PEACH QUALITY ANALYSIS USING SENSORY AND INSTRUMENTAL EVALUATIONS

by

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ABSTRACT

Sensory analysis is a useful methodology to characterize physical and chemical attributes of a produce. The objective of this research was to evaluate a representative group of peach cultivars grown in the southeastern U.S. to assess their quality attributes instrumentally and through sensory evaluation. The appearance, aroma, taste, and texture were evaluated using laboratory procedures standardized for fruit quality determination. A trained sensory descriptive panel was used to establish a lexicon for fresh peach fruit organoleptic attributes. Both the lexicon and the instrumental analyses could be used to evaluate a group of cultivars allowing more in-depth characterization of peach fruit. Instrumental analyses demonstrated the presence of large variation for physical and chemical attributes of the peach cultivars being evaluated. Cultivars with extreme levels for each physical and chemical characteristic could be used to identify intensity differences perceived by the trained panelist when using the lexicon created. The results from this study will be used in the future to characterize the physical and chemical attributes of peach fruit quality associated with consumer preference.

INDEX WORDS: peach, lexicon, quality, chemical peach quality, physical peach quality

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DEDICATION

To my family, friends, and those who believed in me. To the future of the peach and fruit industry. In hopes that our research be a benefit and source of knowledge to the well-being of all.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

Peach quality has been a topic of interest in the horticulture community due to its gradual decline in consumption since the 1980s. While many studies have worked to assess and to establish quality parameters of peaches, the southeastern U.S. do not have a complete study of quality parameters for peach. As of 2016, there is no standard method to measure fresh peach fruit quality in the southeastern United States. Much of the quality research in peaches has focused on soluble solid concentration (SSC) and titratable acidity (TTA). However, the information available about fruit quality and consumer preference is lacking. Some research has focused on the quality of peaches in California, Spain, and France using more in-depth quality analyses.

In California, Crisosto et al. (2006) developed a multi-step process for an in-depth quality index for California peaches. The author proposed that a range of SSC and TTA would first need to be established and later be narrowed into an industry quality range. Next, their studies would focus on pre-harvest factors affecting quality followed by the use of trained panelists to distinguish quality between cultivars. Lastly, consumer tests would provide liking or disliking of fruit attributes into categories related to instrumental data and descriptive intensities.

We are proposing the establishment of a universal sensory lexicon for fresh peaches. This lexicon will include appearance, aroma/flavors, and textures attributes. Due to the wide range of attributes within a peach, this would need to be developed throughout the peach season using multiple varieties. Once developed, the lexicon will be useful in descriptive sensory analysis, which could then be related to consumer acceptability and instrumental measures to gauge the quality of numerous fresh peach varieties across a broad region.

We are also proposing that instrumental evaluations be done for the peaches used in developing the lexicon. The instrumental evaluation of peach varieties grown in the southeastern U.S. will allow the identification of broad chemical and physical differences among varieties. The main objective of this paper would be to collect a large selection of varieties over two seasons to characterize the effect of fruit quality across different seasons. Cultivar and environmental factors have been reported in multiple studies to influence the quality of fruit, specifically highly perishable fruits as peaches. This database will provide information to explain the impact of flesh type, season maturity time, and the impact of environmental factors between years and varieties.

New varieties with different characteristics for aroma/flavor, texture, appearance, sweetness, acidity, etc. are being released every year. The development of a lexicon for fresh peaches coupled with instrumental physical and chemical measurements would allow for greater understanding of what parameters determine a 'quality' standard that will increase consumers' acceptability. In addition, the study of peach fruit quality will allow for future breeding and selection of traits associated with fruit quality that are associated with consumer preference. By combining these evaluations, scientists have the potential to understand what parameters would define a 'quality' standard that will ultimately acceptability in the consumers.

CHAPTER 2

LITERATURE REVIEW

INTRODUCTION

Peaches [*Prunus persica* (L.) Batsch] are believed to have originated in eastern and southeastern Asia (Hedrick, 1917; Bassi and Monet, 2008). They were introduced to the state of Georgia in 1571 and by the 1700s were cultivated throughout the state. Since its introduction, the number of cultivars grown in Georgia has expanded to over 40-60 commercial varieties. The U.S. per capita consumption of this beloved fruit has declined from 6.0lb (2.72kg) in 1990-1992 to 4.4lb (2.00kg) in 2010-2012 per year (USDA ERS, 2015). This decline in consumption has been associated with consumer disapproval of the peach fruit quality being offered (Crisosto *et al*., 2006b).

In 2015, the national production of peaches in the United States was 825,415 tons with a value roughly of $605M. In Georgia, peach production in 2015 was valued at $35M with roughly 10,000 acres harvested from mid-May to late-August (USDA-NASS, 2016). Peach varieties have been bred to be available throughout the season and are often harvested before fully ripe to extend their shelf life.

Characterization of fruit quality

Peach production in the southeastern U.S. is based on multiple varieties. Each variety is ripe for a period of one to two weeks. Peach farms use multiple varieties to have fruit available at different periods to allow supermarkets and the consumers to have peaches throughout the season.

Each peach variety is different from each other. A peach tree and its fruit can be characterized by different phenotypic traits used to understand their composition. The focus of our study is to discuss the phenotype of fresh peach fruit. Several traits have been previously used to describe fresh peach fruit, such as weight, size, shape, tip (presence/absence of beak), suture line depth, redness of skin, firmness, color, redness in flesh, flavor, texture, fibrousness, sugars, acidity, and adherence to stone. Commercially, peaches and nectarines are commonly characterized by some of these traits, for example: fruit shape (round/elongated or flat), flesh color (white or yellow), flesh texture (melting or non-melting), and/or flesh acidity (acidic or low-acid/honey) (Bassi and Monet 2008). The phenotypic composition of a peach variety is based on its genetic composition and the effect of the environment imposed on that variety. The genotypic composition of some of these traits have been previously studied: shape (Lesley, 1940), flesh color (Connors 1920), flesh texture (Bassi and Selli 1990), and lack of acidity in fruit (Monet 1979). However, information on the effect of seasonal variation of quality traits and their perception and impact on consumers is limited.

Peach breeding and selection initially focused on providing varieties with large attractive fruit with superior quality, while lacking taste, cold hardiness, and adaption to different growing systems (Abbot *et al*., 2008). Kramer and Twigg (1966) defined quality as the combination of chemical and physical characteristics that make a produce possess consumer demand and acceptability. Currently, fruit quality is a key component in fruit breeding and selection. Peach fruit quality studies have assessed genes involved in sucrose accumulation (Vimolmangkang, *et al*., 2016) and evaluated the genetics of peach acidity (Wang *et al*., 2016), among others. Past studies have focused on individual quality characteristics of peaches (Contador *et al*., 2014; Crisosto and Crisosto, 2005; Visai and Vanoli, 1997) and an overall quality assessment of a small group of peach varieties (Colaric *et al*., 2005; Contador *et al*., 2014; Delgado *et al*., 2013; Xi *et al*., 2014).

Commercial peach producers seek peach varieties with large fruit size, high yield, and disease resistance. For packers, distributors, and wholesale markets, peach flesh firmness is of concern because of its importance during storage and shelf-life. Retailers are more concerned with color and size to attract consumers to purchase the fruit due to its superior appearance. Similarly, firmness is of importance to reduce fruit damage produced by handling (Crisosto and Costa 2008).

Limitations during pre- and post-harvest management of peach have been previously identified, with the presence of immature fruit (premature harvesting), chilling injury, and poor overall quality. Often parameters of quality valued by consumers, such as firmness, sugar content, aroma, and acidity, are not of major concern to growers and are routinely ignored (Crisosto and Costa 2008).

INSTRUMENTAL EVALUATION OF QUALITY

Instrumental tests in fruit refer to the measurement of chemical and physical properties used to represent color, appearance, flavor, texture, and nutritional quality. Instrumental analyses are sensitive to small differences and can provide accurate and precise results of the chemical and physical makeup of a fruit. These analyses allow a mechanistic understanding of the observed differences between varieties (Barrett *et al.,* 2010). In addition, these instrumental trends can be associated with quality and signs of inadequate quality can be detected instrumentally before perception by the human palate (Brosnan and Sun, 2004; Thai *et al*., 1990).

Sugars and acids

The most common and simplified method to measure fruit quality is by determining the soluble solid concentration (SSC) and individual sugars representing fruit sweetness; and total titratable acidity (TTA), pH, and individual acids representing sour and bitter tastes. Overall, sugars and acids are considered standard quality indicators used for peaches.

SSC, also referred to as Brix, are represented by the sum of sugars (sucrose, fructose, and glucose), acids, and other minor metabolites (Beckles, 2012). It can be thought of as a measurement of the total concentration of sugars within a product. It contributes between 7 - 18% of total fresh weight in peaches (Crisosto and Valero, 2008). Quality standards for yellow-flesh peaches in California have been set at a minimum of 10% SSC (Kader, 1995). In Italy, 10% SSC is the suggested quality minimum for early-season, 11% for mid-season, and 12% for late season (Testoni, 1995, Ventura *et al*., 2000). France also established a minimum quality standard according to Hilaire (2003) with 10% SSC for low-acid peaches and a TTA $<0.9\%$, and a 11% SSC minimum for high acid peaches or those with TTA $\geq 0.9\%$.

Early research on consumer acceptance of peaches has associated fruit acceptability with high SSC (Crisosto and Crisosto, 2005; Parker *et al*., 1991; Ravaglia *et al*., 1966). Fruit taste is perceived by a combination of sweet and sour sensations produced by sugar and organic acids (Sanz and Perez, 2010). Acidity is commonly measured by TTA in percent malic acid; pH has also been used but is not as accurate as TTA (Barnett *et al*., 2010). Organic acids make up between 0.4 – 1.2% of fresh peach weight (Crisosto and Valero, 2008). Sour and bitter tastes are linked to organic acids, with malic and citric acids being the primary components of an acidic flavor (Xi *et al*., 2014; Colaric *et al*., 2005). Malic acid has been reported to give a smooth and tart flavor with a more apparent acidic taste compared to citric acid (Dziezak, 2003). Individual acids in peaches can be measured as well, providing more in depth quality analyses, however, TTA has become the industry standard and is more easily measured in the fruit samples and serves as a rapid indicator of sourness.

A general measure of flavor in peaches is obtained when comparing SSC with TTA using the "sugar:acid ratio" (Barnett *et al*., 2010). This is a simple method to estimate flavor instrumentally in peaches. The use of the sugar/acid ratio has been proposed to classify fruit with acceptable flavor quality using a minimum SSC and maximum TTA (Kader, 2002). However, there is no clear distinction between what is an acceptable and unacceptable ratio, rather in cases where the SSC is above the minimum standard and the TTA is below the maximum standard, a higher overall SSC:TTA ratio suggests that the fruit would be sweeter and more flavorful. A study by Crisosto and Crisosto (2005) supports this with a TTA of > 0.9% as the maximum and SSC < 12% as the minimum being the standards. Cultivars reach consumer acceptance at different SSC levels, suggesting that a set SSC level is not recommended as a general quality index (Crisosto and Crisosto, 2005). Further, Crisosto *et al.* (2006) suggests that fruit be characterized by organoleptic groups so that a quality index be developed for each group rather than a quality index based directly on SSC or SSC:TTA ratio. Organoleptic groups include sweetness, sourness, peach/nectarine flavor intensity, and peach/nectarine aroma intensity.

During ripening and maturation of fruit, biochemical changes occur that influence quality. These changes include color development, texture, sugar, organic acid, and volatile changes (Giovannoni, 2004). Peaches are climacteric, meaning the ethylene response increases after fruit is mature (Ramina, et al., 2008). Ethylene is also present in non-climacteric fruit and has a role in ripening. In climacteric fruit, such as peaches, the ethylene response causes respiration to increase and causes chemical and physical changes within the fruit. In terms of quality development, organic acids decrease, sugars increase, and texture softens (Bae et al., 2012). It is well understood that during these changes, the development and intensity of a fruit flavor becomes more pronounced. This process continues during ripening and postharvest senescence until the fruit is no longer considered to have acceptable quality. In fact, Crisosto and Costa (2008) noted the importance of acids, sugars, and aromatic compounds for their influence in flavor quality of peaches.

Textures

Texture is one of the most important characteristics in peaches (Sams, 1999). Peaches specifically are known for their 'melting' and 'non-melting' texture attributes. Melting flesh types have a blatant softening in the final stage of ripening that will continue through senescence, while non-melting does not (Bassi and Monet, 2008). Brovelli *et al.* (1999) conducted a study on the compositional and sensory differences between fresh market melting and non-melting peaches. They reported that melting peaches had softer and juicier textures in comparison to non-melting peaches which were harder and less juicy. Sherman et al. (1990) reported that the non-melting cultivars developed a rubbery texture through senescence as compared to the melting variety. This is due to the lack of endopolygalacturonase (EPG) enzymes in non-melting flesh. EPG loosens pectin fibers from the cell wall and is primarily found in melting varieties of peaches (Brummell *et al.,* 2004; Lester *et al.,* 1996). EPG activity has been correlated with the degree of 'melting' within a peach fruit with higher degree of enzyme activity in melting flesh compared to non-melting flesh (Morgutti *et al.,* 2006).

When defining texture, Bourne (1982) suggested that a "group of physical characteristics that arise from the structural elements of the food and are sensed by the feeling of touch, are related to the deformation, disintegration, and flow of the food under a force, and are measured objectively by functions of mass, time, and distance." Bourne (1974) subjected melting and non-melting peaches to puncture, compression, and shear coefficient tests on an Instron testing machine. He reported that multiple parameters can be evaluated using these methods, including fracturability, hardness, cohesiveness, gumminess, and chewiness as textural properties of peaches. Figure 2.1 shows the texture profile curve used to determine these differences as measured in compression. The first peak represents fracturability, followed by hardness. Elasticity is measured in the final peak by the distance recovered between the first and second bite. Cohesiveness is determined by dividing Area 2 by Area 1. Gumminess results from multiplying hardness by cohesiveness, and chewiness is measured with gumminess by elasticity. This is the case for many solid foods. Bourne (1974) found that the parameters of texture declined uniformly as peaches ripened. Thus, for measuring peach maturity and quality, any one of these methods can be considered adequate. The same conclusion was reported in a texture study on pears (Bourne, 1968).

Harker *et al.* (2002) studied the correlation between puncture, tensile strength, twist, and Kramer shear tests with trained panelists in apples. Their objective was to match the point at which panelists could detect a textural difference associated with a minimum instrumental difference. They found that an average firmness change of 6 Newtons (N) of force was necessary before trained panelists could detect a textural difference in firmness. In addition, the author suggested human subjects were the best indicator for quality over instrumental testing due to the complex nature of measuring texture.

In fruit and vegetables, empirical tests, those which are verifiable by observation, are most common and measure puncture, compression, extrusion, and shear (Szczesniak et al., 1963). Puncture and compression are considered the most common texture evaluation method

(Barnett et al., 2010). Puncture measures the "force and/or deformation to push a probe into a food product to a depth that causes irreversible damage." In the horticulture community, puncture has been the simple and convenient method in field and laboratory settings.

Compression measures three major points, when measurements are expressed in two bites. The effects are shown in Figure 2.1 in which brittleness represents the peak height in which the force rises steadily, followed by a major break in tissue. The tissue continues to flatten as the downward stroke of the compression plate continues, this requires increasing force and the highest peak is measured as hardness. In the second compression, the same downward stroke is performed with the area of the second peak indicating elasticity (Bourne, 1968). When comparing these methods to human perception, puncture measures the forces required to break intact tissues while compression measures the hardness of the peach flesh. Kramer-Shear measures the "maximum force required to shear a unit weight of a product," which involves combinations of compression, shear, extrusion, and friction forces with 'shear' representing the combination of these forces (Ahmed *et al*., 1972; Szczesniak *et al*., 1970). Kramer, compression, and blade extrusion measurements in fresh and canned clingstone peaches reported good correlation with sensory texture attributes (Schweingruber, 1981).

Texture parameters are effectively measured using instrumental methods (Barnett *et al*., 2010). In peaches, focus has been placed on understanding chilling injury, a textural disorder that negatively influences the perception of peach quality. Chilling injury causes mealiness, a dry, grainy sensation on the tongue and palate similar to that of applesauce (Belisle *et al*., 2017); it typically occurs in melting freestone cultivars (Peace *et al*., 2005). It is classified as internal breakdown in the fruit flesh and typically occurs at 2-5°C within 1 or 2 weeks and at 3 or more weeks when stored at 0°C (Lurie and Crisosto, 2005). Storing peach fruit at -1 to 0°C can avoid chilling injury symptoms (Crisosto and Valero, 2008; Lill *et al*., 1989; Thompson *et al*., 1998).

Texture is composed of a wide range of properties which are affected by turgor pressure, cell wall composition, and organelles and biochemical constituents (Sams, 1999). When affected, these traits can modify textures leading to changes in its perceived quality. Recent studies have evaluated the textural properties of peaches after application of chemicals in an attempt to prolong shelf-life (Serrano *et al*., 2004). Ca^{2+} (0.100 mM) has been studied for its effect on delaying senescence and delaying membrane lipid catabolic processes in apples, carrots, and peaches when applied as spray to trees (Legge *et al*., 1982; Picchioni *et al*., 1996, 1998; Serrano *et al*., 2004). Ca^{2+} was previously reported to reduce fruit softening and to slow cell wall hydrolysis (Eklund *et al*., 1990; Conway *et al*., 1997). When combined together, Ca^{2+}, Mg^{2+} (0.103 mM), and Ti^{4+} (0.042 mM) were shown to improve firmness of peaches at harvest while continuing fruit maturation (Serrano *et al*., 2004); additionally, peaches were able to be stored 14 d longer than control fruits with higher pulp firmness and lower levels of weight, color evolution, SSC:TTA ratio, and ethylene production in treated fruits. Texture properties in peaches are malleable and have the potential to positively or negatively influence the quality perceived.

Color

In the market, appearance is equally important to other quality characteristics. Consumers use appearance and aroma as the initial indicators for purchase, although repeat purchases are due to flavor and texture perceptions over appearance (Baldwin, 2002; Bruhn, 1995; Bruhn *et al*., 1991; Delgado *et al*., 2013; Diehl *et al*., 2013). Additionally, Parker *et al.* (1991) linked appearance (size, shape, color, and number of defects) to the perception of sweetness, juiciness, texture, and flavor by consumers. Although internal quality is not clearly associated with appearance of peaches, the perception of internal quality is often initially marked by the peach's appearance. This stresses the importance of appearance as a quality attribute in attaining consumer approval. Appearance attributes are influenced by cultivar type, maturity, time of harvest, growth environment, and postharvest practices, therefore these quality characteristics are a tremendous concern in the peach industry.

