

2. How much do you **like or dislike** the **OVERALL FLAVOR** of this sample?

Dislike
Extremely ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Like
Extremely

3. Please rate the **INTENSITY** of the **OVERALL FLAVOR** of this sample?

Not at all
Flavorful ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely
Flavorful

4. How much do you **like or dislike** the **BLACK WALNUT FLAVOR** in this sample?

Dislike
Extremely ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Like
Extremely

5. Please rate the **INTENSITY** of the **BLACK WALNUT FLAVOR** in this sample.

Not at all
Flavorful ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely
Flavorful

Please write any other comments you have about this sample below:
_____
_____
_____
_____

Please take a bite of cracker and a drink of water before tasting the next sample.

Demographic Information: **Panelist # _____**

Gender: ☐ Male   or   ☐ Female

1. Which of the following best describes your age?

☐ 18-24   ☐ 25-35   ☐ 36-45   ☐ 46-55   ☐ 56-65   ☐ 66 or older

2. What is your race? (Select all that apply)

☐ Hispanic/Latino   ☐ Black or African American
☐ American Indian or Alaska Native   ☐ Indian Subcontinent
☐ Asian   ☐ White
☐ Native Hawaiian or Pacific Islander ☐ Prefer not to answer

3. How often do you eat Black Walnuts? (Circle one)

☐ Never   ☐ About every 6 months   ☐ About every 2-3 months

☐ About every month   ☐ About once a week   ☐ 2 or more times a week

4. If you eat black walnuts, in what form do you eat them?

☐ Alone/By themselves   ☐ In ice cream/gelato   ☐ In cookies/cake
☐ In granola bars/trail mix ☐ In candy/fudge/confectionary
☐ Other_____

5. What other types of nuts/legumes do you consume? (Check all that apply)

☐ Almonds   ☐ Cashews   ☐ Brazil Nuts
☐ Peanuts   ☐ Macadamia Nuts   ☐ Pistachios
☐ English Walnuts   ☐ Pecans   ☐ Other_____

6. How often do you eat other nuts/legumes BY THEMSELVES? (i.e. not in a food product)

☐ Never   ☐ About every 6 months   ☐ About every 2-3 months

[ ] About every month [ ] About once a week [ ] 2 or more times a week

7. How often do you consume/buy food products (breads, cereals, desserts, etc.) containing nuts of any kind? (Select one)

[ ] Never [ ] About every 6 months [ ] About every 2-3 months

[ ] About every month [ ] About once a week [ ] 2 or more times a week

8. If so, which type of products do you consume/buy? (Check all that apply)

- [ ] Cookies
- [ ] Cakes
- [ ] Candy

- [ ] Ice Cream
- [ ] Granola Bars
- [ ] Breakfast Cereal

- [ ] Breads
- [ ] Trail Mix
- [ ] Other ____

9. Which nuts do you typically look for when purchasing these products?

- [ ] Almonds
- [ ] Peanuts
- [ ] Walnuts
- [ ] Black Walnuts
- [ ] Nuts are not the focus of my purchase

- [ ] Cashews
- [ ] Macadamia Nuts
- [ ] Pecans
- [ ] Pistachios

- [ ] Chestnuts
- [ ] Hazelnuts
- [ ] Pine Nuts
- [ ] Other _____

Date: _____   **Panelist # _____**

Please rate how much you **agree or disagree** with the following statements by marking an X in the box that best represents your answer.