When peach fruit are harvested, workers evaluate flesh and ground color along with firmness to determine fruit maturity (Crisosto and Valero, 2008). Ground color is referred to as the undertone green/yellow color developed on peach skin, often covered with a darker red/orange hue as the fruit ripen. Methods to measure the ground color have been established using the Hunter tristimulus 'a' value, which is representative of redness with a higher value (Delwiche and Baumgardner, 1983, 1985; Kader *et al*., 1982; Rood, 1957). As fruit mature, ground color of skin will darken and a red hue will develop on the peach fruit. The compounds credited for pigmentation in plants are chlorophylls (green) and carotenoids (yellow, orange, and red), both fat soluble compounds; in addition, with anthocyanins (red, blue), flavonoids (yellow), and betalains (red), which are water soluble compounds (Barrett *et al*., 2010). In peaches, the blush pigmentation, or red pigmentation, is due to an accumulation of anthocyanins. These compounds are noted for their color along with their health, nutrient, and flavor attributes (Balasundram *et al*., 2006; Frett *et al*., 2014; Parr and Bolwell, 2000; Sun *et al*., 2002). The pattern and extent of the peach blush developed is dependent on the genotype and light available within the tree canopy (Frett *et al*., 2014; Layne *et al*., 2001).

Instrumental methods for measuring color have utilized the science of receptors in the human eye. In the back of the retina there are rods, which function at low light levels, and cones, which function at higher light levels (Leggett, 2004). Within the cones, receptors sense light at different wavelengths: long wavelengths impart red color, medium wavelengths impart green, and short wavelengths impart blue. The sensed wavelengths are integrated to allow us to perceive color (Barrett *et al*., 2010). In instrumental evaluations of peaches, tristimulus colorimeters are used to simulate the red, blue, and green receptors within the human eye (HunterLab, 1995). Values are measured as L*, a*, and b*. L* represents the lightness with 0 for perfect black and 100 for perfect white (HunterLab, 1996; Leggett, 2004). The a* axis is constituted by positive and negative values representing red and green, respectively. The b* axis considers positive values as yellow and negative values as blue. In peach fruit, negative a* values (green) and positive a* values (red) are the most critical measurements in understanding quality instrumentally (Byrne *et al*., 1991). Previous research has used a* as the indicator for maturity of peaches (Byrne *et al*., 1991; Delwiche and Baumgardner, 1983, 1985; Kader *et al*., 1982; Rood, 1957).

There is controversy between measuring colors instrumentally versus using analytical sensory methods. Instrumental measurements are more precise and are able to measure small differences in color. These instruments are portable and relatively easy to use. However, equipment may be expensive and the method of evaluation can take longer than with sensory (Barrett *et al*., 2010). Sensory evaluation for color is often difficult to measure in a universal setting, as colorimeters allows. This is due to the need for color charts or disks to be standardized before sensory evaluation can take place. The likeliness of differences in human perception is also evident along with human error (Barrett *et al*., 2010).

Size, shape, and color development in peaches is not only a concern for the postharvest retail market, but it is also studied in growth and pre-harvest. For instance, size, shape, and color are dependent on the environment and the peach's genetic composition (Layne *et al*., 2001; Wert *et al*., 2007). In one study, high average temperatures at night during fruit set affected fruit development and were linked to a more elongated fruit, while lower average temperature conditions at night fruit set produce a rounder fruit. This is also true for other fruit, such as grapefruit, oranges, lemons, and peppers (Wert *et al*., 2007).

Volatiles

Volatile compounds eliciting aroma are becoming a key component on quality evaluations in fruit. They are able to influence the aroma and flavor perception of a product. In peaches, compounds eliciting peach aroma and imparting flavor have been studied extensively. Sevenants and Jennings (1966) reported peach aroma to be a response of multiple volatile compounds incorporating. Lactones (γ- and δ- decalactone and γ- and δ- dodecalactone) have been reported to represent the major influence of peach aroma in many studies (Broderick, 1966, 1975; Sevenants and Jennings, 1964, 1966, 1971; Do et al., 1969; Visai and Vanoli, 1997).

With over 100 volatiles identified, the major volatiles in peaches include aldehydes, alcohols, esters, lactones, and norisoprenoids (Xi et al., 2014). Detection thresholds of volatiles differ between compounds. The thresholds vary between cultivars and maturity stages and can vary from a few ppb to several ppm (Visai and Vanoli, 1997). Peach aroma is a response to a series of compounds rather than one or several volatile compounds (Sevenants and Jennings, 1966).

SENSORY EVALUATION OF PEACH QUALITY

Sensory studies can be effective in defining fruit quality and differentiating attributes of peach varieties (Colaric et al., 2005). Two main components constitute sensory evaluation: analytical testing and affective testing (Institute of Food Technologists, 1981). Analytical measurements are collected from a small group of trained panelists and are used to detect differences or describe a product. Affective measurements are used to determine preferences between or among samples and use a large number of untrained panelists. These methods are presented in a manner in which to "evoke, measure, analyze, and interpret those responses to products as perceived through the senses of sight, smell, touch, taste, and hearing", as defined by Stone and Sidel (2004). Procedures for each test are implemented for precision, accuracy, sensitivity, and to avoid false positives (Meiselman, 1993).

Descriptive analysis studies

Descriptive analysis starts with developing a ballot in which to rate products. This ballot is developed from a lexicon containing terms, definitions, and references. Lexicons are widely used to describe a product, compare products, and in comparing consumer preferences and instrumental data (Drake and Civille 2003). A lexicon is a standardized sensory vocabulary that consists of terms, definitions, and references that allow individual attributes to be quantified (Lawless *et al*., 2013). The descriptors developed for a lexicon can be as few as five and up to 50 (Barrett *et al*., 2010). In horticulture, produce lexicons have been established for apples (Vara-Ubol *et al*., 2006), green leafy vegetables (Talavera-Bianchi *et al*., 2010), mangoes (Suwonsichon *et al*., 2012), pomelo fruit (Rosales and Suwonsichon, 2015), and tomatoes (Hongsoongnern and Chambers IV, 2008). Typically, a broad range of samples is desired to represent the potential variation within a product so that major and minor attributes can be established. Once the lexicon has been selected, the trained panelists calibrate themselves with the references. This is to ensure the results are consistent and accurate. After training, sample evaluation is individually recorded in separated sensory booths. Inaccuracy is possible in panelists with a lack of sensitivity and/or a lack of training.

A set of descriptors was developed for the texture attributes of melting and non-melting peaches and nectarines by Contador *et al.* (2014). Terms included 'crispness', 'crunchiness', 'melting', 'juiciness', and 'hardness'. In evaluating samples, the author found that 'melting' (the degree to which samples disintegrate in the mouth), was negatively correlated with 'hardness' (the force to compress sample between molars). 'Hardness' was in turn correlated with 'crispness' and 'fracturability'. Overall, non-melting flesh had higher scores in 'crispness', 'hardness', and 'crunchiness' compared to melting cultivars (Contador *et al*., 2014). In peaches, a comprehensive lexicon for flavors has not been established. Instead, for flavor (aroma and tastes) general terms of 'sweetness', 'sourness', 'peach flavor', and 'peach aroma' have been recognized to report flavor characteristics (Crisosto et al., 2006b). The information available on peach flavor is quite limited due to the conventional use of soluble solids content and titratable acidity as indicators of sweetness and sour/tartness, respectively (Colaric et al., 2005).

Consumer studies

Sensory evaluations have an advantageous appeal in research. Sensory can show the direct evaluation of what consumers like and dislike in a product using affective testing. In fact, utilizing consumer studies are sought as a more effective method than any type of instrumental method in understanding consumer behavior (Bett, 2002; Delgado *et al*., 2013; Harker *et al*., 2008; Saftner *et al*., 2008). Since human perception is the character component of sensory evaluation, features of a product can be defined by their "quality" in terms of consumer acceptance. Affective sensory testing is the only method that can do this. Sensory tests are key in setting limits on consumer acceptability in quality testing (Kemp *et al*., 2009).

The most common influences of quality in fresh fruit have been recognized as taste, aroma, firmness, and appearance (Bruhn *et al*., 1991; Bruhn, 1995; Colaric *et al*., 2005; Delgado *et al*., 2013). Multiple studies have reported consumer preference in peaches. Hayama *et al.* (2008) reported high consumer preference to soft textured, melting flesh cultivars. Cuquel *et al.* (2012) reported that consumers prefer sweet, soft, and juicy fruits. In a consumer survey by Olmstead *et al.* (2015) consumers were reported to rate an "ideal" peach as one with sweet, juicy, round, and freestone to semi-freestone characteristics. According to consumer studies, it appears that texture is the most influential quality parameter in the acceptance or rejection of food (Szczesniak, 2002), more so than the influence of aromatic properties on fresh fruits (Abbott, 1999). This is not to say that appearance, aroma, and flavor are not influential attributes. The claim of textures impact on quality is supported with Olmstead's study in which consumers were less likely to purchase fruit with mealy, dry, or meaty textures. It is important to note that consumer preferences differ by age and ethnic group (Olmstead *et al*., 2015).

COMBINING INSTRUMENTAL AND SENSORY ANALYSES

The measurements of SSC and TTA have been the standard elements used in studies of peach fruit quality. According to Crisosto *et al.* (2006), SSC and TTA are dependent on the cultivar (Ravaglia *et al*., 1996; Ventura *et al*., 2000), environment, fruit position in the canopy (Crisosto *et al*., 1997), crop load, maturity (Crisosto *et al*., 1997; Testoni 1995), and rootstocks.

Research has focused more on quality of peaches and their evaluation since the mid-1990s due to the lack of information about consumer acceptance and quality composition of peaches and other *Prunus* species fruit (Claypool, 1977; Crisosto *et al*., 1997; Mitchel *et al*., 1990). Although SSC was being studied for its association with consumer acceptance in many fruits (Crisosto *et al*., 1997; Parker *et al*., 1991), little information was available earlier to develop any quality standards (Crisosto, 1994). Lack of information on TTA, SSC/TTA ratio, and flavor compounds and intensities were of concern for understanding consumer acceptance in more depth. Such analyses are necessary to develop comprehensive quality standards that researchers, growers, and marketers can use.

In other fruits, this has already been studied. Harker *et al.* (2008) assessed consumer acceptance of popular apple varieties. In their study, SSC, TTA, puncture tests, and pH were evaluated to test if the appropriate quality standards are set for apples and if these quality parameters are useful in determining quality consumer acceptance. They found highest consumer acceptance related to firmness. SSC and TTA were found to influence quality for specific cultivars. Firm apples were more accepted with increased SSC, while soft apples with high SSC were rejected by consumers.

In blueberries, Saftner *et al.* (2008) evaluated the sensory and instrumental characteristics of 12 cultivars grown in the northeastern U.S. They looked at the consumer preferences, and at the sensory and instrumental quality characteristics impacting acceptability of consumers. Color, fruit weight, firmness (compression), SSC, TTA, SSC:TTA ratio, pH, and volatile concentrations, were all evaluated for comparison with consumer data using sensory analysis. In consumer testing, overall flavor and blueberry flavor intensity were correlated highest with overall liking. Texture and visual characteristics contributed to overall liking as well. Unfortunately, the instrumental measurements were not able to predict acceptability accurately. It should be noted that intensity can be predicted by instrumental measurements, but acceptability cannot. Research may now focus on rating/developing intensity quality standards for flavor, since that was the major contribution to overall liking.

In peaches, the major classification of differences has been for 'melting' and 'non-melting' cultivars along with yellow, white, and red flesh types; round, flat, or beaked shape; pubescent or smooth skin; freestone or clingstone; and sweet, sour, or astringency. While non-melting has been bred initially for the canning market, more current breeding programs have focused on its quality for the fresh market (Brovelli *et al*., 1999). Thus, assessing and understanding the differences and acceptability of fresh market peaches is crucial between melting and non-melting varieties because of their noticeable texture differences. Brovelli *et al.* (1999) studied non-melting and melting flesh differences in regards to instrumental and descriptive analyses. SSC, TTA, pH, and fruit diameter/size were evaluated in the same set of peaches evaluated by a set of trained panelists. Texturally, non-melting fruit were "harder", "less juicy", and "more rubbery" than melting fruit. Additionally, some variability within flesh types can be expected. No differences were noted on flavor between the two different melting and non-melting peach flesh types.

In a study by Colaric *et al.* (2005), nine peach and nectarine cultivars were evaluated for sensory and chemical quality characteristics. Individual sugars and acids were evaluated. Data was compared with trained panelists to assess potential correlations. Sweetness, taste, and aroma were most correlated with chemical measurements. Citric acid, shikimic acid, and total sugars/organic acids ratio were influential for perceived sweetness. In aroma perception, correlations were found with total organic acids, sucrose, sorbitol, and malic acid. Lastly, taste was associated with malic/citric acid ratio, total sugars, sucrose, sorbitol, and malic acid. Although this approach to studying peach quality may be beneficial, more comprehensive studies need to be performed to assess the causation of such links between sensory and instrumental attributes.

In the same year Crisosto *et al.* (2005) looked at the relationship of SSC on peaches with low and high acidity as related to consumer acceptance. The hypothesis was that high SSC was associated with high consumer acceptance (Parker *et al*., 1991; Ravaglia *et al*., 1966). This claim was supported by Crisosto *et al.* (2005). Furthermore, a higher degree of liking was associated with SSC, while it was not associated with TTA in the low and high acidity varieties. Overall, they found that the ideal SSC is cultivar dependent. Additionally, Crisosto *et al.* (2005) proposed that quality characteristics (sweetness, sourness, flavor intensity, aroma intensity and texture) be determined for cultivars in hopes that the combined information can give understanding in developing a minimum quality index. From an in-store consumer study, Crisosto *et al.* (2006) reported that peaches and nectarines with prevalent flavor and aroma had consumer acceptance at a higher rate than standard peaches by 10%.

While SSC and TTAs impact on quality have been evaluated, the impact of volatile concentrations and textural properties has not been studied. Echeverria *et al.* (2012) looked at the influence of volatile emissions on consumer acceptance in peaches and nectarines. While taste is related to the water soluble compounds, aroma is produced by the emission of volatile or gaseous compounds. This study found that of the 43 volatiles identified in peaches and nectarines, five to nine of the compounds contributed to the majority of volatile total content in a variety (60%). Additionally, gamma-dodecalactone, 1-pentanol, butyl octanoate, pentyl acetate, 2-methylpropyl hexanoate, and ethyl octanoate were the compounds associated with higher acceptance scores. Volatiles reported in this study included terpene, aldehyde, ester, alcohol, acid, and ketone chemical classes.

In textures, the methods for instrumentally evaluating peach fruit were established by Bourne (1974): puncture, modified texture profile, compression coefficient, and shear coefficient. As the goal to understand parameters of peach quality continues, Contador *et al.* (2014) utilized sensory analysis by developing a set of texture terms, definitions, and references to characterize peaches. Descriptors of 'hardness', 'juiciness', 'melting', 'crispness', and 'crunchiness' were developed to describe textural properties of peaches and nectarines.

Delgado et al. (2013) evaluated the consumer acceptance of peaches and nectarines in association with their instrumental quality. Association between descriptive analyses, consumer testing, and instrumental evaluation were used to provide comprehensive quality analyses. This evaluation method has been useful in apples (Daillant-Spinnler *et al*., 1996; Kühn and Thybo 2001; Harker *et al*., 2002, 2003, 2008; Oraguzie *et al*., 2009), tomatoes (Causse *et al*., 2010; Lee *et al*., 1999; Sinesio *et al*., 2010), and strawberries (Ares *et al*., 2009). Flesh firmness, SSC, and TTA were evaluated in a study by Delgado *et al.* (2013) on peaches and results compared with descriptive and consumer testing. They found that overall liking increased significantly from 'like slightly' to 'like moderately' (on a 9-point hedonic scale from dislike extremely to like extremely) as SSC increased from 10% to 14%. The relationship with TTA and overall liking was not significant, but the author suggested that the cultivars with high acidity might be less preferred. TTA values ranged from 0.21 to 0.77% in the study, parameters for high acidity were not discussed. In peaches with predominant flavor and high SSC, liking and acceptance were at 91%, while those with predominant flavor and medium acidity with a low SSC ($< 9\%$) had a low level of acceptance. The author concluded that consumers liking increased in peaches with high flavor and SSC $\geq 9\%$, while peaches with medium acidity plateaued above a SSC of 9%. This work supported the importance of understanding flavor characteristics in fresh peach quality. In addition, Delgado *et al.* (2013) clustered consumer peach preferences into three groups, with one driven mainly by aromas, another by sourness and sweetness, and the last by sweetness.

Sensory evaluations are effective at predicting consumer behavior, however these methods are often expensive and not practical for every fruit quality evaluation. By utilizing sensory and instrumental techniques and comparing findings as a unit, information on quality can be understood more practically. This approach benefits those interested in interpreting quality and selecting for and/or improving varieties based on their sensorial properties and their impact on the fruit.

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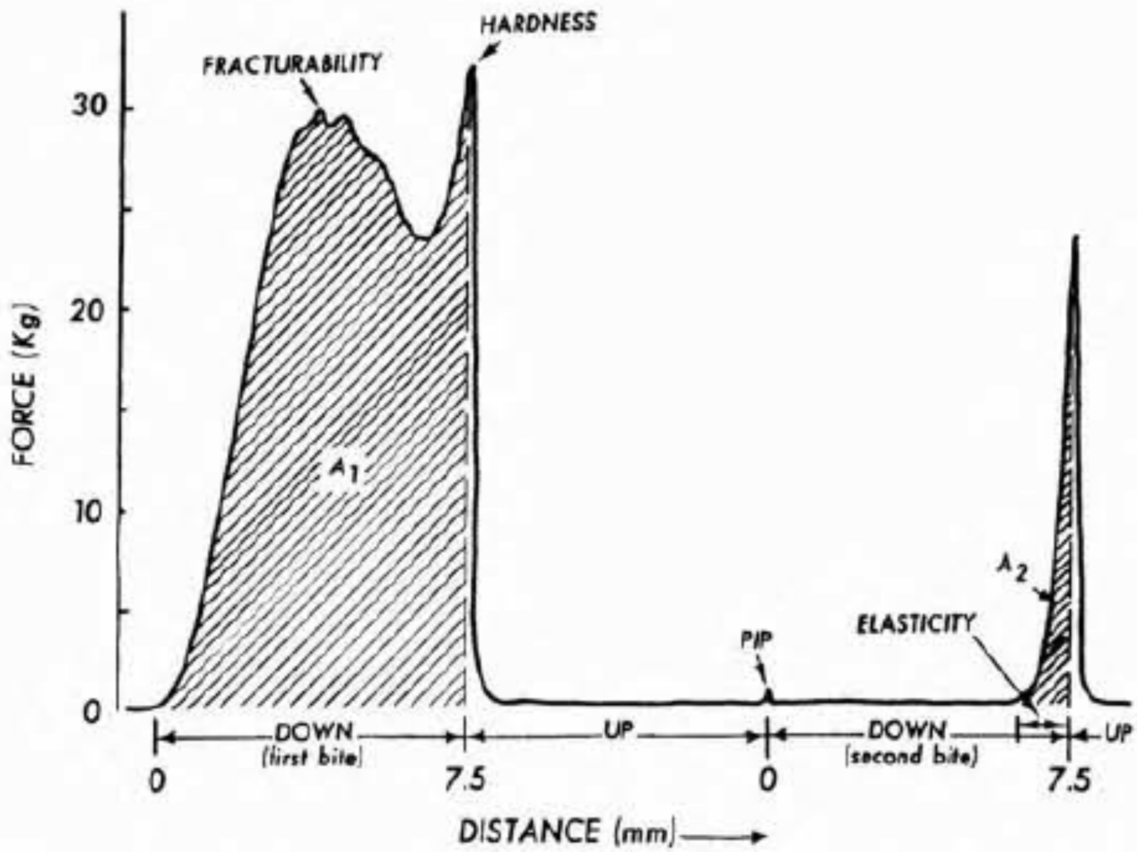

Fig. 1. Typical force-distance curve for GF Texture Profile on clingstone peach.