1. When I eat out, I like to try the most unusual items, even if I am not sure I would like them.

Completely
Disagree | | | | | | Completely
Agree

2. While preparing foods or snacks, I like to try out new recipes.

Completely
Disagree | | | | | | Completely
Agree

3. I think it is fun to try out food items one is not familiar with.

Completely
Disagree | | | | | | Completely
Agree

4. I am eager to know what kinds of foods people from other countries eat.

Completely
Disagree | | | | | | Completely
Agree

5. I like to eat exotic foods.

Completely
Disagree | | | | | | Completely
Agree

6. Items on the menu that I am unfamiliar with make me curious.

Completely
Disagree | | | | | | Completely
Agree

7. I prefer to eat food products that I am used to.

Completely
Disagree | | | | | | Completely
Agree

8. I am curious about food products I am not familiar with.

Appendix G - Descriptive Analysis Test Designs

Black Walnut Kernel Evaluation

Evaluation Day 1

Panelist	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
1	Pounds	Sparks 127	Neel	Emma K	Tomboy	Football
2	Sparks 127	Davidson	Vandersloot	Neel	Pounds	Tomboy
3	Pounds	Davidson	Sparrow	Brown Nugget	Sparks 127	Tomboy
4	Neel	Football	Emma K	Brown Nugget	Vandersloot	Pounds
5	Vandersloot	Davidson	Neel	Pounds	Emma K	Brown Nugget
6	Neel	Pounds	Vandersloot	Davidson	Football	Brown Nugget

Evaluation Day 2

Panelist	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
1	Davidson	Brown Nugget	Vandersloot	Sparrow	Pounds	Neel	Sparks 127
2	Sparrow	Football	Emma K	Brown Nugget	Davidson	Football	Neel
3	Neel	Vandersloot	Football	Emma K	Pounds	Tom Boy	Sparks 127
4	Sparrow	Davidson	Sparks 127	Tomboy	Emma K	Neel	Tomboy
5	Sparks 127	Tomboy	Sparrow	Football	Vandersloot	Neel	Sparks 127
6	Sparks 127	Tomboy	Sparrow	Emma K	Pounds	Neel	Davidson

Evaluation Day 3

Panelist	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
1	Vandersloot	Football	Davidson	Sparrow	Emma K	Brown Nugget	Tomboy
2	Sparks 127	Tomboy	Sparrow	Brown Nugget	Vandersloot	Pounds	Emma K
3	Football	Vandersloot	Sparrow	Davidson	Neel	Emma K	Brown Nugget
4	Sparrow	Davidson	Vandersloot	Pounds	Sparks 127	Brown Nugget	Football
5	Emma K	Pounds	Sparrow	Davidson	Brown Nugget	Football	Tomboy
6	Sparks 127	Brown Nugget	Football	Emma K	Vandersloot	Tomboy	Sparrow

Evaluation Day 4

Panelist	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
1	Neel	Brown Nugget	Football	Davidson	Vandersloot	Pounds	Sparks 127
2	Brown Nugget	Vandersloot	Football	Emma K	Neel	Davidson	Sparrow
3	Neel	Vandersloot	Sparks 127	Emma K	Tomboy	Davidson	Brown Nugget
4	Tomboy	Pounds	Sparks 127	Emma K	Football	Sparrow	Davidson
5	Neel	Football	Tomboy	Emma K	Brown Nugget	Vandersloot	Davidson
6	Sparrow	Pounds	Vandersloot	Neel	Emma K	Brown Nugget	Tomboy

Evaluation Day 5

Panelist	Sample 1	Sample 2	Sample 3
1	Emma K	Tomboy	Sparrow
2	Sparks 127	Tomboy	Pounds
3	Football	Pounds	Sparrow
4	Brown Nugget	Neel	Vandersloot
5	Sparks 127	Sparrow	Pounds
6	Sparks 127	Football	Davidson

Black Walnut Gelato Evaluation

Replication 1 (5/6/14)

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Panelist 1	Pounds	Sparks 127	Davidson	Football	Vandersloot	Emma K
Panelist 2	Davidson	Emma K	Vandersloot	Sparks 127	Pounds	Football
Panelist 3	Sparks 127	Pounds	Emma K	Vandersloot	Football	Davidson
Panelist 4	Emma K	Davidson	Football	Pounds	Sparks 127	Vandersloot
Panelist 5	Vandersloot	Football	Pounds	Emma K	Davidson	Sparks 127
Panelist 6	Football	Vandersloot	Sparks 127	Davidson	Emma K	Pounds