FIG 2.1: TYPICAL FORCE-DISTANCE CURVE FOR GF TEXTURE PROFILE ON CLINGSTONE PEACH (BOURNE, 1974)

CHAPTER 3

DEVELOPMENT OF A LEXICON FOR FLAVOR AND TEXTURE OF FRESH PEACH CULTIVARS[1]

[1]Belisle, C.E., Adhikari, K., Chavez, D.J., and Phan, U.T.X. Submitted for review in *Journal of Sensory Science*

ABSTRACT

A universal lexicon to describe the appearance, aroma/flavors, and textures/feeling factors of peaches was developed. The objective was to provide a standardized lexicon for descriptive validation. A trained descriptive panel established twenty-nine attributes using 51 peach cultivars grown throughout the production season. This lexicon includes eighteen aroma and flavor attributes to describe mature peaches as well as under-ripe and over-ripe, redness of flesh for appearance, three feeling factors, and seven terms for describing textures. Principal component analysis was used to discern if differences were found among peach samples using the lexicon terms utilized by trained panelists. Texture was the primary differentiating factor in the first dimension of the biplot followed by peach-identity in the second dimension. Additionally, the attributes ‘peach-identity’, ‘fruity’, ‘sweet’, ‘tart’, ‘citrus’, ‘sour’, along with textures and feeling factors were prominent in all peach varieties.

PRACTICAL APPLICATIONS

The assessment of peach fruit varieties grown throughout the southeastern U.S. would create a basis for understanding the prominent and unique characteristics of peach varieties and their inherited variability. The peach lexicon created in this study will provide a platform for researchers and producers to understand the desirable sensory traits in peaches. It will allow comparisons among varieties currently available, create a database to be used in breeding applications, and help the growers to produce peaches with desirable sensory traits that could be commercially successful.

INTRODUCTION

In the southeastern U.S., more than 40 to 60 varieties of peaches are grown commercially with only one to three weeks of marketable fruit available per variety. Variation in fruit quality attributes (appearance, aroma and flavor, and texture) are expected due to the variation in the genetic makeup among varieties and also differences created by environmental factors during fruit development. A decline in the per capita consumption of peaches from 2.4kg in 1995 to 1.3kg in 2015 (USDA, ERS, 2016) can be attributed to the dissatisfaction of the consumer with the fruit currently available. The sensory characteristics of fruits, including peaches are of utmost importance for successful marketing. Therefore, it is very important to understand the sensory characteristics of peaches. The variability in sensory characteristics for peach is not well documented except for some studies describing the flavor and texture of peaches (Contador *et al.*, 2014; Crisosto *et al.*, 2006).

A lexicon is a standardized sensory vocabulary that consists of terms, definitions, and references that allow individual attributes to be quantified (Lawless and Civille, 2013). Lexicons are widely used for descriptive tests to describe a product, compare products, and to relate consumer liking and instrumental data to descriptive data (Drake and Civille, 2003). Lexicons have been established for many food products including fruits and vegetables. Some examples are: apples (Vara-Ubol *et al*., 2006), green leafy vegetables (Talavera-Bianchi *et al*., 2010), mangoes (Suwonsichon *et al*., 2012), pomelo fruit (Rosales and Suwonsichon, 2015), and tomatoes (Hongsoongnern and Chambers IV, 2008). However, no such vocabulary has been established for fresh peaches.

In general, aroma and flavor attributes lack terms of description in peaches. In regards to flavor descriptors, Crisosto *et al.* (2006) evaluated the perception of ‘sweetness’, ‘sourness’, and ‘peach flavor’ along with ‘peach aroma’. It is believed that the information available on peach flavor is limited due to a history of using soluble sugars and titratable acidity as indicators of sweetness and sour/tartness, respectively (Colaric *et al.*, 2005; Esti *et al.*, 1997). However, acids, sugars, and aromatic compounds have been reported for their influence on flavor quality of peaches (Crisosto and Costa, 2008). Other fruits, such as mango, have a lexicon with flavor attributes unique to certain cultivars and attributes characteristic to mango fruit (Suwonsichon *et al.*, 2012). Additionally, Koppel and Chambers (2010) described flavors of pomegranate juices as reminiscent of a combination of flavors in their lexicon. This information on peaches has not yet been reported in such depth.

In textural descriptive studies, Contador *et al.* (2014) developed a set of texture terms for describing the melting and non-melting characteristics of peaches and nectarines. These include ‘crispness’, ‘crunchiness’, ‘melting’, ‘juiciness’, and ‘hardness’. The authors found that non-melting flesh cultivars had higher intensities in ‘crispness’, ‘hardness’, and ‘crunchiness’ compared to melting cultivars. A study by Brovelli *et al.* (1999) used terms of ‘hardness’, juiciness’, and ‘rubberiness’ to describe peach textures of melting and non-melting varieties. Fresh peach fruit are primarily differentiated by their ability to ‘melt’ in the consumer’s mouth. This is due to the breakdown of pectin in the cell walls. The enzyme responsible for cleaving pectins and loosening the peach cell wall, endopolygalacturonase (EPG), causes the fruit flesh to have more liquid dispersed, thus resulting in a free flowing, ‘melting’ characteristic (Brovelli *et al.*, 1999). Conversely, ‘non-melting’ does not have this attribute. Non-melting peaches do not contain EPG and thus breakdown or ‘melting’ of cell walls does not occur (Brummell *et al.*, 2004; Lester *et al.*, 1996). Growers, marketers, and consumers label these textural differences as ‘melting’ and ‘non-melting’ of peaches. Researchers have recently stressed the importance of quality in peaches with an influence on flavor and appearance as well as texture attributes.

The demand for a higher peach fruit quality stresses the necessity for terminology to describe sensory attributes. The use of a lexicon can provide in depth understanding of flavor and texture characteristics of peaches. Therefore, the objective of this study was to develop a universal peach lexicon that can be used for future research to address this need.

MATERIALS AND METHODS

Lexicon Development

Peach Samples. A wide selection of 51 peach cultivars (Table 1) were evaluated from May through August in 2015, representing the main peach season in the southeastern United States. Fruits were harvested at commercial maturity and packed by a commercial grower in Fort Valley, Georgia, following standard procedures. Commercial maturity was determined by the development of redness on peach skin and firmness of fruit, both of which change along with sweetness and aroma development (Ramina *et al.*, 2008). Peaches were stored in commercial packaging boxes at 7 to 10 C. Additional varieties were hand harvested in experimental orchards from the same commercial grower to discover potentially unique characteristics. These were older commercial varieties that were once produced commercially and make up 10 of the 51 varieties. Among the 48 peach varieties and 3 nectarine varieties selected, 33 were melting and 18 non-melting flesh varieties; 20 were clingstone, three semi-clingstone, six semi-freestone, and 22 freestone. Additionally, 47 were yellow-fleshed and four white-fleshed; 41 varieties had standard acidity and 10 low acidity/honey (Table 1). Packed fruits were transported to the University of Georgia’s Pilot Plant, Griffin, Georgia for analyses.

Sample Storage and Preparation. Upon arrival at the research location, the samples were stored in a walk-in cooler at 4 C for three to five days. Prior to evaluation, samples were transferred to room temperature (22 C) for two to three days for ripening. This step followed commercial practices to ensure a standardized ripening procedure prior to evaluation. Approximately five varieties were evaluated per week from May through August 2015. Immediately prior to evaluation, samples were gently washed with lukewarm water to remove wax coating applied in packing. This process was gently performed to avoid damaging or bruising the fruits.

Lexicon Development Protocol. The protocol was adapted from methods by Drake and Civille (2003) and Lawless and Civille (2013), and was approved by the University of Georgia's Institutional Review Board (STUDY00002124).

Six trained panelists at the UGA Sensory Evaluation & Consumer Lab on the Griffin campus were selected to participate in the study. Each panelist had at least 120 hours of general descriptive analysis training and had a minimum of 1200 hours of descriptive sensory testing, including fresh produce. Ten 3-hour sessions were conducted to establish attributes, definitions, and reference standards for the lexicon. Published terms from previous fresh fruit lexicons were provided to the panelists as a reference for lexicon development. Such studies included apples (Vara-Ubol *et al.*, 2006), mangoes (Suwonsichon *et al.*, 2012), pomelo fruit (Rosales and Suwonsichon, 2015), and texture attributes developed for peach and nectarine descriptive analysis (Contador *et al.*, 2014). Modalities included appearance, aroma/flavors, textures, and feeling factors. Panelists set rated intensities on a 150-mm unstructured line scale. The scale ranged from 0, representing no presence, to 150 representing extremely high presence. All terms and references were agreed in consensus with the panelists.

The panelists each received a whole fruit and five slices of fruit, each slice from a different fruit. All the samples were coded with 3-digit random numbers. The panelists first evaluated the samples individually and recorded the attributes that they detected. They were instructed to cleanse with unsalted crackers and deionized water between samples. The panel leader then led the group discussion to reach a consensus on the final list of descriptors. Once the agreement was reached, definitions and reference standards were established for each attribute. Throughout the peach season, the developed list of attributes was continuously refined to reduce redundant and unnecessary terms.

Evaluation Technique. The panelists evaluated the samples in the order of appearance, aroma, flavor, texture, and feeling factor. For aroma evaluation, the panelists were asked to sniff the circumference of the whole peach and a cluster of sliced peaches to evaluate the intensity. Aroma attributes of whole and sliced samples were evaluated separately. Panelists were instructed to re-sniff if needed. For flavor and texture, panelists evaluated sliced samples using multiple bites from multiple slices as needed. After samples were evaluated and terms were discussed with the panelists, definitions and references were established.

Validating the Lexicon

Peach Sample, Storage, and Preparation. Fruit collection and sample preparation followed the same procedure used in the lexicon development, as described above. For lexicon validation, eight melting cultivars and three non-melting cultivars (11 total) were selected and evaluated in the 2016 season (Table 2). Commercial cultivars were obtained from the same commercial grower from Fort Valley, GA.

Procedure. Lexicon validation was performed using descriptive analysis to determine how effectively the lexicon was at capturing the differences and diversities in sensory characteristics among the 11 peach samples. Seven trained panelists were used in this phase. Four of these seven panelists have previously participated in the lexicon development. The panelists were first provided with the lexicon to familiarize themselves with the terms, definitions, and references. During two two-hour sessions, the panelists underwent training and orientation of the lexicon. In the two-hour sessions, panelists evaluated two commercial and two experimental varieties that were at the sufficient maturity stage for consumption. This allowed panelists to become familiar with its attributes and to highlight to any needed adjustments on the lexicon during the practice phase.

Validation of the lexicon took place over a three-week period with nine 2-hour sessions (May 25 to June 9, 2016), three sessions per week. In the first session of each week, the panelists collectively underwent training and orientation with that week's fruit using the developed reference. On the second and third sessions each week, the panelists evaluated the blind samples individually in separate booths under white light. Each cultivar was presented to the panelists three times within two sessions. Each sample consisted of five slices and a whole fruit. To account for fruit to fruit variation, the five slices were taken from different fruits. Depending on availability, three to four varieties were evaluated per week, with 4 varieties the first and third week and 3 varieties the second week. The data was collected on Compusense *five* ver. 5.6 (Compusense Inc., Guelph, Canada).

Data Analysis. Principal Component Analysis (PCA) was done on the data using XLSTAT (ver. 2016.03; Addinsoft, New York, NY) to find out if the lexicon was effective in differentiating the various varieties.

Analysis of variance with panelist and replicate as random effects were performed using PROCEDURE GLIMMIX (SAS 9.4; SAS Institute, Cary, NC) on the data. Post-hoc mean separation using Tukey HSD was also carried out on the data set. All univariate analyses were done at 5% level of significance.

RESULTS AND DISCUSSION

Lexicon Development

From evaluating 51 peach varieties throughout the peach season, 47 terms were initially recorded as the sensory attributes of fresh peaches (Table 3). After multiple reviews with the trained panelists, redundant terms were eliminated. For instance, green and viney were established and later combined to capture the aroma and flavor of under-ripe fruits. In a lexicon for leafy greens by Talavera-Bianchi et al. (2010), multiple attributes for ‘green’ were established because of the complexity of that attribute in leafy vegetables, whereas in this lexicon more specific characterization of green is not needed and therefore was considered redundant. Another example is the ‘acidic’ and ‘orange’ characteristics in aromas and flavors combined to represent ‘citrus.’ The similarities in aroma and taste entailed in ‘acidic’, ‘orange’, and ‘citrus’ caused confusion among the panelists during evaluation, thus the terms were combined.

Four appearance attributes were initially established for internal and external appearance. External appearance (redness of skin) was removed because it was not able to be characterized accurately with the wide variation of skin color found within peaches. Peaches can vary in the percentage of their external appearance greatly between and within varieties. Internal appearance of redness in peach was the only color measured due to its interest by industry and consumers (Werner *et al.* 1998), largely due to the association of health benefits in fruits with greater redness accumulation, very commonly linked to anthocyanin accumulation.

In aromas and flavors, ‘peach identity’ was the attribute developed to capture the characteristic element of a peach. References were developed from flavor formulations to capture the simplest and most characteristic peach aroma possible. Commonly marketed peach essence products containing peach aroma were not able to represent ‘peach-identity’ effectively. Sensient (Sensient Technologies Corporation, Milwaukee, WI), a flavor company, supplied several powdered and liquid samples of peach aroma and flavor. In those, their WONF 1543 SN2000019614 was diluted with water containing sugar and citric acid and utilized for a ‘musty’ reference and low-intensity ‘peach-identity’ reference. Sensient’s Clingstone Peach WONF SN2000019615 was also diluted with water containing sugar and citric acid and was used for high and moderate intensity references for ‘peach-identity’, entitled Peach Essence (PE) and Peach Essence 2 (PE2), respectively. Multiple dilutions were tested until panelists agreed upon an effective intensity, aroma, and flavor. It should be noted here that the aroma attributes can be utilized to evaluate both whole fruits and sliced fruits. Literature previously available on peach aroma and flavors is limited to a study on the overall intensity of peach aroma and peach flavor by Crisosto *et al.* (2006). Multiple researchers have studied the chemistry of the impact odorants responsible for ‘peach-identity’ and have associated the characteristic of peach with lactone compounds (Broderick, 1966, 1975; Do *et al.*, 1969; Sevenants and Jennings, 1964, 1966, 1971; Visai and Vanoli, 1997). However, information defining or referencing peach aroma for sensory use was not available until this study.

Fruity and floral characteristics were established as prominent aromas/flavors in peach. Fruity was characterized to represent an association of a blend of multiple fruits independently from ‘peach-identity.’ In addition, a sweet, light aroma associated with flowers was perceived in nectarines and white flesh peaches during lexicon development. The character aroma this presented is represented as ‘floral.’ Many researchers have identified the chemical compounds representative of fruity and floral characteristics and have noted their prominence in peach fruit (Bacvonkralj *et al.*, 2014; Kakiuchi and Ohmiya, 1991; Sumitani *et al.*, 1994; Visai and Vanoli, 1997). In addition, ‘apple,’ ‘apricot’, ‘cherry’, and ‘nectarine’ were selected to represent distinct aromas while other attributes were removed or combined due to potentially blending with other attributes. Distinct attributes were eminent in select varieties, for instance apple, which was commonly found in nectarines and white flesh peaches.

With regards to basic tastes, sweetness and sourness were prominent, followed by bitter taste. Sweet and sour tastes are reported as impact attributes in peach along with peach flavor and aroma, according to how they are perceived (Crisosto *et al.*, 2006b). While the sweetness is perceived by sugars developed, sour sensations of ‘citrus’ and ‘tart’ have been reported as products of organic acids (Sanz and Perez, 2010). To reference ‘citrus’ and ‘tart’ appropriately, ‘citrus’ definition and references focused on the acidic taste prominent in citrus fruits; whereas ‘tart’ was defined as the combination of astringent and sour flavor with Smarties candies being the appropriate reference for that sensation. Sourness was included as a basic taste and can be used in replace of ‘tart’ ‘and ‘citrus’ for general acidity evaluation.

Attributes of over-ripened peaches have been developed as ‘fermented’ and ‘musty.’ ‘Fermented’ note is the combination of ‘sweet, slightly brown, overripe, somewhat sour’, while ‘musty’ is associated with ‘rotting peach, also with roots and wet soils.’ The idea was to capture the degree of spoilage in over-ripened peaches, with ‘fermented’ capturing a lower degree compared to ‘musty.’ Therefore, these two aroma terms were maintained in the lexicon together with ‘over-ripe’ flavor.

The textural characteristics of peaches are described by seven terms, including ‘crispness’, ‘crunchiness’, ‘firmness’, ‘fibrousness’, ‘melting’, ‘juicy’, and ‘mealy.’ Texture is an important quality indicator of fresh fruit with non-melting peaches reported as harder/firmer and less juicy, while melting peaches have been associated with juiciness and melting (Brovelli *et al.*, 1999; Contador *et al.*, 2011). Generally, textures have been reported as hard/firm, juicy, and melting. Terms of ‘crispness’ and ‘crunchiness’ were added to understand the type of hardness, while ‘fibrousness’ was added to assess stringiness in flesh, often detected in melting varieties.

The final lexicon included twenty-nine attributes, including one term for appearance, 18 terms for aroma and flavor, and seven terms for texture and three terms for feeling factor. The definitions and reference standards for these terms are presented in Table 4 and preparation methods are presented in Table 5.

Lexicon Validation

Twenty descriptive terms were selected from the developed peach lexicon to evaluate the 11 peach varieties in this validation phase. These terms were chosen based on their importance in characterizing and differentiating these 11 peach varieties. Four descriptors for aroma – ‘peach identity’, ‘fruity’, ‘citrus’ and ‘sweet aromatics’ were evaluated for the whole fruits. The remaining 16 attributes, including the four aroma terms above, were evaluated in sliced peaches. Figure 1 illustrates the PCA biplot that resulted from the validation data. As shown in the map, there were visual differences among these 11 peaches and those differences were captured by the sensory attributes developed in the peach lexicon.

The first important difference was in texture, which was characterized by 4 terms: ‘firmness’, ‘melting’, ‘fibrousness’, and ‘juiciness’, in which firmness was an opposite textural property to the other three (dimension one of the biplot). This texture dimension separated the non-melting (Zee Diamond, Springflame, Springprince) from the melting (Zee Pride, Juneprince, Rubyprince, Sureprince, Goldprince, and Gala) peaches, with the exception of Carored which is a melting peach. The high firmness in Carored may be explained by its early-season harvest. In commercial production, it is not uncommon for varieties to be harvested prior to optimum maturity for consumption in order to be available on the market sooner. Since the varieties used in this study were collected following commercial harvesting and packaging procedures, it is presumable that Carored was not given sufficient time to ripen and thus was not able to display characteristics typical of melting varieties. Overall, non-melting peaches were high in 'firmness', while melting peaches were characterized by 'melting', 'fibrousness' and 'juiciness.' This trend was confirmed by the mean separation results as shown in Table 6. The non-melting varieties were firmer in general compared to the melting varieties with the exception of Carored, which as noted above was harvested early and hence was firmer in texture.

The second major difference was related to peach identity or in other words, which peach was perceived 'more peach-y' than the others (dimension two of the biplot). Springprince, Carored, Rubyprince, Zee Pride, and Juneprince appeared to have more of that identity than Fiesta Gem, Zee Diamond, Springflame, and Gala. Springprince and Carored were high in 'sweet aromatics' and 'fruity' characteristics and especially stronger than the others in 'peach aroma' when peach slices were evaluated. Zee Pride, Rubyprince, and Juneprince were strong in both peach aroma and flavor. This gain was corroborated by the mean scores for 'peach' aromas and flavor as illustrated in Table 6. For example, Rubyprince and Springprince were characterized by 'peach' aroma in the sliced fruit. The mean scores (Table 6) also shows the same trend. 'Sweet' and 'fruity' characteristics are normally developed during the ripening process of peaches (Bononi *et al.*, 2012), which suggests a high correlation among these attributes in mature peaches. On the other hand, Fiesta Gem and Gala were more ‘citrus’ and less ‘peach-y’ while Springflame and Zee Diamond were dominantly ‘astringent’, ‘sour’, and ‘tart.’ This result was consistent with the finding of Aubert *et al.* (2003) that there was negative correlation between citric acid and sugars, peach aroma compounds, and fruity aroma compounds. This is perhaps because sugars and volatiles develop as peaches are ripening, while organic acids decrease in that process.

Exploring further, the PCA map shows a strong association of sour, astringent, and tart among the varieties. Tart is recognized in the lexicon as a combination of the feeling factor astringent, which is the dry sensation produced on the mouth and or tongue, and of sour, which is the taste associated with acid solution such as citric acid. Due to the close association of these characteristics in the peach cultivars it can be inferred that ‘sour’ and ‘astringent’ may be combined to represent ‘tart’ for evaluating peach fruit. This was seen in Fiesta Gem, Zee Diamond and Springflame which were high in both ‘tart’ and ‘sour’ as seen in both the PCA biplot and mean scores (Table 6).

The findings show that the panelists were able to discern differences among peach samples using the terms developed in the peach lexicon. Some attributes were in all of the evaluated peaches (‘peach-identity’, ‘fruity’, ‘sweet’, ‘tart’, ‘citrus’, ‘sour’, along with textures and feeling factors). Other attributes such as ‘apple’, ‘apricot’, ‘cherry’, and ‘nectarine’ tend to be associated with unique characteristics found only in a few varieties.

CONCLUSIONS

A sensory vocabulary was established to describe the sensory characteristics of fresh peach varieties. These terms were carefully selected to represent attributes of mature peaches with additional focus on under-ripe and over-ripe characteristics, with twenty-nine descriptive attributes. The validation of the lexicon with 11 peach cultivars demonstrates the lexicon is effectively working and those 20 selected terms in the lexicon may represent peach varieties more so than others. This lexicon can be used for pre-, post-harvest, and commercialized peaches on a uniform scale. Lastly, although this lexicon has referenced fresh peaches, peaches that have been frozen, dried, or processed may be evaluated using terms from this lexicon. Additional terms as needed may be developed by individual researchers. In conclusion, the terms, definitions, and references of this lexicon are a platform for researchers and producers to collect and universally communicate sensory characteristics of peaches.

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TABLE 3.1. PEACH AND NECTARINE CULTIVARS USED IN DEVELOPMENT OF THE LEXICON: CHARACTERIZED BY FLESH AND CLING TYPE

Flesh texture	Flesh adherence to endocarp	Varieties
Peach cultivar		
Melting	Clingstone	Carored, Fiesta Gem, Flavorich, Goldprince, Rubyprince
	Semi-clingstone	Flordacrest, Juneprince
	Semi-freestone	Burpeach5, Caro King, Sureprince
	Freestone	All-Star, Berta, Blazeprince, Blazing Star, Crimson Rocket, Dixiland, Sierra Rich, Fireprince, Gala, Harvester, Julyprince, Junepride[3], Loring[3], Majestic, PF-23, Red Globe, Ruston Red, Scarletprince, Star Fire, Sweet-N-Up, White Lady[2,3]
Non-melting	Clingstone	AP04-08W[2], Brittney Lane, Country Sweet[3], Gulfcrimson, Gulfprince, May Sweet[3], Rich Pride, Sierra Snow[2,3], Springflame21, Springprince, Summer Gold, UFBest, UFSun, Vista, Zee Diamond
	Semi-freestone	AP08-12H[3,4], Rich Lady[3]
Nectarine cultivar		
Melting	Semi-freestone	Karla Rose[2,3]
	Freestone	AP10-03N[1,4]
Non-melting	Semi-clingstone	AP01-11N[1,3,4]

[1]Nectraine cultivars. All others are peaches.
[2]White fleshed cultivars. All others are yellow fleshed.
[3]Low acidity (sub-acid = honey). All others are standard acidity.
[4]Breeding selections from the UGA-USDA-UF South Georgia Peach Breeding Program in Attapulgus, GA.

TABLE 3.2. PEACH CULTIVARS EVALUATED IN VALIDATION OF LEXICON CHARACTERIZED BY FLESH AND CLING TYPE*

Flesh texture	Flesh adherence to endocarp	Varieties
Melting	Clingstone	Carored, Fiesta Gem, Gala, Goldprince, Rubyprince, Zee Pride
	Semi-clingstone	Juneprince
	Semi-freestone	Sureprince
Non-melting	Clingstone	Springflame21, Springprince, Zee Diamond

*All varieties are yellow flesh and standard acidity.

TABLE 3.3. LIST OF INITIAL ATTRIBUTES DEVELOPED BY DESCRIPTIVE PANEL FOR PEACH LEXICON

Attributes
Appearance
Yellow flesh color, orange flesh color, red flesh color, blush of flesh, blush of skin
Aroma/Flavor*
Cucumber, orange (f), pear (f), unripe (f), over-ripe (a), oxidized (a), viney (a), green, nectarine (f), balanced, nectar, almond, cherry, dull (a), bland (f), melon, sweet, sour, tart, peach-identity, apple (a), apricot (f), citrus, floral (a), fruity, fermented (a), musty (a)
Texture
Aged, soft, smooth, firm skin, mushy, mealy, firmness, crispness, crunchiness, fibrousness, juiciness, melting
Feeling factors
Astringent, fuzzy, toothetch

*(a) – aroma only; (f) – flavor only

TABLE 3.4. DEFINITIONS AND REFERENCES FOR FRESH PEACH ATTRIBUTES

Attribute	**Definition**	**References**
Appearance		
Redness of flesh*	Percent of overall redness within flesh of a halved peach.	10-15% Light blush = 20 70-75% Heavy blush = 110
Aroma & Flavor		
Peach identity*	Amount of peach flavor identity within the sample that is associated with whole fresh peaches.	Aroma/Flavor Sensient Clingstone Peach WONF (Musty-Peach or MP1) = 40 (a), 50 (f) Peach Essence 2 (PE2) = 90 (a), 25 (f) Sensient WONF 1543 "Peach Essence" (PE) = 130 (a), 110 (f)
Apple	Aroma associated with green apples.	Aroma Fresh Granny Smith apple = 35 (a)
Apricot	Flavor associated with apricots.	Flavor Great Value Unpeeled Canned Apricot = 60 (f)
Cherry	Sweet, fruity impression associated with cherries.	Aroma/Flavor 9% Watkins Almond extract = 40 (a) Very Cherry Jelly Belly = 45(f)
Citrus*	Flavors associated with citrus fruits such as orange, lemon, and lime.	Aroma/Flavor Sprite = 40 (a), 65 (f) 33% Watkins Orange extract = 60 (a) 50 % Watkins Orange extract = 100 (a) Simply Lemonade = 75 (f)
Floral*	A sweet, light, slightly perfumery aroma associated with flowers.	Aroma Celestial Chamomile tea = 20 Fujian Tea Import & Export Jasmine tea = 75
Fruity*	Aroma associated with a blend of fruits such as found in grapes	Aroma 50% Sparkling Ice Peach Nectarine water = 35 100% Sparkling Ice Peach Nectarine water =65 Welch's 100% White Grape juice = 90
Melon*	Aroma associated with fresh melon	Aroma Honeydew melon = 40
Nectarine	Flavors associated with nectarines.	Flavor Sparkling Ice Peach Nectarine water = 35

Sweet aromatics*	Aroma associated with sweet material such as caramels.	Aroma SweeTART candy = 40 Kraft Caramels (individually wrapped) = 90 (a)
Tart*	A combination of astringency and sour flavor in mouth.	Flavor Smarties candy (1 piece in the mouth) = 40 Smarties candy (2 pieces in the mouth) = 80 Smarties candy (3 pieces in the mouth) = 120
Green*	Impression associated with green or under-ripe fruit.	Aroma/Flavor Green banana = 60 (a), 50 (f) Fresh parsley water = 100 (a), 90 (f)
Bitter*	The taste on the tongue associated with bitter agents such as in a caffeine solution.	Flavor 0.05% (w/v) caffeine solution = 20 0.08% (w/v) caffeine solution = 50 0.15% (w/v) caffeine solution = 100
Sour*	The taste on the tongue associated with acid solutions such as citric acid.	Flavor 0.05% (w/v) citric acid solution = 20 0.08% (w/v) citric acid solution = 50 0.15% (w/v) citric acid solution = 85
Sweet*	The taste on the tongue associated with sucrose solutions.	Flavor 2% (w/v) sucrose solution = 20 5% (w/v) sucrose solution = 50 10% (w/v) sucrose solution = 100
Fermented	A combination of aromas that are sweet, slightly brown, overripe, somewhat sour and associated with fermented fruits.	Aroma Sun-Maid dried peaches =110
Musty*	Aroma associated with rotting peach, also with roots and wet soils.	Aroma MP1 = 25 Fresh beets = 40
Over-ripe*	Flavor associated with over-ripe fruit.	Flavor Over-ripe banana = 45
<u>**Texture**</u>		
Crispiness	The high pitch sound made during the first incisor bite.	Kroger Saltines unsalted cracker = 30 Lays Original Potato chips = 105

Crunchiness	A low pitch sound made during first molar bite of flesh and skin.	Fresh Granny Smith apple = 30 (sliced, flesh only) Trois Petits Cochons Petits toasts = 105
Fibrousness*	The amount of stringy fibers in sample after first five bites.	Kroger no sugar added applesauce = 35 Kroger pineapple tidbits 1"× 0.5" (2 pieces in mouth) = 100
Firmness*	Force to compress sample between tongue and palate. (flesh only)	Philadelphia cream cheese = 30 Ripe banana=50 Honeydew melon=130
Juiciness*	Amount of moisture released after chewing 2 pieces of pineapple tidbits two times.	Kroger pineapple tidbits 1"× 0.5" (2 pieces in mouth) = 60
Mealy*	Amount of crumbly fruit flesh, a meal or grainy feeling on tongue and palate.	Kroger no sugar added applesauce = 25 Quaker Oats Stovetop Oatmeal = 100
Melting*	Degree to which flesh of sample dissolves in mouth.	Wilton white chocolate = 30 Philadelphia cream cheese = 100 Fun Sweets Cotton candy (bite size in mouth) = 130
Feeling Factors		
Astringent	The puckering or drying sensation on the mouth or tongue surface.	0.015% (w/v) alum (McCormick) solution = 20 0.0375% (w/v) alum (McCormick) solution = 50
Fuzzy	A sensation on the lips and tongue caused by peach fuzz.	FLN Royal Blue solid flannel fabric fiber (100% cotton) = 25 Naked Baby Bee Angel fleece yarn (97% acrylic) = 50 Wilson Tennis ball = 75
Toothetch	A sensation of abrasion and drying of the surface of the teeth.	Kroger no sugar added tomato juice = 25 Sparkling Ice Peach Nectarine water = 100

*Major attributes that were considered common in southeastern U.S. peaches and used in descriptive testing for validation of the lexicon; (a) – aroma; (f) – flavor

TABLE 3.5. INSTRUCTIONS FOR PREPARATION OF LEXICON REFERENCES FOR FRESH PEACHES

Reference	Preparation directions
"Musty-Peach" (MP1)	10% sugar and 0.15% citric acid solution; Mix 500 mL deionized water with 50 g of granulated sugar and 0.750 g of citric acid. Add 125 µl of WONF 1543, Sensient SN2000019614)
"Peach Essence"	10% sugar and 0.15% citric acid solution; Mix 500 mL deionized water with 50 g of granulated sugar and 0.750 g of citric acid. Add 125 µl of Clingstone Peach WONF, Sensient SN2000019615)
"Peach Essence 2" (PE2)	Peach essence diluted 1:1 with deionized water
9% Watkins Almond extract	Ratio of 20 mL propylene glycol, food grade to 2 mL of Watkins Almond extract
33% Watkins Orange extract	(2:1) 10 mL propylene glycol, food grade to 5 mL Watkins Orange extract
50% Watkins Orange extract	(1:1) 10 mL propylene glycol to 10 mL Watkins Orange extract
Chamomile tea	2 bags of tea in 2 cups boiling water, steep for 5 min
Jasmine tea	3 g loose jasmine tea in 2 cups boiling water, steep for 5 minutes
50% Sparkling Ice Peach Nectarine water=35	10 mL Peach Nectarine water diluted with 10 mL deionized water
Honeydew melon	1"×1" Slice
Green banana	Period where the majority of banana peel is green
Fresh Parsley Water	25 g of fresh parsley, rinse, cut and add 300 mL of water. Place parsley and water in blender. Blend on medium speed 30 sec. Let it sit for 15 min. Filter with cheese cloth and serve liquid part
Fresh beets	1"×1" Slice
Over-ripe banana	Ripe banana left at room temperature (22 C) for 7 days
Philadelphia cream cheese	Tempered to room temperature ~22 C
Ripe banana	Period where banana peel has little to no green coloring and no visible sign of damage or bruising or browning from breakdown

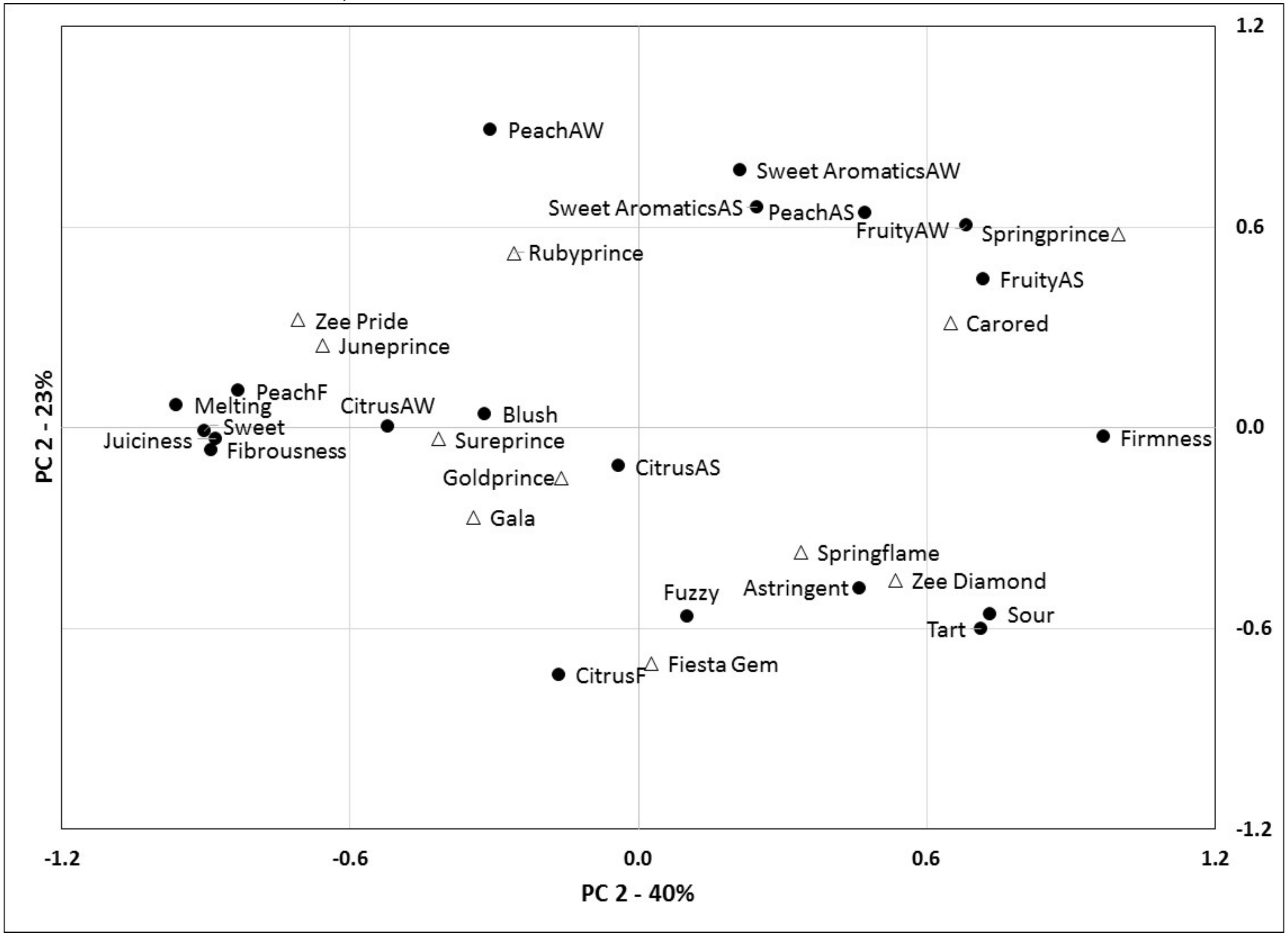
TABLE 3.6. MEAN INTENSITY SCORES FOR THE DESCRIPTIVE ANALYSIS VALIDATION DATA

Attributes	PEACH CULTIVARS										
	Carored	**Fiesta Gem**	**Gala**	**Goldprince**	**Juneprince**	**Rubyprince**	**Springflame**†	**Springprince**†	**Sureprince**	**Zee Diamond**†	**Zee Pride**
Whole Fruit											
Aroma											
Peach identity	52.3abcd	39.2f	49.3bcd	48.0cde	59.7a	55.4abc	46.3def	58.0a	55.6ab	41.5ef	58.3a
Citrus	0.0b	0.0b	13.9a	0.0b	16.1a	0.0b	12.7a	0.0b	0.0b	0.0b	14.1a
Fruity	27.0ab	17.1e	20.8cdef	22.5bcde	20.8cde	25.0bcd	26.3abc	31.7a	19.5de	20.8cde	20.6cde
Sweet Aromatics	24.7ab	17.4d	22.3abc	19.8cd	23.0abc	21.8bc	22.7abc	26.1a	23.3abc	19.9cd	23.5abc
Sliced Fruit											
Appearance											
Redness of flesh	28.4de	46.5b	20.2efg	14.0g	18.9efg	19.3efg	16.3fg	24.7def	39.3bc	33.8cd	90.3a
Aroma											
Peach-identity	48.5abc	41.7d	41.3bcd	45.0cd	42.6cd	51.7a	46.8abcd	49.2ab	41.4d	43.2cd	43.9bcd
Citrus^{ns}	21.7	20.2	22.8	19.8	22.3	21.8	22.8	21.0	23.0	23.7	21.6
Fruity	30.6a	23.6d	24.8cd	26.8abcd	25.6cd	28.5abc	30.3ab	30.3ab	26.1bcd	28.0abcd	26.0bcd
Sweet Aromatics^{ns}	23.9	20.7	20.7	20.5	21.5	22.8	20.6	21.8	21.6	21.5	21.7
Flavor											
Peach-identity	51.8cd	53.2bcd	58.4ab	57.9abc	62.1a	61.2a	58.4ab	48.7d	58.6ab	49.5d	57.4abc
Citrus	23.6bc	26.4ab	27.1ab	23.1bc	23.0bc	22.6bc	29.4a	20.3c	26.2ab	24.2abc	23.5ab
Tart	50.1abc	49.7abc	43.1bcd	43.5bcd	36.2de	39.5de	50.9ab	42.3cde	37.7de	51.4a	34.6e
Sour	38.7ab	41.2a	29.4cdef	30.4cde	23.9ef	28.0def	35.5abc	31.9bcd	26.5def	39.2a	22.7f
Sweet	23.1de	26.6abcd	27.4abc	28.0ab	30.1a	29.0a	23.6cde	21.3e	26.9abcd	24.1bcde	27.0abc
Texture											
Firmness	73.4bc	62.1cd	49.0efg	52.6de	41.1e	42.5efg	74.3bc	100.0a	45.8e	75.9b	40.5e
Juiciness	49.3cd	50.4bc	56.9ab	54.2abc	57.7a	58.8a	49.9cde	34.7e	58.4a	43.2d	54.3abc
Melting	53.0e	57.8de	68.7cd	71.2bc	81.9abc	77.0abc	55.2e	26.2f	79.7abc	47.8ef	86.4a
Fibrousness	47.7de	54.8bcd	59.9bc	57.0bcd	60.0bc	58.3bcd	58.1bcd	40.4e	62.2b	51.0cde	74.7a
Feeling Factors											
Astringent	21.1abc	20.1abc	21.8ab	18.7bc	19.9abc	18.8bc	22.4a	20.4abc	21.5ab	22.3a	18.2c
Fuzzy^{ns}	24.1	24.6	24.1	25.6	24.1	23.6	25.7	24.2	24.6	24.6	24.4

†Non-melting varieties; ^{ns}Not significant ($P > 0.05$); $^{a-g}$Means across rows with different letters are significantly different ($P \leq 0.05$)

FIGURE CAPTION

FIG. 3.1. PRINCIPAL COMPONENT ANALYSIS BIPLOT SHOWING THE PEACH CULTIVARS (△) IN RELATION TO THE DESCRIPTIVE ATTRIBUTES (●); 'AW' REPRESENTS AROMA OF WHOLE PEACH FRUIT. 'AS' REPRESENTS AROMA OF SLICED PEACH FRUIT, AND 'F' REPRESENTS FLAVOR OF SLICED FRUITS.