Replication 2 (5/7/14)

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Panelist 1	Emma K	Pounds	Football	Sparks 127	Davidson	Vandersloot
Panelist 2	Football	Vandersloot	Sparks 127	Emma K	Pounds	Davidson
Panelist 3	Pounds	Emma K	Vandersloot	Davidson	Sparks 127	Football
Panelist 4	Vandersloot	Football	Davidson	Pounds	Emma K	Sparks 127
Panelist 5	Sparks 127	Davidson	Emma K	Football	Vandersloot	Pounds
Panelist 6	Davidson	Sparks 127	Pounds	Vandersloot	Football	Emma K

Replication 3 (5/8/14)

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Panelist 1	Football	Sparks 127	Davidson	Vandersloot	Pounds	Emma K
Panelist 2	Emma K	Vandersloot	Pounds	Sparks 127	Davidson	Football
Panelist 3	Sparks 127	Davidson	Emma K	Pounds	Football	Vandersloot
Panelist 4	Pounds	Football	Sparks 127	Emma K	Vandersloot	Davidson
Panelist 5	Vandersloot	Pounds	Football	Davidson	Emma K	Sparks 127
Panelist 6	Davidson	Emma K	Vandersloot	Football	Sparks 127	Pounds

Appendix H - Black Walnut Gelato Consumer Evaluation Test Design

Sample Set	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
1	720	291	407	139	501	154
2	407	501	720	154	291	139
3	139	720	291	154	407	501
4	501	720	139	407	291	154
5	720	407	501	154	139	291
6	291	501	407	139	154	720
7	291	501	407	139	154	720
8	720	407	154	501	139	291
9	407	291	720	501	139	154
10	501	154	291	720	139	407
11	291	720	154	139	407	501
12	154	720	501	291	139	407
13	154	291	720	501	139	407
14	501	407	291	154	139	720
15	720	407	291	154	501	139
16	154	139	291	407	501	720
17	720	154	139	291	407	501
18	407	501	139	154	720	291
19	720	501	291	154	139	407
20	154	720	501	139	291	407
21	720	407	291	139	501	154
22	501	291	407	154	139	720
23	407	501	291	154	139	720
24	139	154	501	720	407	291
25	501	407	720	291	154	139
26	291	139	154	501	720	407
27	154	501	720	407	291	139
28	139	501	291	154	407	720
29	501	407	720	154	291	139
30	501	154	139	720	407	291
31	291	501	407	720	154	139
32	139	501	291	720	407	154
33	154	501	720	139	407	291
34	501	154	139	720	291	407
35	407	501	139	720	291	154
36	407	291	720	501	154	139

37	720	154	139	291	501	407
38	154	407	501	291	720	139
39	720	154	501	291	139	407
40	291	407	501	154	139	720
41	501	407	139	154	291	720
42	154	407	720	291	501	139
43	407	154	291	139	501	720
44	501	154	139	407	291	720
45	139	291	407	720	154	501
46	501	720	407	291	139	154
47	720	139	154	291	501	407
48	720	139	501	291	407	154
49	720	154	139	291	501	407
50	139	720	154	501	407	291
51	407	139	501	154	291	720
52	720	154	407	139	291	501
53	720	291	139	407	501	154
54	154	407	720	291	501	139
55	407	501	291	720	154	139
56	501	291	154	139	720	407
57	407	720	154	139	291	501
58	407	291	154	139	501	720
59	501	139	407	154	720	291
60	407	154	720	139	291	501
61	291	720	501	154	139	407
62	501	154	139	407	720	291
63	407	501	720	291	139	154
64	720	407	139	291	501	154
65	291	139	720	501	154	407
66	291	154	501	720	407	139
67	720	407	291	154	139	501
68	501	720	407	139	291	154
69	291	501	139	407	720	154
70	154	501	139	407	720	291
71	291	407	154	720	501	139
72	501	139	407	154	720	291
73	407	720	291	501	139	154
74	291	139	720	407	154	501
75	139	501	154	407	291	720
76	501	407	139	154	291	720
77	407	139	501	291	154	720