CHAPTER 4

A FRUIT QUALITY SURVEY OF PEACH CULTIVARS GROWN IN THE SOUTHEASTERN U.S.[1]

[1]Belisle, C.E., Phan, U.T.X., Adhikari, K., and Chavez, D.J. To be submitted to *HortScience*

ABSTRACT

Peach production in the southeastern U.S. extends from mid-May to mid-September. There are approximately 40-60 peach varieties commercially grown. Each variety has unique fruit quality characteristics, which could influence consumer perception and likability. The present study is a survey of chemical and physical characteristics of mature, commercially grown, fresh peaches in Georgia. A collection of 30 cultivars were evaluated in 2015 and 2016 for °brix (SSC, soluble solid concentration), titratable acidity (TTA), SSC/TTA ratio, texture (compression, puncture, Kramer-shear), and color (colorimeter values L*, a*, b* for skin and flesh). There was significant variation between seasons for all variables ($P<0.05$) except for TTA ($P=0.12$) and skin color as represented by a* colorimeter value ($P=0.75$). Statistical differences between varieties within each year were reported for all variables ($P<0.05$). SSC showed variation seasonally and among varieties, while TTA variation was prominently related to variety differences. Similarly, variety-to-variety differences were found when comparing the different texture tests evaluated with varieties such as 'Goldprince', 'Early August Prince', 'Flameprince', 'Majestic', and 'Red Globe' having the most variation across seasons. Other varieties analyzed had little variation between seasons. Moreover, the differences across the three texture tests were inconsistent. In color, broad differences in values suggested variation in individual and overall colors. No significant variation was found for a* values, redness in skin, for varieties. While L*, lightness, and b*, yellow, were highly correlated at (r2015 = 0.89; r2016 = 0.84). The results of this survey demonstrated the quality variation present in the commercial peach varieties grown in Georgia.

INTRODUCTION

Peach in the southeastern U.S. is one of the most important fruit commodities. South Carolina and Georgia rank second and third nationally in peach production in the U.S., respectively. Per capita consumption per year of fresh peaches in the U.S has been in decline from 2.4 kg in 1995 to 1.4 kg in 2015 (USDA, ERS, 2016). This decline has been associated with consumer disapproval of fresh peach quality (Crisosto et al., 2006). Peach appearance and aroma are the initial indicators used by consumers to purchase fresh peaches, while repeat purchases are due to flavor and texture perceptions of the fruit previously purchased (Delgado et al., 2013; Diehl et al., 2013; Baldwin, 2002; Bruhn, 1995; Bruhn et al., 1991). For appearance, color is the characteristic commonly associated with fruit maturity. In commercial peach production systems, fruit appearance is first evaluated by field workers using redness, ground color, and firmness, as the reference distinctions to determine optimal fruit maturity at harvest (Crisosto and Valero, 2008).

Most peach fruit quality research has been focused on measuring SSC (soluble solid content) and TTA (total titratable acidity) (Echeverria, 2012), with SSC used as a sweetness indicator and TTA as a sour indicator. Quality standards for yellow-flesh peaches in California have been set at 10% SSC (Kader, 1995). In Italy, 10% SSC is the suggested quality minimum for early-season, 11% for mid-season, and 12% for late-season peaches (Testoni, 1995, Ventura et al., 2000). In France, a quality index was also developed for low-acidity peaches with 10% SSC and TTA $<0.9\%$, and for high acid peaches with 11% SSC and TTA $>0.9\%$, according to Hilaire (2003). Human taste is not primarily driven by SSC, it is rather a combination of sweet and sour sensations produced by sugar and organic acids (Sanz and Perez, 2010). In addition, the use of the sugar/acid ratio has been proposed as a measurement of acceptable flavor quality with a minimum SSC and maximum TTA (Kader, 2002).

Texture is an additional quality characteristic and one that can vary drastically based on the maturity of the peaches and between varieties. Peaches are known because of textural differences, such as ‘melting’ and ‘non-melting’ flesh types. Melting flesh peaches have a blatant softening in the final stage of ripening that will continue through senescence, while non-melting flesh peaches do not (Bassi and Monet, 2008). Melting flesh have been reported as softer and juicier in textures, compared to non-melting which have been reported as harder and less juicy (Brovelli et al., 1999). The use of different texture parameters such as compression, puncture, and Kramer-shear, have been previously reported in peaches and can be used to classify these flesh differences (Bourne, 1974).

The majority of the fruit quality studies in peach have focused on individual quality characteristics (Crisosto and Crisosto, 2005; Contador et al., 2015; Visai and Vanoli, 1997). A collection of phenotypic quality descriptors for individual varieties has yet to be established for the southeastern U.S. These traits may include shape, skin and flesh color, texture type, volatile profile, and sugar and acidity content. A survey of the quality characteristics for a large collection of fresh peaches can allow us to understand the inherent variation present within southeastern U.S. peach production, in addition, to create a database that can be used for more in-depth research in the effect of pre-harvest and postharvest management, the genetic component of quality, and which quality characteristics define consumer preference and likeness. This is the first report of a series of studies focused at the University of Georgia in understanding fresh peach fruit quality in the southeastern U.S.

MATERIALS AND METHODS

Plant material.

Thirty commercial peach cultivars were used in this study (Table 1). Peach samples were collected from May to August in 2015 and 2016 representing early, mid, and late season varieties being grown in the Southeastern U.S. Fruit were harvested and graded following standard commercial procedures by one commercial grower in Fort Valley, GA. Graded peaches were packed in 11.3 kg commercial boxes and stored at 7 to 10 ºC for 1-3 days until transported on ice to the University of Georgia's Pilot Plant, Griffin, GA. Samples were then stored at 4 °C for three days. Prior to evaluation, samples were moved to room temperature (22 °C) for two to three days to allow fruit to ripen. Cold storage and ripening procedures followed practices used in supermarkets and produce stores to ensure a standardized ready to eat product. Bruised and damaged fruit were removed from samples following procedures practiced in supermarkets and produce stores. Graded peaches were used for further analyses. Out of the 30 peach varieties used in this study, 25 were melting and five non-melting flesh varieties. Similarly, nine were clingstone, one semi-clingstone, four semi-freestone, and 16 freestone. Twenty-nine peach varieties were yellow-flesh and one white-flesh; with 29 having standard acidity and one being low acid/honey (Table 1).

Soluble solid content and titratable acidity measurements

Juice preparation.

Flesh with skin from five representative peaches per cultivar were separated from their pits, quartered and stored in a freezer-safe plastic bag at -80 °C in a U725 INNOVA Ultra-low freezer

(Eppendorf, Hauppauge, NY). Frozen bags were thawed at 4 °C for 24 h and representative fruit samples per bag were puréed for approx. 5 min in a Ninja Ultima™ Blender BL810 series (Balance Inc., Cleveland, OH). Three replicates of 33 g of the peach purée per variety were weighed and poured in a 50-mL oak ridge Nalgene centrifuge tube (Thermo Scientific, Waltham, MA). Tubes were then centrifuged at 18,824 gn and 5 °C, for 20 min, in a 5810R centrifuge (Eppendorf). Supernatant was removed and filtered using a pre-cut, four-layered, cheesecloth, 95 mm × 95 mm. The total volume of the filtered juice obtained per replicate per variety was measured and poured in a 15-mL conical tube and stored at -20 °C for later processing.

Juice analyses.

The 15-mL conical tubes were thawed at room temperature (20-22°C) for one hour. Tubes were then vortexed prior sampling. SSC was measured using 300 µL of peach juice in the PR-32 palette digital refractometer (Atago, Tokyo, Japan). TTA was measured using a solution of 6 mL of peach juice diluted in 50 mL of deionized water (pH=7.0) with the Easy PRO, Easy plus™ titrator (Mettler Toledo, Greifensee, Switzerland) using 0.1N NaOH as titrant. The initial pH, the volume (mL) of 0.1N NaOH visual end point (VEP), and the TTA (expressed as R%) were calculated as described by Mitcham et al. (1996) using an endpoint titration pH=8.2 and an acid milliequivalent (meq.) factor of 0.067 for malic acid. pH and VEP values are not presented. Three juice samples per variety were read for TTA and SSC as replicates.

Texture analyses

Puncture, compression, and Kramer-shear measurements were made using an Instron 5542 (Illinois Tool Works Inc., Norwood, MA) using graded peach fruit ripened at room temperature as previously described. For puncture, the top 1 to 2 mm of fruit skin and flesh surface were removed using a stainless-steel blade. Once removed, puncture measurements were conducted using a 7.9 mm diameter probe to penetrate the peach flesh at a depth of 8 mm. This protocol was adapted from Shinya et al. (2013). The probe ran at a speed of 5 mm/min. Measurements were taken both in the blush and light side of each fruit for a total of five fruit per cultivar.

For compression, peach flesh was cut into a 10 × 15 mm (H × D) cylinder shape and placed on a 15 cm flat horizontal plate attached to an inverted load cell. A 1.5 to 4 cm plate was then attached to the moving crosshead. Crosshead speed was set at 50 mm/min. The moving plate compressed vertically the sample from a starting point of 10 mm to 2 mm height, then retreated back to the starting position (10 mm height) and the compression was repeated. Thus, each sample was subjected to two "bites". The compression protocol was adapted from Bourne (1968). Fruit flesh cores were taken from both the blush and light side of each fruit for a total of five fruit per cultivar.

For Kramer-shear, a 70 mm wide upper blade with ten 3 mm thick blades were used to shear the sample held in a standard cell (Instron, Illinois Tool Works Inc.). Approximately, 50 g of peach flesh per cultivar were added to the standard cell and placed in position for shear compression. A downward stroke set at 100 mm/min vertically compressed the sample to a 46 mm depth. The Kramer-shear protocol was adapted from Ahmed and Dennison (1972). A total of five replicates per variety were measured.

Color measurements

Skin and flesh color were measured using a MiniScan XE colorimeter (HunterLab, Reston, VA). A 3.5 cm diameter ocular lens was used for each sample measurement. Values were taken in C/2° color-space coordinates of L*, a*, and b*. The lightness coefficient, L*, ranges from 0 (black) to 100 (white). Colorimeter space value a* ranges from positive (red) to negative (green), and b* ranges from positive (yellow) to negative (blue). The colorimeter was calibrated with a white MiniScan reference tile (X = 80.1, Y 85.1, Z89.4 for D65/10°). Peach color skin was evaluated in the blush and light side of the fruit. The same peach was then cut vertically, avoiding the peach pit, with the goal to capture the maximum surface area to measure the flesh color for the blush and light side of the fruit. Five fruit per variety were evaluated.

Data Analyses

Analyses of variance (ANOVA) were performed using the general linear model (GLM) procedure in SAS Software 9.2 (SAS Institute Inc., Cary, NC) to examine differences between cultivars and years. Differences among cultivars within a year were examined using Tukey HSD test with a confidence level of 95%. Correlations between variables were performed in JMP Pro 12 software (SAS Institute Inc.) These methods were used to determine the relationships between variables across seasons.

RESULTS AND DISCUSSION

Soluble solid content and titratable acidity

SSC and TTA were evaluated for 30 varieties of peaches grown in Georgia for the 2015 and 2016 seasons (Table 1). There were statistical significant differences ($P \leq 0.05$) when comparing data across seasons for SSC and SSC/TTA, but not for TTA ($P=0.12$). Differences between varieties were identified for SSC, TTA, and SSC/TTA ($P \leq 0.05$). Due to the variation present across years, hereafter, all the analyses are based on within year comparisons, although, TTA from year 2015 and 2016 were not significantly different from each other.

SSC values ranged from 8.3% for 'Juneprince' to 15.6% for 'Summerflame' in 2015 and 8.4% for 'Carored' to 15.6% for 'Flameprince' in 2016. These values are similar to those reported by Contador et al. (2011) with a range from 10.87 to 13.77% and Cantín et al. (2009)

with a range of 7.6 to 17.5% for SSC. The variability of sugar content from year-to-year has been previously reported in peach and has been attributed to the environmental effects, the inherit variation among varieties, and their interaction (Cirilli, et al., 2016). Climate and crop load are the major impact for variability (Culpepper and Caldwell, 1930), along with individual variety differences. Similarly, varieties varied slightly between years, with the highest variation in 'Summerflame' with 15.6% SSC in 2015 to 12.1% SSC in 2016.

For TTA, values ranged from 0.26% for 'White Lady' to 1.11% for 'Flavorich' in 2015 to 0.22% for 'White Lady' to 0.75% for 'Juneprince' and 'Rich Pride' in 2016. Similar values were reported in Crisosto and Crisosto (2005) with ranges of 0.22% to 0.92%, and in Contador et al. (2011) of 0.27 to 1.06%. Reports have shown that TTA is less affected by growing conditions between seasons (Cirilli et al., 2016). This supports the lack of significant difference across years for TTA. Additionally, acidity has been shown to be affected by fruit maturity (Ryugo and Davis, 1958); and abiotic and biotic conditions affecting the tree: climate (Peynaud 1950; Gonzalez et al., 1992), fertilization, and pruning practices (Cummings and Reeves, 1971; Schneider et al., 1958). The highest variation for TTA between the two seasons for the 26 cultivars was reported in 'Flavorich' with 1.11% in 2015 and 0.64% in 2016. While many values showed little to no variation between seasons. In our study, no trends were identified when comparing data across years or harvesting time other than standard acidity compared with low-acidity. In our study, 'White Lady was the only low-acid variety. Low-acid cultivars are characterized by having higher gene expression of two particular genes (PRUpe and VP2) which allow vascular proton pumps to have an increased expression, producing proton leakage and leading to lower accumulation of organic acids in the fruit (Etienne et al., 2002). Furthermore, the variation in fruit acidity has been associated with cultivar type rather than by seasonal variation (Souty et al., 1967; Peynaud, 1950).

The SSC/TTA ratio was calculated and values ranged from 10.18 for ‘Flavorich’ to 46.95 for ‘White Lady’ in 2015 and 12.01 for ‘Zee Diamond’ to 50.94 ‘White Lady’ in 2016 (Table 2). Previous studies have linked consumer’s sweetness perception with high SSC/TTA values (Lopez et al. 2011; Ortiz et al. 2008; Colaric et al. 2005; Esti et al. 1997; Bassi and Selli, 1990). For instance, Colaric et al. (2005) found positive correlation between sweetness and SSC/TTA ratio, where the cultivar with the lowest ratio was perceived as the sourest cultivar while the cultivar with the highest ratio was perceived as the sweetest cultivar. Due to the low-acidity in ‘White Lady’, a standard-acidity peach cannot be compared to this variety using their ratio values. For instance, a 12.2% SSC with a standard acidity of 0.66% TTA, as found in ‘Scarletprince’, would yield a ratio of 17.8. In ‘White Lady, a low-acid cultivar, similar SSC of 12% and a 0.22% TTA, would yield a ratio of 46.95. Although the soluble solid concentration has little difference, the TTA value has shown to have a large impact on the ratio. The SSC/TTA ratio is biased in favor of low acid cultivars when used to compare different acidity level cultivars types. Similar findings were reported in Crisosto and Crisosto (2005).

Texture

Puncture, compression, and Kramer-shear measurements for 26 varieties of peaches were measured for the 2015 and 2016 peach seasons. ‘Carored’, ‘Flavorich’, ‘Springprince’ and ‘Zee Diamond’ peach varieties were not included in these analyses because of missing data. There were significant differences across years and varieties for all texture measurements ($P \leq 0.05$), thus mean comparisons hereafter are presented within each year (Table 3).

For compression and puncture, there were no significant differences when comparing measurements for blush and light side of the fruit (data not shown, P>0.05). Hereafter, the results of blush and light side measurements were averaged per fruit (replicate). For compression, there was significant difference when comparing the first compression versus the second compression in 2015 (P<0.0001) and 2016 (P<0.0001). The first compression measures hardness. While the second compression measures elasticity and its highest peak is a second measure of hardness. It is presumable that the values are significantly different due to the deformation produced by the first compression significantly impacts the textural forces of the second compression. Additionally, the first and second compression values range from each other in varying ranges with differences from 0.11 to 2.64 in the 2015 season and 0.13 to 1.24 in the 2016 season (data not shown).