78	154	720	407	139	291	501
79	720	407	139	501	291	154

Blinding Codes		
Sample number	**Sample Name**	**Blinding Code**
1	Emma K	407
2	Davidson	154
3	Vandersloot	720
4	Sparks 127	139
5	Pounds	291
6	Football	501

Appendix I - SAS® Codes for Statistical Analysis

SAS® Codes for Black Walnut Seasonal Variation

```
title 'BW Seasonal Variation without EmmaK';
data Walnut;
Input Year$  Cultivar$     Panelist$      Rep$ Bwal_fOvNutt_f      NutWd_f      NGL_f
      NutBut_f      Brown_f      Carml_f      Acrid_f      Burnt_f      FlorFr_f
      FD_f Piney_f      MD_f ME_f Woody_f      OverSw_f      Oily_f Rancid_f
      Astrin_f      Bitter_f      Sour_f Sweet_f;
cards;

[Input raw data from both years here]

;
ods rtf;
Proc Print data=walnut;
run;

%macro mix(resp,title);
TITLE "&title with REPEATED";
PROC MIXED data=Walnut covtest cl;
CLASS Year Cultivar Panelist;
MODEL &resp=Year Cultivar Year*Cultivar/ddfm=satterth;
RANDOM Panelist  Panelist*Year  Panelist*Year*Cultivar;
REPEATED / group=Year;
LSMEANS Year Cultivar   Year*Cultivar /cl;
LSMEANS Cultivar / pdiff adjust=tukey;
LSMEANS Year*Cultivar / slice=Cultivar;
ods output LSMEANS=LSM;
run;

data yc;
set LSM; if Effect="Year*Cultivar";
if year=2011 then y=1; else y=3;

SYMBOL1 value=circle color=red line=20 i=join;
SYMBOL2 value=diamond color=blue line=20 i=join;
Proc gplot data=yc;
plot estimate*cultivar=y;
run;
%mend mix;

%mix(Bwal_f,Black Walnut);
```

```
%mix(OvNutt_f,Overall Nutty);

%mix(NutWd_f,Nutty-Woody);

%mix(NGL_f,Nutty-Grain-like);

%mix(NutBut_f,Nutty-Buttery);

%mix(Brown_f,Brown);

%mix(Carml_f,Caramelized);

%mix(Acrid_f,Acrid);

%mix(Burnt_f,Burnt);

%mix(FlorFr_f,Floral/Fruity);

%mix(FD_f,Fruity-dark);

%mix(Piney_f,Piney);

%mix(MD_f,Musty/Dusty);

%mix(ME_f,Musty/Earthy);

%mix(Woody_f,Woody);

%mix(OverSw_f,Overall Sweet);

%mix(Oily_f,Oily);

%mix(Rancid_f,Rancid);

%mix(Astrin_f,Astringent);

%mix(Bitter_f,Bitter);

%mix(Sour_f,Sour);

%mix(Sweet_f,Sweet);
run;

ods rtf close;
QUIT;
```

SAS® Codes for Descriptive Analysis

Latin Square Design

```
dm 'log;clear;output;clear;';
title 'Latin Square Design (Rep 1)';
ods rtf;
proc plan seed=480540;
factors rows=6 ordered cols=6 ordered / noprint;
treatments tmts=6 cyclic;
output out=g
 rows cvals=('P1' 'P2' 'P3' 'P4' 'P5' 'P6') random
 cols cvals=('S1' 'S2' 'S3' 'S4' 'S5' 'S6') random
 tmts nvals=(1 2 3 4 5 6) random;
quit;

Proc tabulate;
 class rows cols;
 var tmts;
 table rows, cols*(tmts*f=6.) / rts=8;
run;
ods rtf close;
quit;
```