First compression measurements ranged from 0.39 kgf•g-1 for 'Fiesta Gem' to 2.75 kgf•g-1 for 'Goldprince' in 2015 and 0.32 kgf•g-1 for 'Ruston Red' to 6.37 kgf•g-1 for 'Flameprince' in 2016. These values represent hardness of the produce. As the fruit flesh is compressed, the force from the downward stroke increases and the maximum height is defined as hardness (Bourne, 1968). For the second compression, values ranged from 0.21 kgf•g-1 for 'Scarletprince' to 1.51 kgf•g-1 for 'Goldprince' in 2015 and 0.21 kgf•g-1 for 'Juneprince' to 3.73 kgf•g-1 for 'Flameprince' in 2016. The second compression is a measure of the elasticity and is defined by "the distance that the food recovers between first and second bites" (Bourne, 1968). Puncture measurements ranged from 0.21 kgf for 'Augustprince' to 0.83 kgf for 'Early August Prince' in 2015 and 0.24 kgf for 'Rich Lady' to 1.56 kgf for 'Redglobe' in 2016. Puncture measures the "force and/or deformation to push a probe into a food product to a depth that causes irreversible damage" and is considered a standard measurement in fruit texture tests due to the widely known Magness and Taylor pressure test (Bourne, 1974). In Kramer-shear, forces ranged from 0.22 kgf•g-1 for 'Augustprince' to 0.46 kgf•g-1 for 'Rich Lady' in 2015 and 0.22 kgf•g-1 for 'Fireprince' to 0.94 kgf•g-1 for 'Early August Prince in 2016. Kramer-shear measures a combination of multiple texture attributes. These include, compression, shear, extrusion, and friction (Ahmed and Dennison, 1972).

For variety-to-variety comparisons, compression, puncture, and Kramer-shear, all captured the textural ranges variation among varieties. Throughout all the tests, many of the varieties had little variation between seasons, while some varieties had extreme variation. Additionally, varieties with high firmness in one texture test did not necessarily were the highest for the other two texture tests (Table 3). For instance, 'Goldprince' was high for compression (2.75 kgf•g-1 in 2015 compared to 0.79 kgf•g-1 in 2016), but not notably different for Kramer or puncture in that same year. For 'Early August Prince', values were high for Kramer (0.36 kgf•g-1 in 2015 compared to 0.94 kgf•g-1 in 2016), but had a different trend for puncture and compression measurements.

Texture measurements were inconsistent for certain varieties when comparing values across years. These varieties included 'Goldprince' and 'Early August Prince' in 2015; and 'Flameprince', 'Majestic', and 'Red Globe' in 2016. Puncture values had little deviation among replicates within a variety, with the exception of 'Early August Prince' in 2015 and 'Majestic' and 'Red Globe' in 2016 (Fig 1). These varieties' puncture values were identified as outliers using the Quantile method (data not shown). In compression, a similar trend was observed as replicates within varieties had a small degree of variation. Overall when comparing the different texture measurements, Kramer-shear produced the lowest firmness values when compared to compression and puncture measurements, suggesting that the force to shear a sample is less than the force to puncture or compress the same sample. Additionally, the Kramer-shear machinery may be less likely to capture the texture variation of the samples as compared to compression and puncture measurements due to the nature of the test. No clear trend between melting and non-melting varieties in regards to firmness for all three texture tests was observed. Additionally, the variation observed for certain varieties across seasons was inconsistent when comparing the different texture tests. These results could be due to differences in ripening time of the varieties analyzed, various degrees of ripening, differences in ripening rate between fruit replicates and varieties, among others.

As previously tested by Bourne (1974), we compared puncture, Kramer and compression tests, to understand the texture characteristics of different peach varieties (Fig. 3-6). Bourne (1974) studied the textural changes in ripening peaches and reported a positive linear relationship between compression and puncture, but not between Kramer and puncture tests, suggesting that "compression contributed to the major part of the puncture force", whereas Kramer and puncture do not (lack of linear relationship). In addition, compression could capture a greater variation of textural changes that Kramer was not. The results of our study supported Bourne's (1974) conclusions. The relationship when comparing compression and puncture, shown in Fig. 3 and 4, values within each season were captured using a regression analyses (r2015 = 0.615; r2016 = 0.297). However, this relationship is not strong probably due to the fruit maturity variation within each variety and the ripening rate differences among varieties. Our results do not show clear trends across seasons for all the texture methods studied, however, textural differences suggested overall variation among varieties and variation found across testing methods.

Color

Skin and flesh color were evaluated for peaches in the 2015 and 2016 season. For skin, there were significant differences between years ($P<0.0001$) and varieties ($P<0.0001$) for L* and b*. No significant differences were found across years for a* ($P=0.75$). For flesh, there were significant differences for years and varieties for L* ($P<0.0001$), a* ($P<0.0001$), and b* ($P<0.0001$). Hereafter, all the analyses are based within a year comparisons, although, skin values of a* from year 2015 and 2016 did not show differences across years. Mean separation between varieties are presented within each year (Tables 4 and 5).

In skin, L* values ranged from 32.89 for 'Springflame' to 76.06 for 'Julyprince' in 2015 and 31.20 for 'Springflame' to 73.49 for 'Augustprince' in 2016 (Table 4). In a*, values for skin ranged from 11.36 for 'Elberta' to 40.4 for 'Goldprince' in 2015 and 11.82 for 'Elberta' to 39.91 for 'Juneprince' in 2016. In b*, values ranged from 15.05 for 'Springflame' to 58.30 for 'Ruston Red' in 2015 and 16.32 for 'Rich Lady' to 52.43 for 'Augustprince' in 2016. The range in colorimeter values suggests a large variation of individual and overall color in varieties. Independent of the base or ground color in peaches, measured as L* and b*, the majority of redness, noted as positive a*, is associated with the buildup of anthocyanins in the skin of peach. The accretion in peach skin is influenced by light exposure (Bassi and Monet, 2008), and accumulated mostly in later stages of ripening, thus the value of a* has most often been associated with maturity (Byrne et al., 1991; Delwiche and Baumgardner, 1983, 1985; Kader et al., 1982; Rood, 1957). The lack of statistical variation for a* between seasons in addition to the significant difference among varieties suggests that the redness accumulated on peach skin is variety dependent and relatively consistent between years.

For flesh values, L* ranged from 50.29 for 'Fiesta Gem' to 68.46 for 'Julyprince' in 2015 and 56.05 for 'Fiesta Gem' to 91.62 for 'White Lady' in 2016 (Table 5). For a* of flesh, values ranged from 0.38 for ‘Julyprince’ to 23.03 for ‘Summerflame’ in 2015 and 0.85 for ‘White Lady’ to 23.01 for ‘Flameprince’ in 2016. For b*, values ranged from 22.52 for ‘White Lady’ to 57.18 ‘Springprince’ in 2015 and 34.38 for ‘White Lady’ to 87.36 for ‘Ruston Red’ in 2016. In comparisons between the skin and flesh colorimeter values, flesh had higher L* compared to skin, suggesting there was more white hues in flesh. In a*, values had greater range and were higher in skin, suggesting that peach skin had greater red hues compared to the peach flesh. Lastly, b* values were relatively equal between skin and flesh although there is not enough evidence to suggest that the yellow ground color in skin and yellow in flesh were directly associated with each other. Our correlations showed b* of skin and flesh are slightly correlated in 2015 (r=0.40; P=0.0394) and in 2016 (r= 0.55; P=0.0032). The single white flesh cultivar evaluated, ‘White Lady’, had the lowest a* in comparison with all yellow-flesh varieties. The lack of carotenoids in white flesh peaches causes the distinct white ground color. However, ‘White Lady’ was not highest in L*. It is possible that the colorimeter was not able to pick up the lightness in L*, however a combination of low a* and low b* suggest that the skin of ‘White Lady’ was more green than yellow in hue. Color values have been used as indicators of maturity, such as by Kader et al. (1982) in which a*, redness, was used to measure maturity.

Correlations between variables

Tables 6 and 7 show the correlation coefficients of each test and between years. SSC, TTA, SSC/TTA ratio along with all skin colors (L*, a*, b*) and a* and b* values of flesh were positively correlated between seasons. This suggested that among a large selection of varieties, these are the most stable quality measurements across seasons and more likely less affected by the environment. However, compression, puncture and Kramer, along with L* of flesh, showed no correlations between seasons. This suggested that the texture values were not consistent between seasons and more likely were affected by the environment and the inherited variation present for each peach variety.

The SSC/TTA ratio values across varieties seasons were compared and correlated statistically between peach seasons for 2015 and for 2016 (r=0.86) (Table 6). As it was expected, SSC/TTA ratio was slightly positively correlated with SSC in 2015 (r=0.42) and in 2016 (r=0.48). SSC/TTA ratio was strongly negatively correlated with TTA in 2015 (r=-0.79) and in 2016 (r =-0.84) (Table 7). Several studies have previously reported this pattern in peaches as an explanation of ripening identified by the gradual decline of TTA as peaches ripen (Bakshi and Masoodi, 2009; Kwon et al., 2007; Moing et al., 1998).

The ranges for texture measurements per variety in 2016 were slightly higher than in 2015. There were no changes in the protocol or methodology for the different texture tests. For compression, two force peaks (bites) were measured. Both values, compression 1 and 2, were positively correlated in 2015 ($r = 0.989$, $P<0.0001$) and 2016 ($r = 0.776$, $P=0.0014$). For puncture and Kramer-shear, significant correlations were not found between years. Bourne (1974) suggested that compression contributes to force more so than Kramer-shear.

In comparing the relationship between the texture measurements, there is no strong relationship between puncture and Kramer in 2015 (r=0.126) and 2016 (r=0.446). This suggests these tests do not relate in the texture values that are detected on Instron and cannot be used interchangeably. In comparing puncture with compression, there was a slight correlation in 2015 (r=0.613) but no correlations in 2016 (r=0.297). According to Bourne (1974), when fruits are selected in varying ripeness stages puncture, compression, and shear could be used interchangeably. However, in the period of maturity that was provided from the commercial market, standardizing the maturity level in such stages proves difficult.

Color values for peach skin, L*, a*, and b* were correlated when comparing varieties between years (rL*=0.76, ra*=0.70, rb*=0.72; P<0.0001). Similarly, flesh color values of a* and b* were correlated when comparing varieties between years (ra*= 0.67, rb*= 0.51; P < 0.008). No significant correlation was observed between 2015 and 2016 for flesh color measurement L*. Anthocyanin content and genotypic differences of the peach varieties can explain the variation in L* values. Higher L* values represent a higher degree of lightness. As the anthocyanin develops in peaches, a redder hue appears and the lightness values decreases (Frett et al., 2014). Between color values, L* skin was negatively correlated with a* skin in 2015 (r=-0.55, P=0.0027) and 2016 (r=-0.66, P=0.0002). Additionally, L* skin was positively correlated with b* skin in 2015 (r=0.89; P<0.0001) and 2016 (r=0.84; P< 0.0001). The value of b* increases with an increasing yellow pigment. Peaches are characteristic for their light hue ground color, often being yellow to orange. The pigment variation demonstrated phenotypic differences among peach genotypes, which can be impacted by environmental factors, mainly shade and exposure to sunlight (Bible and Singha, 1993).

In our study, correlations between data for color and SSC, TTA and puncture, and SSC and first compression were reported in 2016 season (Table 7). However, this was not similar in the 2015 peach season. Genard and Bruchou (1992) reported that color variation is almost independent of firmness and the biochemical composition in a peach fruit, whereas SSC and TTA have been correlated strongly with firmness (Delgado et al., 2013). Several physiological changes characterize fruit ripening. Some of these changes include the slight increase of SSC, decrease in TTA, softening of textures, and development of pigment. Additionally, across the peach season there was a positive relationship between SSC increasing at later harvest dates (r2015= 0.656; r2016= 0.832). This could be due to longer fruit development periods for late varieties which allow compounds to accumulate in the fruit for a longer period of time in comparison to early fruit varieties.

CONCLUSIONS

. A survey of quality variation between commercial peach varieties should allow researchers to better select varieties based on quality. It should be kept in mind that in addition to the variety-to-variety variation; year-to-year variation was prominent in textures, SSC, and SSC/TTA ratio, suggesting that these values are sensitive to environmental impacts (maturity, harvest location, packing procedures, and storage time). Whereas the redness of skin and TTA was relatively constant.

In addition, quality is becoming more apparent and is being defined by consumers now more than in the past 50 years. Many of the quality characteristics have been given parameters of acceptability. Research to evaluate the effects of such quality characteristics in regards to their perception and liking are the next step in understanding the quality attributes of peaches in the southeastern U.S. Texture values need to be compared with descriptive sensory analysis to determine the most practical physical measurement as compared with sensory perception. In addition, the provided database of information can be utilized to select varieties for future studies based on quality attributes.

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TABLE 4.1. COMMERCIAL PEACH CULTIVARS, PHENOTYPIC CHARACTERISTICS AND HARVEST DATES

Varieties	Flesh Type	Pit Adherence	Flesh Color	Acidity	Harvest Date[z]	
					2015	2016
Augustprince	Melting	Freestone	Yellow	Standard	07/29/15	07/12/16
Blazeprince	Melting	Freestone	Yellow	Standard	06/17/15	06/14/16
Caro King	Melting	Semi-free	Yellow	Standard	06/17/15	06/15/16
Carored	Melting	Clingstone	Yellow	Standard	05/22/15	05/18/16
Early Augustprince	Melting	Freestone	Yellow	Standard	07/17/15	07/12/16
Fiesta Gem	Melting	Clingstone	Yellow	Standard	05/29/15	05/22/16
Fireprince	Melting	Freestone	Yellow	Standard	06/26/15	06/23/16
Flameprince	Melting	Freestone	Yellow	Standard	08/05/15	07/29/16
Flavorich	Melting	Clingstone	Yellow	Standard	05/12/15	05/14/16
Gala	Melting	Semi-free	Yellow	Standard	06/02/15	06/02/16
Goldprince	Melting	Clingstone	Yellow	Standard	05/26/15	05/26/16
Harvester	Melting	Freestone	Yellow	Standard	06/10/15	06/09/16
Julyprince	Melting	Freestone	Yellow	Standard	06/23/15	07/01/16
June Fire	Melting	Freestone	Yellow	Standard	06/18/15	06/16/16
Juneprince	Melting	Semi-cling	Yellow	Standard	06/01/15	06/01/16
Majestic	Melting	Freestone	Yellow	Standard	06/26/15	06/23/16
Elberta	Melting	Freestone	Yellow	Standard	06/23/15	06/23/16
Red Globe	Melting	Freestone	Yellow	Standard	07/02/15	07/06/16
Rich Lady	Non-melting	Semi-free	Yellow	Standard	06/11/15	06/09/16
Rich Pride	Non-melting	Clingstone	Yellow	Standard	06/11/15	06/08/16
Rubyprince	Melting	Clingstone	Yellow	Standard	06/02/15	05/27/16
Ruston Red	Melting	Freestone	Yellow	Standard	07/07/15	07/07/16
Scarletprince	Melting	Freestone	Yellow	Standard	07/02/15	06/30/16
Sierra Rich	Melting	Freestone	Yellow	Standard	06/18/15	06/16/16
Springflame21	Non-melting	Clingstone	Yellow	Standard	05/26/15	05/19/16
Springprince	Non-melting	Clingstone	Yellow	Standard	05/21/15	05/18/16
Summerflame	Melting	Freestone	Yellow	Standard	07/31/15	07/14/16
Sureprince	Melting	Semi-free	Yellow	Standard	06/02/15	06/02/16
White Lady	Melting	Freestone	White	Low-acid	06/18/15	06/23/16
Zee Diamond	Non-melting	Clingstone	Yellow	Standard	05/22/15	05/18/16

[z]Harvest date obtained from commercial producer in Fort Valley, GA.

TABLE 4.2. MEAN VALUES FOR SOLUBLE SOLID CONCENTRATION (SSC), TITRATABLE ACIDITY (TTA), AND SSC/TTA RATIO OF 30 COMMERCIAL PEACH CULTIVARS OVER TWO SEASONS IN GEORGIA

Varieties	SSC (%)[z]				TTA (%)				SSC/TTA			
	2015		2016		2015		2016		2015		2016	
Augustprince	11.6	h-m[y]	14.1	b	0.51	g-j	0.55	f-i	23.19	c-f	25.46	bc
Blazeprince	12.2	d-i	10.8	g-i	0.53	g-f	0.58	e-h	23.00	c-f	18.48	e-i
Caro King	11.3	j-n	9.9	i-l	0.48	h-j	0.60	d-h	23.56	c-e	16.37	g-n
Carored	9.2	o	8.4	o	0.70	b-g	0.61	c-h	12.93	no	13.82	l-o
Early August Prince	11.8	g-l	13.1	cd	0.68	b-i	0.64	b-g	17.26	h-m	20.33	d-f
Fiesta Gem	11.5	i-m	9.9	i-l	0.62	d-i	0.74	ab	18.46	g-l	13.07	no
Fireprince	13.0	cd	10.0	i-l	0.63	d-i	0.55	f-i	20.50	e-h	18.25	e-j
Flameprince	12.6	c-f	15.6	a	0.48	h-j	0.64	a-g	25.98	bc	23.91	b-d
Flavorich	11.1	l-n	9.5	k-n	1.11	a	0.64	b-g	10.18	o	14.74	i-o
Gala	9.2	o	9.9	i-l	0.69	b-h	0.64	b-g	13.54	m-o	15.40	h-o
Goldprince	11.1	k-n	10.3	h-k	0.89	b	0.65	a-f	12.80	no	15.63	h-o
Harvester	10.9	mn	10.7	g-j	0.80	b-d	0.53	g-i	13.68	m-o	19.70	e-g
Julyprince	13.3	bc	12.1	e	0.62	d-j	0.65	a-f	21.57	d-g	18.80	e-h
June Fire	12.7	c-f	12.3	de	0.85	bc	0.71	a-d	14.75	l-n	17.18	f-l
Juneprince	8.3	p	10.7	g-j	0.55	f-j	0.75	a	15.26	k-n	14.16	k-o
Majestic	14.1	b	11.9	ef	0.50	g-j	0.54	f-i	28.30	bc	21.85	c-e
Elberta	12.1	e-j	8.8	no	0.62	d-i	0.47	i	19.52	f-i	18.67	e-h
Red Globe	11.9	f-k	13.8	bc	0.62	d-i	0.54	f-i	19.22	f-k	25.32	bc
Rich Lady	12.4	d-h	11.0	f-h	0.79	b-e	0.74	ab	15.85	i-n	14.95	h-o
Rich Pride	12.8	c-e	10.6	g-j	0.82	b-d	0.75	a	15.43	j-n	14.38	j-o
Rubyprince	10.6	n	10.6	h-j	0.64	c-i	0.64	a-g	16.46	i-n	16.43	g-n
Ruston Red	13.3	bc	13.9	bc	0.47	i-k	0.51	hi	28.44	bc	27.19	b
Scarletprince	12.2	e-i	11.1	f-h	0.66	c-i	0.65	a-f	17.80	g-l	17.05	f-m
Sierra Rich	12.4	d-g	9.8	j-m	0.73	b-f	0.59	e-h	16.79	h-n	16.43	g-n
Springflame	9.3	o	9.6	k-n	0.63	d-i	0.72	a-c	14.72	l-n	13.24	m-o
Springprince	8.9	op	9.2	l-o	0.40	jk	0.55	f-i	20.75	e-h	16.88	f-n
Summerflame	15.6	a	12.1	e	0.62	d-j	0.67	a-e	25.30	b-d	18.02	f-l
Sureprince	10.9	mn	9.8	j-l	0.65	c-i	0.58	e-h	16.49	i-n	17.01	f-m
White Lady	12.0	e-j	11.5	e-g	0.26	k	0.22	j	46.95	a	50.94	a
Zee Diamond	11.2	k-n	8.9	m-o	0.58	e-j	0.73	ab	19.37	f-j	12.01	o

[z]SSC=soluble solids content. TTA=titratable acidity

[y]Different letters within a column indicate significant difference between genotypes using Tukey's test, *P*-value <0.05.