Notes

1. The seed number was changed to a different 6-digit random number for each Latin Square design created,.

Descriptive Analysis (ANOVA)

```
dm'log;clear;output;clear;';
Data (data name);
input Product$      Rep$  Panelist$      attribute1      atributer2      attribute3
      attribute4      attriubte5      attribut6      attribute7      attribute8      attribute9
      attribute10      attribute11      attribute12      attribute13      attribute14;
cards;
[Insert raw data here]
;
ods rtf;
Proc means; var attribute1—attribute22;
run;
```

```
proc glimmix;
title (Attribute Name);
        class Product Rep Panelist;
        model attribute = Product/ddfm=sat;
        random rep panelist;
        lsmeans product/ pdiff lines;
        run;
```

Notes

2. In the Proc Means statement, attribute1 corresponds to the first attribute listed, and attribute 22 corresponds to the last attribute listed.
3. The Proc Glimmix procedure is repeated for every attribute

SAS® Codes for Analyzing Consumer Data

All Liking Scores (ANOVA)

```
dm'log;clear;output;clear;';
title 'BWGelato-CLUSTER OVERAL LIKING';
data BWGelato;
Input Cluster$ Cons$ Sample$ Overall OvFlvr FlvrIn BWFlvr BWFlvrIN;
cards;

[Raw data was inputted here]

;
ods rtf;

proc mixed data= BWGelato covtest cl;
class Sample Cons;
Model Overall= sample/outp= BWGelato;
Title 'Overall Liking';
random Cons;
lsmeans Sample/cl pdiff;
run;

proc mixed data= BWGelato covtest cl;
class Sample Cons;
Model OvFlvr= sample/outp= BWGelato;
Title 'Overall Flavor Liking';
random Cons;
lsmeans Sample/cl pdiff;
run;
```

```
proc mixed data= BWGelato covtest cl;
class Sample Cons;
Model FlvrIn= sample/outp= BWGelato;
Title 'Overall Flavor Intensity';
random Cons;
lsmeans Sample/cl pdiff;
run;

proc mixed data= BWGelato covtest cl;
class Sample Cons;
Model BWFlvr= sample/outp= BWGelato;
Title 'Black Walnut Flavor Liking';
random Cons;
lsmeans Sample/cl pdiff;
run;

proc mixed data= BWGelato covtest cl;
class Sample Cons;
Model BWFlvrIn= sample/outp= BWGelato;
Title 'Black Walnut Flavor Intensity';
random Cons;
lsmeans Sample/cl pdiff;
run;
ods rtf close;
quit;
```

Liking Scores across Clusters (ANOVA)

```
dm'log;clear;output;clear;';
title 'BWGelato-CLUSTER OVERAL LIKING';
data BWGelato;
Input Cluster$ Cons$ Sample$ Overall OvFlvr FlvrIn BWFlvr BWFlvrIN;
cards;

[Raw data was inputted here]

;
ods rtf;

proc glm data= BWGelato;
class Cluster Cons Sample;
model Overall = Sample Cluster Cons(Cluster) sample*Cluster/ss3;
means sample/lsd;
```

```
lsmeans Cluster*sample/pdiff lines;
run;

proc glm data= BWGelato;
class Cluster Cons Sample;
model OvFlvr = Sample Cluster Cons(Cluster) sample*Cluster/ss3;
means sample/lsd;
lsmeans Cluster*sample/pdiff lines;
run;

proc glm data= BWGelato;
class Cluster Cons Sample;
model FlvrIn = Sample Cluster Cons(Cluster) sample*Cluster/ss3;
means sample/lsd;
lsmeans Cluster*sample/pdiff lines;
run;

proc glm data= BWGelato;
class Cluster Cons Sample;
model BWFlvr = Sample Cluster Cons(Cluster) sample*Cluster/ss3;
means sample/lsd;
lsmeans Cluster*sample/pdiff lines;
run;

proc glm data= BWGelato;
class Cluster Cons Sample;
model BWFlvrIn = Sample Cluster Cons(Cluster) sample*Cluster/ss3;
means sample/lsd;
lsmeans Cluster*sample/pdiff lines;
run;

ods rtf close;
quit;
```