TABLE 4.3. MEAN VALUES OF TEXTURE ATTRIBUTES FOR 26 COMMERICAL PEACH VARIETES OVER TWO SEASONS

Varieties	Compression (kgf·g^{-1})^{z}								Puncture (kgf)				Kramer (kgf·g^{-1})			
	2015				2016											
	1st compression		2nd compression		1st compression		2nd compression		2015		2016		2015		2016	
Augustprince	0.40	de^{y}	0.27	bc	1.50	c-f	0.96	c-e	0.21	c	0.70	b	0.22	b	0.53	ab
Blazeprince	0.48	c-e	0.28	bc	0.42	fg	0.24	e	0.24	c	0.30	bc	0.40	ab	0.23	b
Caro King	0.63	b-e	0.34	bc	0.56	fg	0.33	e	0.40	bc	0.34	bc	0.46	a	0.29	b
Early Augustprince	1.07	b	0.61	b	0.97	d-g	0.60	c-e	0.83	a	0.56	bc	0.36	ab	0.94	a
Fiesta Gem	0.39	e	0.23	c	1.50	c-f	1.09	c-e	0.25	bc	0.49	bc	0.35	ab	0.71	ab
Fireprince	0.53	c-e	0.37	bc	0.40	g	0.23	e	0.30	bc	0.29	bc	0.39	ab	0.22	b
Flameprince	0.43	c-e	0.30	bc	6.37	a	3.73	a	0.36	bc	0.63	bc	0.33	ab	0.29	b
Gala	0.49	c-e	0.34	bc	0.87	e-g	0.57	c-e	0.33	bc	0.42	bc	0.30	ab	0.43	ab
Goldprince	2.75	a	1.51	a	0.79	e-g	0.46	de	0.24	c	0.30	bc	0.39	ab	0.31	b
Harvester	0.70	b-e	0.53	bc	2.04	b-d	1.60	cd	0.37	bc	0.33	bc	0.33	ab	0.30	b
Julyprince	0.52	c-e	0.28	bc	1.66	b-e	1.08	c-e	0.35	bc	0.27	bc	0.35	ab	0.63	ab
Junefire	0.55	b-e	0.33	bc	1.21	d-g	0.68	c-e	0.32	bc	0.45	bc	0.29	ab	0.31	b
Juneprince	0.54	c-e	0.38	bc	0.36	g	0.21	e	0.26	bc	0.30	bc	0.24	ab	0.33	b
Majestic	0.55	b-e	0.36	bc	-	-	-	-	0.27	bc	1.29	a	0.38	ab	0.42	ab
Elberta	0.52	c-e	0.33	bc	0.47	fg	3.05	ab	0.26	bc	0.30	bc	0.27	ab	0.25	b
Red Globe	0.60	b-e	0.39	bc	2.42	bc	1.38	c-e	0.47	b	1.56	a	0.33	ab	0.54	ab
Rich Lady	0.42	c-e	0.22	c	1.38	c-g	0.86	c-e	0.26	bc	0.24	c	0.46	a	0.34	b
Rich Pride	0.52	c-e	0.30	bc	1.39	c-g	1.04	c-e	0.27	bc	0.25	c	0.32	ab	0.47	ab
Rubyprince	0.50	c-e	0.30	bc	0.56	fg	0.38	de	0.27	bc	0.40	bc	0.26	ab	0.38	ab
Ruston Red	0.92	b-d	0.53	bc	0.32	g	0.64	c-e	0.35	bc	0.37	bc	0.27	ab	0.28	b
Scarletprince	0.40	de	0.21	c	0.52	fg	0.28	e	0.25	bc	0.34	bc	0.25	ab	0.25	b
Sierra Rich	0.43	c-e	0.24	c	0.53	fg	0.33	e	0.28	bc	0.24	c	0.39	ab	0.25	b
Springflame	0.44	c-e	-	-	2.68	b	1.82	bc	0.23	c	0.49	bc	0.40	ab	0.57	ab
Summerflame	0.92	bc	0.61	b	0.73	e-g	0.50	de	0.40	bc	0.48	bc	0.28	ab	0.32	b
Sureprince	0.50	c-e	0.27	bc	0.59	e-g	0.37	de	0.22	c	0.30	bc	0.24	ab	0.25	b
White Lady	0.55	b-e	0.32	bc	0.46	fg	0.30	e	0.23	c	0.35	bc	0.29	ab	0.32	b

^{z}Compression=texture measurement where 1st compression is when the moving plate is compressed vertically from a starting point of 10 mm to 2 mm height. 2nd compression is when the moving plate repeats the previous compression. Puncture = texture measurement where a 7.9 mm diameter probe vertically punctures into at an 8 mm depth. Kramer-Shear= a 70 mm wide upper blade with ten 3 mm thick blades vertically shears to a 46 mm depth at 100 mm/min vertically.

^{y}Different letters within a column indicate significant difference between genotypes using Tukey's test, *P*-value <0.05.

TABLE 4.4. MEAN VALUES FOR SKIN COLOR ATTRIBUTES OF 30 COMMERCIAL PEACH VARIETIES GROWN IN GEORGIA OVER TWO SEASONS

Varieties	L*[z]				a*				b*			
	2015		2016		2015		2016		2015		2016	
Augustprince	68.78	a-d[y]	73.49	a	28.49	a-d	23.55	ef	48.07	a-d	52.43	a
Blazeprince	49.28	e-i	50.24	e-i	34.62	a-d	37.61	ab	26.48	d-h	26.68	f-k
Caro King	50.74	d-i	62.19	a-d	38.69	ab	25.38	c-f	30.33	b-h	36.68	b-g
Early August Prince	65.75	a-e	70.60	a	30.38	a-d	23.19	e-g	47.86	a-d	47.77	ab
Fiesta Gem	44.39	g-i	49.07	f-i	31.53	a-d	31.21	a-f	20.84	gh	26.80	f-k
Fire Prince	67.01	a-e	62.05	a-e	27.90	a-d	27.46	b-f	41.85	a-g	38.59	b-g
Flameprince	70.41	ab	65.01	ab	27.97	a-d	25.85	c-f	43.25	a-f	43.66	a-c
Gala	59.68	a-g	52.52	c-h	32.74	a-d	34.99	a-d	38.72	a-g	43.54	a-d
Goldprince	40.93	hi	45.96	g-j	40.40	a	29.85	a-f	37.35	a-h	29.01	e-k
Harvester	64.59	a-f	62.00	a-e	24.45	a-e	25.79	c-f	42.10	a-g	48.42	ab
Julyprince	76.06	a	66.26	ab	18.56	de	20.64	fg	51.55	ab	40.84	a-e
June Fire	49.98	e-i	46.20	f-j	34.24	a-d	32.00	a-f	29.15	c-h	26.13	f-k
Juneprince	56.25	b-h	48.17	f-i	37.15	a-c	39.91	a	42.70	a-g	39.76	a-f
Majestic	69.27	a-c	64.17	a-c	21.05	c-e	23.82	de	46.48	a-e	42.29	a-e
Elberta	75.25	a	72.92	a	11.36	e	11.82	g	55.31	a	42.58	a-e
Red Globe	64.01	a-f	58.00	b-f	26.60	a-e	31.62	a-f	41.52	a-g	32.35	c-h
Rich Lady	53.13	b-h	39.74	i-k	24.84	a-e	26.88	b-f	24.20	e-h	16.32	k
Rich Pride	44.94	g-i	42.85	h-k	27.37	a-e	28.27	b-f	21.96	f-h	17.68	jk
Rubyprince	49.58	e-i	52.07	d-h	28.90	a-d	28.31	b-f	23.84	f-h	31.62	c-i
Ruston Red	75.71	a	71.95	a	22.84	b-e	25.26	c-f	58.30	a	45.25	a-c
Scarletprince	63.49	a-f	55.36	b-g	30.74	a-d	27.66	b-f	38.50	a-g	30.01	d-j
Sierra Rich	47.19	f-i	42.93	h-k	29.92	a-d	30.64	a-f	23.45	f-h	18.04	i-k
Springflame	32.89	i	31.20	k	26.56	a-e	32.60	a-e	15.05	h	18.41	i-k
Springprince	61.02	a-g	36.23	jk	34.69	a-d	29.73	a-f	51.46	a-c	18.76	h-k
Summerflame	62.85	a-g	52.84	c-h	33.03	a-d	30.68	a-f	40.96	a-g	25.78	g-k
Sureprince	70.43	ab	46.21	f-j	27.85	a-d	32.03	a-f	54.02	a	42.14	a-e
White Lady	51.15	c-i	46.13	g-j	30.61	a-d	35.37	a-c	21.13	f-h	19.78	h-k

[z]L* values range from 0 (black) to 100 (white), represents lightness; a* values range from positive (red) to negative (green); and b* values range from positive (yellow) to negative (blue).
[y]Different letters within a column indicate significant difference between genotypes using Tukey's test, *P*-value <0.05.

TABLE 4.5. MEAN VALUES FOR FLESH COLOR OF 30 COMMERCIAL PEACH VARIETIES GROWN IN GEORGIA OVER TWO SEASONS

Varieties	L*[z]				a*				b*			
	2015		2016		2015		2016		2015		2016	
Augustprince	56.59	b-d[y]	80.95	a-f	17.32	ab	19.22	ab	50.14	a-d	71.70	b-d
Blazeprince	60.20	a-c	75.80	c-h	5.53	d-f	7.52	c-h	47.83	a-e	59.53	e-h
Caro King	62.23	ab	78.51	b-g	6.24	c-f	3.41	gh	47.21	a-e	60.56	d-h
Early August Prince	60.22	a-c	84.62	a-d	14.63	a-d	16.20	a-d	52.07	a-c	75.49	bc
Fiesta Gem	50.29	d	56.05	k	13.62	a-e	15.12	a-e	38.23	de	47.15	i
Fireprince	63.38	ab	85.54	a-c	7.08	b-f	14.61	a-f	53.76	a-c	75.92	a-c
Flameprince	56.48	b-d	86.38	a-c	17.13	a-c	23.01	a	36.04	e	80.27	ab
Gala	64.62	ab	78.08	b-g	5.52	d-f	3.83	f-h	47.98	a-e	69.41	b-e
Goldprince	59.61	a-d	62.53	i-k	7.58	b-f	5.72	d-h	48.25	a-e	49.67	hi
Harvester	61.73	ab	79.87	b-f	3.36	ef	7.18	c-h	44.21	b-e	66.09	c-e
Julyprince	68.46	a	72.64	e-i	0.38	f	4.74	e-h	50.07	a-d	51.19	g-i
June Fire	61.82	ab	83.12	a-f	8.02	b-f	11.40	b-h	50.98	a-c	64.88	c-f
Juneprince	56.23	b-d	73.41	e-h	5.85	d-f	11.78	b-h	41.40	de	75.11	bc
Majestic	64.73	ab	87.48	ab	3.39	ef	10.21	b-h	55.26	ab	80.97	ab
Elberta	62.08	ab	88.35	ab	3.58	ef	5.45	d-h	51.85	a-c	76.11	a-c
Red Globe	63.75	ab	71.22	f-j	3.10	ef	14.42	a-g	47.84	a-e	60.23	d-h
Rich Lady	65.77	ab	74.52	d-h	3.65	d-f	4.77	e-h	42.90	b-e	60.97	d-h
Rich Pride	58.68	a-d	71.00	f-j	8.55	b-f	17.38	a-c	46.54	a-e	61.42	d-g
Rubyprince	61.86	ab	65.75	h-k	8.34	b-f	6.61	c-h	45.68	a-e	54.25	f-i
Ruston Red	62.47	ab	85.95	a-c	2.42	f	12.19	a-g	56.72	a	87.36	a
Scarletprince	62.59	ab	73.14	e-i	1.88	f	4.96	e-h	43.76	b-e	52.11	g-i
Sierra Rich	58.91	a-d	77.71	b-g	8.15	b-f	8.40	b-h	52.44	a-c	66.80	c-e
Springflame	57.10	b-d	61.64	jk	9.39	b-f	5.08	d-h	51.59	a-c	61.96	d-g
Springprince	67.48	a	70.83	f-j	10.35	b-f	17.51	ac	57.18	a	59.68	e-h
Summerflame	50.92	cd	84.68	a-d	23.03	a	14.56	a-f	41.84	c-e	74.47	bc
Sureprince	60.00	a-d	68.59	g-j	8.32	b-f	15.57	a-e	45.38	a-e	64.91	c-f
White Lady	65.97	ab	91.62	a	0.69	f	0.85	h	22.52	f	34.38	j

[z]L* values range from 0 (black) to 100 (white), represents lightness; a* values range from positive (red) to negative (green); and b* values range from positive (yellow) to negative (blue).
[y]Different letters within a column indicate significant difference between genotypes using Tukey's test, *P*-value <0.05.

TABLE 4.6. PAIRWISE CORRELATIONS OF PEACH QUALITY EVALUATION ATTRIBUTES BETWEEN SEASONS

Variable 1	Variable 2	Correlation (*r*)	*P*-value
Skin L*[z] 2015	Skin L* 2016	0.76	<.0001
Skin a* 2015	Skin a* 2016	0.70	<.0001
Skin b* 2015	Skin b* 2016	0.72	<.0001
Flesh a* 2015	Flesh a* 2016	0.67	0.0001
Flesh b* 2015	Flesh b* 2016	0.51	0.007
SSC 2015	SSC 2016	0.49	0.0064
TTA 2015	TTA 2016	0.50	0.0047
SSC/TTA 2015	SSC/TTA 2016	0.86	<.0001

[z]L* values range from 0 (black) to 100 (white), represents lightness; a* values range from positive (red) to negative (green); and b* values range from positive (yellow) to negative (blue). SSC= soluble solid concentration. TTA= total titratable acidity.

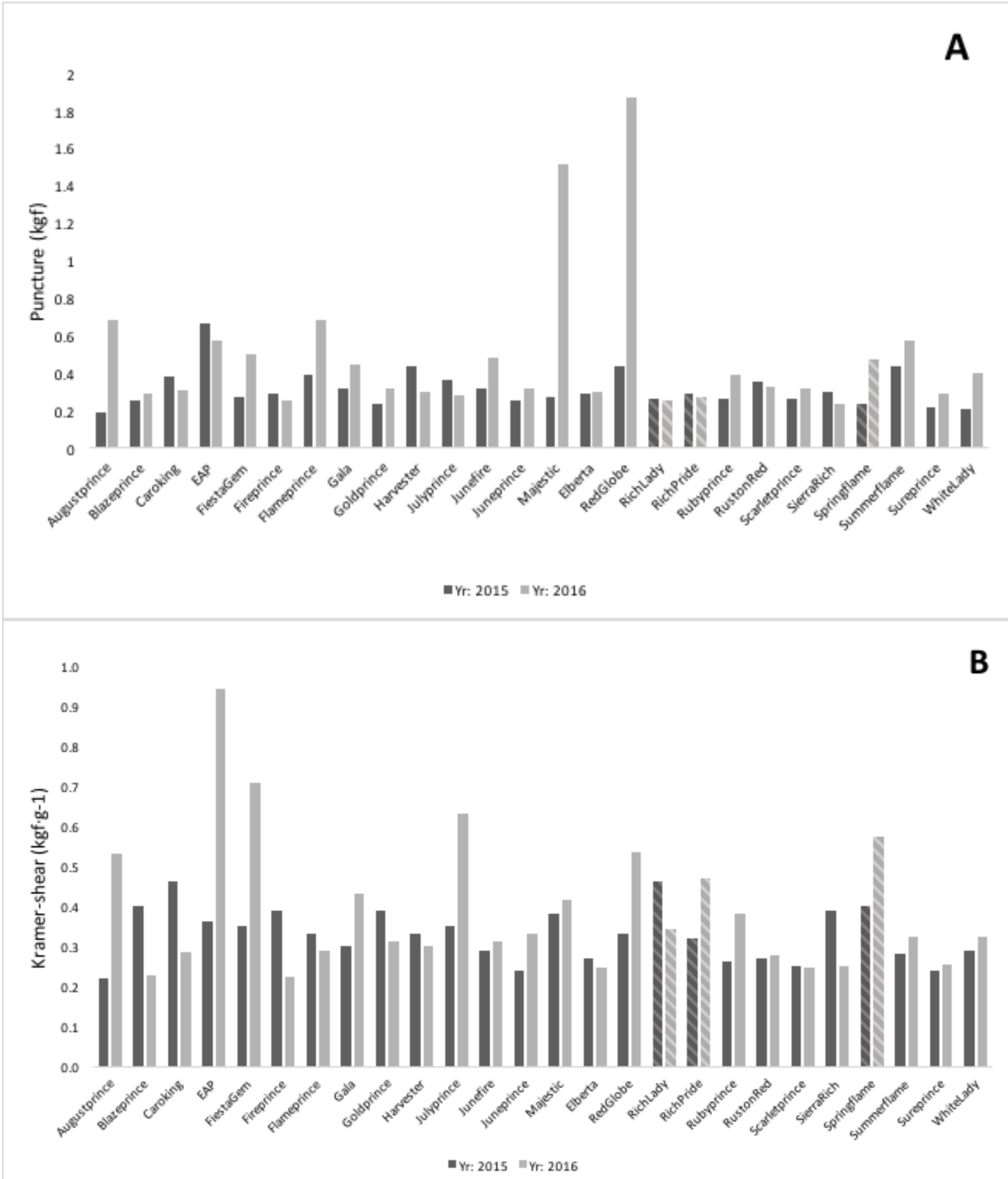
TABLE 4.7. PAIRWISE CORRELATIONS BETWEEN DIFFERENT QUALITY ATTRIBUTES OF 30 PEACH GENOTYPES PER SEASON IN GEORGIA

2015 Correlations				2016 Correlations			
Variable 1	Variable 2	Correlation (*r*)	*P*-value	Variable 1	Variable 2	Correlation (*r*)	*P*-value
Skin L*[z]	Skin a*	-0.55	0.0027	Skin L*	Skin a*	-0.66	0.0002
	Skin b*	0.89	<.0001		Skin b*	0.84	<.0001
					Flesh L*	0.56	0.0025
					Flesh b*	0.49	0.0098
					SSC	0.51	0.0065
				Skin b*	Flesh b*	0.55	0.0032
Flesh L*	Flesh a*	-0.74	<.0001	Flesh L*	Flesh b*	0.5	0.0081
					TTA	-0.57	0.002
					SSC/TTA	0.56	0.0022
				Flesh a*	Flesh b*	0.46	0.0147
					SSC	0.46	0.014
SSC/TTA	TTA	-0.79	<.0001	SSC/TTA	SSC	0.48	0.0068
					TTA	-0.84	<.0001
				TTA	Puncture	0.5	0.0098
				SSC	Compress 1	0.54	<.0001
First compression[y]	Second Compression	0.99	<.0001	First compression	Second compression	0.78	0.0014

[z]L* values range from 0 (black) to 100 (white), represents lightness; a* values range from positive (red) to negative (green); and b* values range from positive (yellow) to negative (blue). SSC= soluble solid concentration. TTA= total titratable acidity.

[y]Compression test. First compression is when the moving plate is compressed vertically from a starting point of 10 mm to 2 mm height. Second compression is when the moving plate repeats the previous compression.

[y]Compression test. First compression is when the moving plate is compressed vertically from a starting point of 10 mm to 2 mm heigh


A
B
Puncture (kgf)
Kramer-shear (kgf·g-1)
Augustprince
Blazeprince
Caroking
EAP
FiestaGem
Fireprince
Flameprince
Gala
Goldprince
Harvester
Julyprince
Junefire
Juneprince
Majestic
Elberta
RedGlobe
RichLady
RichPride
Rubyprince
RustonRed
Scarletprince
SierraRich
Springflame
Summerflame
Sureprince
WhiteLady
Yr: 2015
Yr: 2016

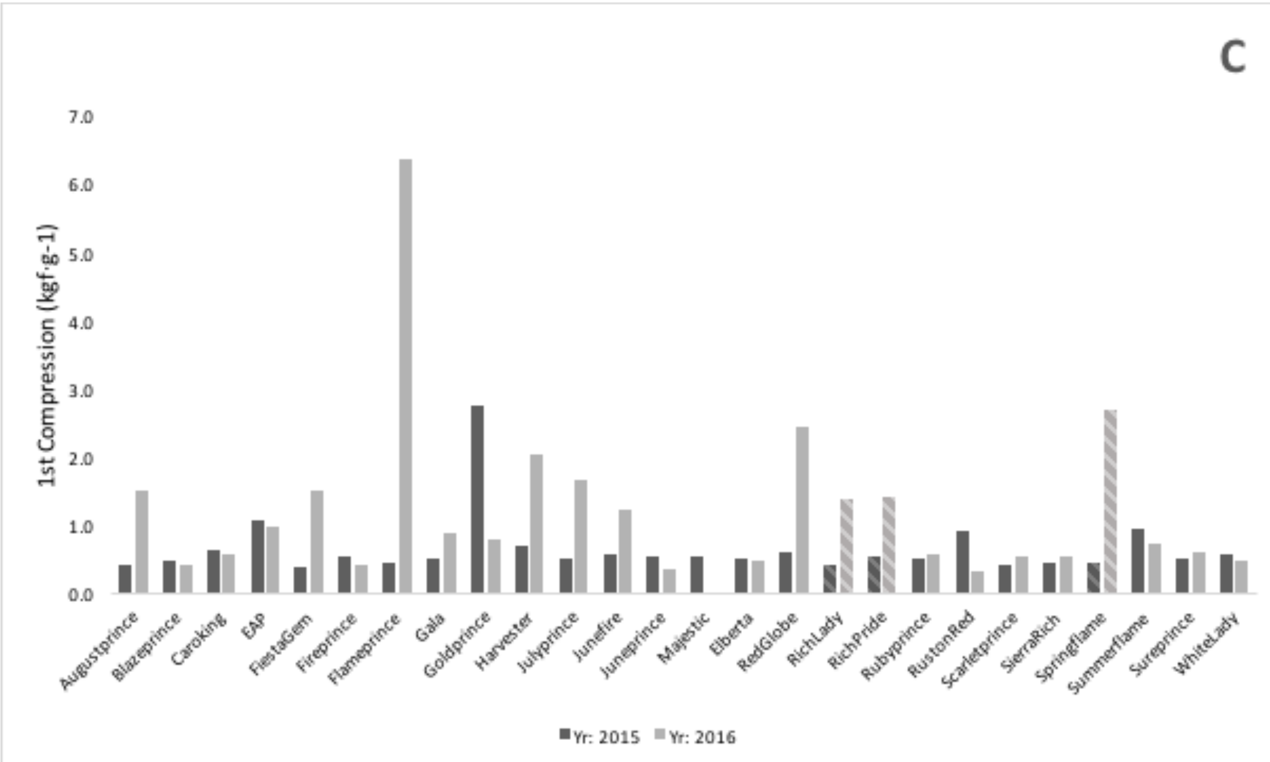


Fig. 4.1. Mean texture values for 26 commercial melting and non-melting peach varieties grown in Georgia over two seasons. A) Puncture measured where a 7.9 mm diameter probe vertically punctures into at an 8 mm depth, B) Kramer-shear measured where a 70 mm wide upper blade with ten 3 mm thick blades vertically shears to a 46 mm depth at 100 mm/min vertically, C) Compression measured as the kgf/g used for a moving plate to compress 10 x 15mm (L x W) section of peach fruit vertically from a starting point of 10 mm to 2 mm height. Values are presented as means of 3-5 replicates. Dashed bars represent non-melting cultivars.

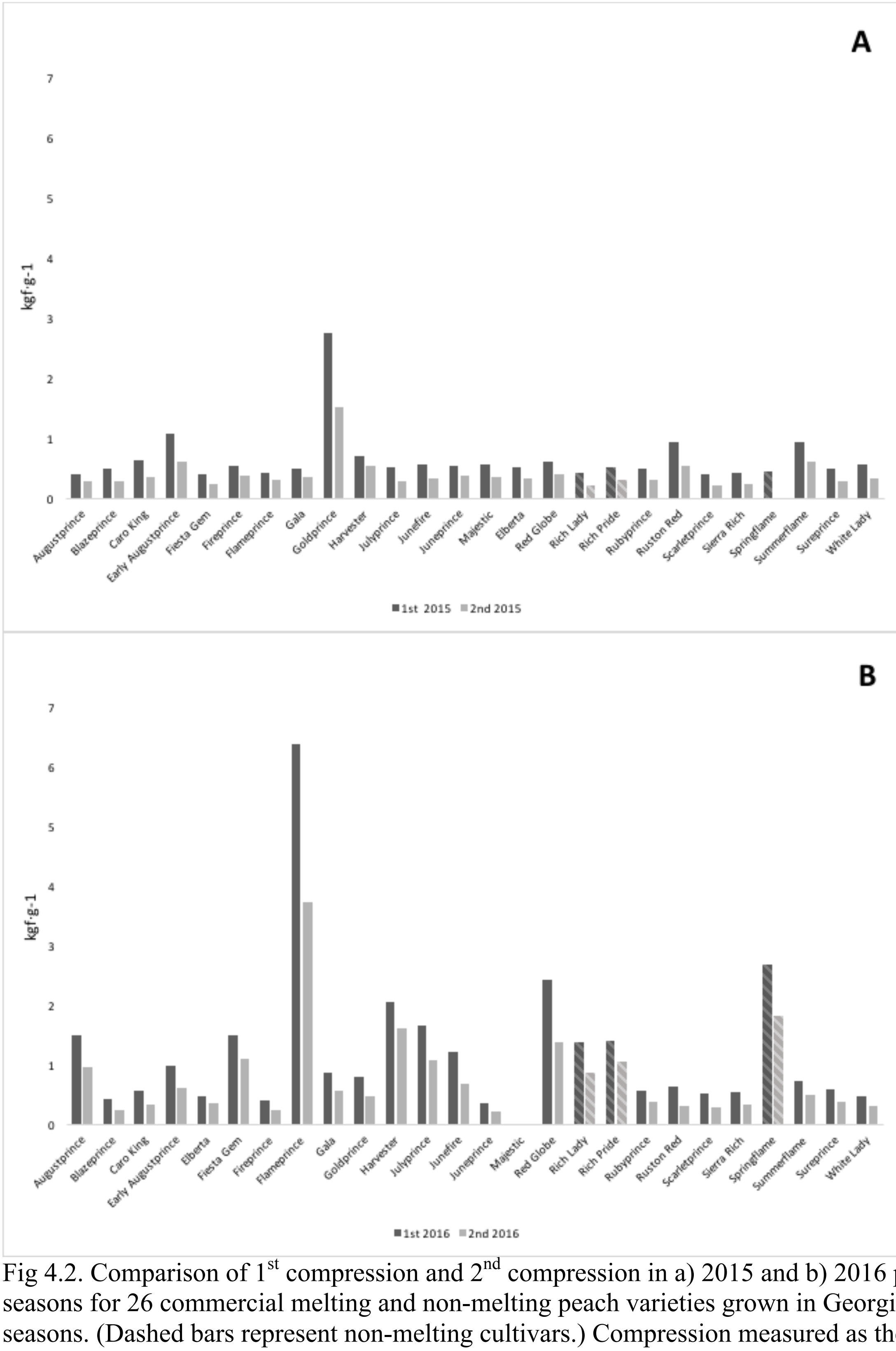


Fig 4.2. Comparison of 1st compression and 2nd compression in a) 2015 and b) 2016 peach seasons for 26 commercial melting and non-melting peach varieties grown in Georgia over two seasons. (Dashed bars represent non-melting cultivars.) Compression measured as the kgf/g used for a moving plate to compress 10 x 15mm (L x W) section of peach fruit vertically from a starting point of 10 mm to 2 mm height. Values are presented as means of 3-5 replicates.

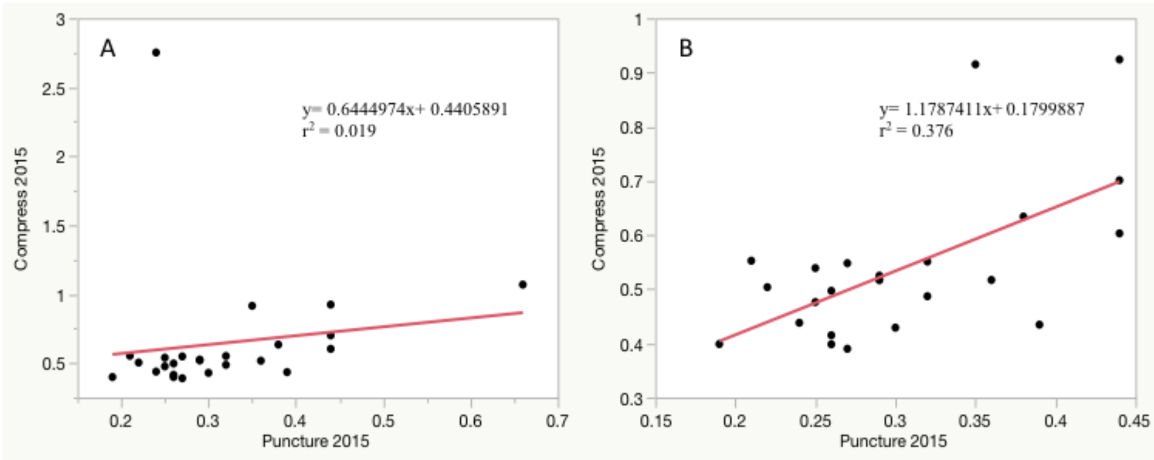


Fig 4.3. Linear fit of puncture values by compression values in 2015. (A) Represents mean values of each variety (26) from five replicates (r = 0.17). (B) Quantile method used to calculate 'Goldprince' and 'Early August Prince' as outliers (r = 0.613). Regression equation and r^2 value shown.

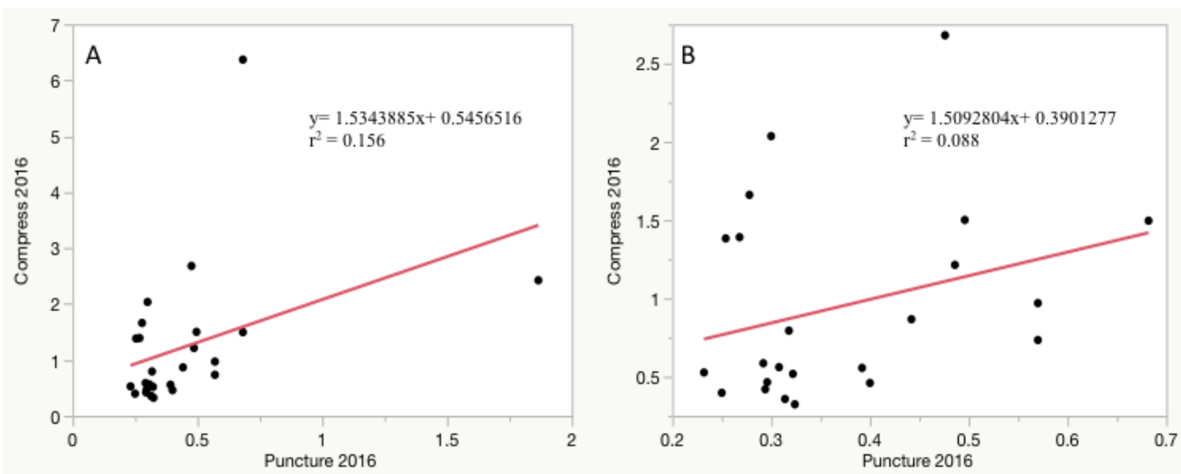


Fig 4.4. Linear fit of puncture values by compression values in 2016. (A) Represents mean values of each variety (26) from five replicates (r = 0.395). (B) Quantile method used to calculate 'Flameprince', 'Majestic', and 'Red Globe' as outliers (r = 0.297). Regression equation and r^2 value shown.

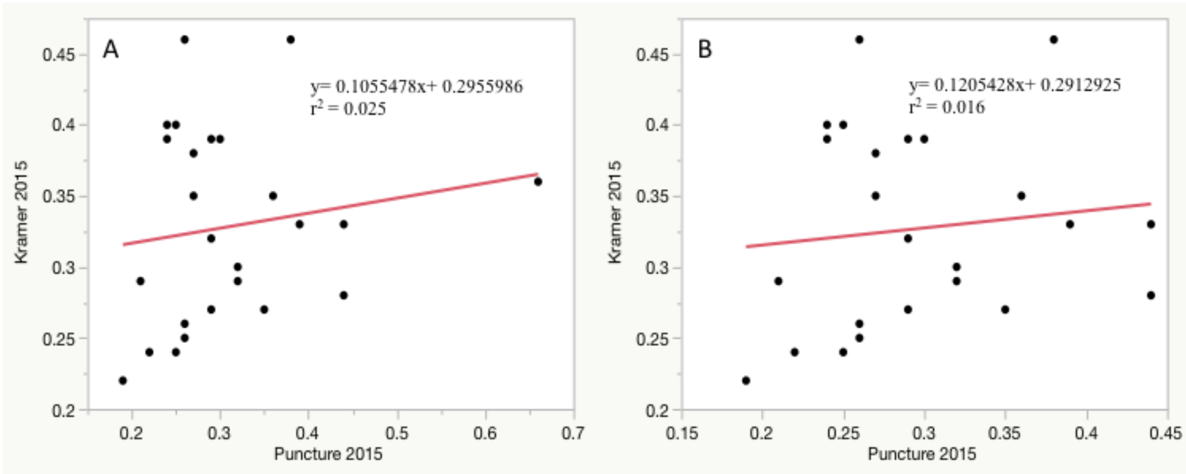


Fig 4.5. Linear fit of puncture values by Kramer-shear values in 2015. (A) Represents mean values of each variety (26) from five replicates (r = 0.158). (B) Quantile method used to calculate 'Early August Prince' as outliers (r = 0.126). Regression equation and r^2 value shown.

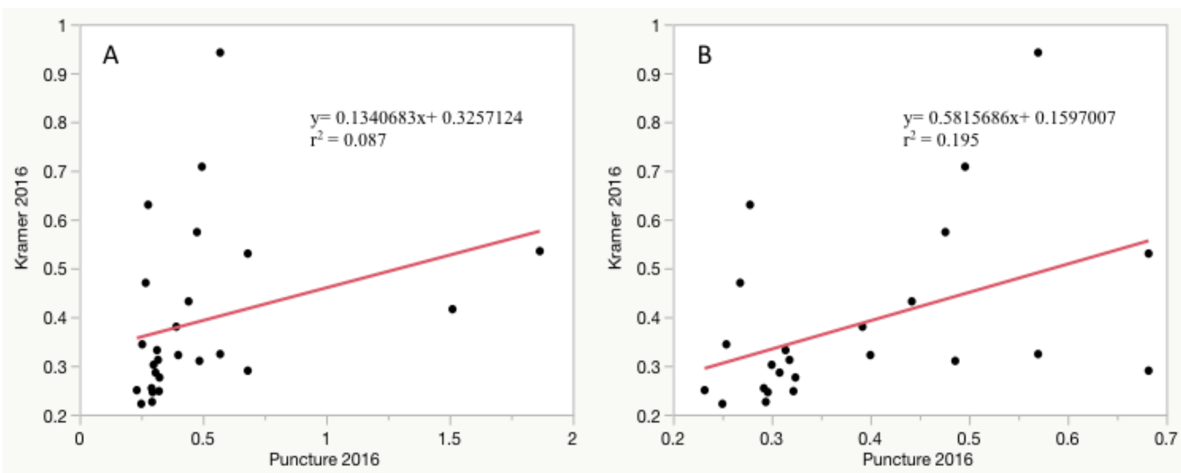


Fig 4.6. Linear fit of puncture values by Kramer-shear values in 2016. (A) Represents mean values of each variety (26) from five replicates (r = 0.295). (B) Quantile method used to calculate 'Majestic' and 'Red Globe' as outliers (r = 0.442). Regression equation and r^2 value shown.

CHAPTER 5

CONCLUSIONS

A peach lexicon for describing characteristics of peach fruit is now standardized and able to be used universally. Texture and feeling factor characteristics were adapted to provide suitable terms for all types of peach textures as well as with varying degrees of ripeness. Additionally, aroma and flavor attributes were successfully identified and characterized. These terms were carefully selected to represent attributes of mature peaches with additional focus on under-ripe and over-ripe characteristics. With a total of twenty-nine descriptive attributes established, the sensory characteristics of fresh peach varieties can be understood in more depth than previously available. In future studies, this lexicon can be used with trained descriptive panelists to distinguish the perceived intensities of attributes in comparing varieties or the effects of flavor and/or texture on treatments of peaches. From that point, consumer studies could be conducted and acceptance/liking results can be related with the attributes and the strength at which they were perceived by the descriptive panel. This is essentially useful for pre-, post-harvest, and commercialized peaches on a uniform scale; and can be exceedingly beneficial for comparing varieties currently available, creating a database useful in breeding applications, and evaluating the effects of certain treatments on quality. Studying the sensory characteristics of peach fruit are becoming of utmost importance for successful marketing and consumer purchases. This will help growers produce fruit with desirable quality traits to be successful on the market.

Surveying a large variation of commercial peach fruit showed to be beneficial as well. With this study, the quality evaluations for a large variety of commercially mature peach fruits were collected and can be used to understand the variation in parameters such as color, SSC, TTA, and texture profiles. In addition, peach quality is becoming more critical and is being defined by consumers now more than in the past 50 years. Many of the quality characteristics have been given parameters of acceptability. Research to evaluate the effects of such quality characteristics with regards to their perception and liking by today's consumers are the next step in understanding the quality attributes of peaches in the southeastern U.S. Texture values need to be compared with descriptive sensory analysis to determine the most practical physical measurement as compared with sensory perception. In addition, the provided database of information can be utilized to select varieties for future studies based on quality attributes.

With providing a database of attributes in the lexicon, it is also essential to provide the instrumental values in which they can be compared. Researchers more often use chemical and physical values to compare and relate products with quality. The purpose of these studies was to provide further and more useful information to producers and researchers so that a positive movement can be made in the peach industry in regards to quality and desired attributes by consumers in the future.