Cluster Analysis with Consumer Overall Liking Scores (K-Means)

```
Title 'Black Walnut Gelato Clusters';
data BWGelato;
input Cons$ EmmaK Davidson VndrSlt Sparks Pounds Football;
cards;

[Raw data was inputted here]

;
ods rtf;
proc fastclus data=BWGelato maxc=3 maxiter=20 out=clus;
```

```
id cons;
var EmmaK Davidson VndrSlt Sparks Pounds Football;
run;

proc sort data=clus;
by cluster;
run;

proc print data=clus;
var EmmaK Davidson VndrSlt Sparks Pounds Football cluster cons;
run;

ods rtf close;
quit;
```

Appendix J - Black Walnut Gelato Formulas

Gelato Base Ingredients

	Quantity (g)	Percent (%)
Whole Milk (4% fat)	16,000	57.21
Nonfat Dry Milk	475	1.70
Heavy Whipping Cream (35% fat)	5,968	21.34
Sucrose	3,257	11.65
Dextrose (Dry Glucose)	1,484	5.31
PreGel Base 50	785	2.81
Total	27,969	100.00

Gelato Base Preparation

(Adapted from the Carpigiani Pastomaster 60 RTX handbook, The Carpigiani Group, Anzola Dell'emilia, Italy)

1. Mix all dry ingredients together and set aside (Nonfat dry milk, sucrose, dextrose, and PreGel Base 50).
2. Press AUTO and select 'Ice Cream Mix Workings' using the arrow keys on the Carpigiani Pastomaster 60 RTX. Then select 'High Pasteurization.'
3. Press 'Start' and pour all of the milk into the machine.
4. When the milk reaches 40°C, the machine will beep. At this time, add the dry ingredients to the machine.
5. When the milk temperature reaches 85°C, the machine will inform you that the cooling step is starting. When the milk temperature reaches 65°C, the machine will beep and tell you to add the cream. Add all of the heavy whipping cream to the machine.
6. The machine will beep again when the mixture temperature reaches 4°C. At this point, the pasteurization process has finished, and the ageing process will begin. Allow the mixture to age in the machine for 24 hours before starting to make gelato batches with the base.

Individual Gelato Batch Preparation

(Adapted from the Carpigiani LB 302 RTX Handbook, The Carpigiani Group, Anzola Dell'emilia, Italy)

1. Place all metal gelato trays in the blast freezer 10 minutes prior to dispensing gelato.
2. Pour 3,500g of the base mix into the front hopper of the batch freezer (Carpigiani LB 302 RTX). Close hopper lid and press
3. Press 'Ice Cream Production' and select type 'EC.' Press start.
4. When the machine beeps (after approximately 8 minutes), press the 'Dispense' button to dispense the gelato. Hold a metal gelato try underneath the ice cream door, and turn the handle to start dispensing the gelato.
5. After you have dispensed all of the gelato, press 'Stop.'
6. Weigh 3,000g grams of the frozen gelato into a bowl. Add 200g of chopped nuts and stir with a spatula until blended (30 seconds).
7. Cover the tray with Cling Wrap (The Glad Products Company, Oakland, CA, USA) and place it in the blast freezer (-34°C ± 1°C) for two hours.
8. Transfer the gelato trays to a freezer (-18°C ± 1°C) until ready to place in the display case.
9. Place gelato trays in the display case 1 hour prior to serving.