

EVALUATION OF BLUEBERRY FRUIT QUALITY USING INSTRUMENTAL ANALYSES
AND CONSUMER SENSORY PERCEPTION

by

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(Under the Direction of Rachel Itle and Koushik Adikari)

ABSTRACT

Three main commercially grown blueberry types are grown in the United States: southern highbush (SHB, species complex of *Vaccinium corymbosum* L. and *V. darrowii* Camp), rabbiteye (RE, *V. virgatum* Aiton), and northern highbush (NHB, *V. corymbosum* L). Within the blueberry industry, there is a subjective bias that NHB have superior fruit quality traits over SHB and RE. The objective of this research was to compare the main commercially grown cultivars within each type for physicochemical traits (appearance, texture, and flavor) using instrumental analyses and consumer acceptability to determine whether or not NHB have superior fruit quality. Overall, there was significant variation among types and cultivars within a year and across years. Results do not support the industry's subjective bias, nor that RE are inferior to highbush types. Results will be shared with the industry to assist marketing and may help increase Georgia's overall share in the blueberry market.

INDEX WORDS: Southern highbush, Rabbiteye, Northern highbush, Physicochemical traits, Texture, Fiber, Seed, Soluble solid content, Total titratable acids, Anthocyanins, Overall liking

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DEDICATION

To my parents, avô, padrinhos, and auntie. “Deep roots are not reached by the frost.”

– J.R.R. Tolkien

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CHAPTER 1

INTRODUCTION

Blueberry fruit quality has been an important topic in the fresh fruit industry, in part due to their increased production and consumer demand (Gilbert et al., 2015; USDA-NASS, 2017). There are three main blueberry types in the U.S. that are commercially grown for fresh consumption: southern highbush (species complex of *V. corymbosum* L. and *V. darrowii* Camp), rabbiteye (*V. virgatum* Aiton), and northern highbush (*V. corymbosum* L.). Georgia is one of the top ten blueberry producing states in the U.S., often ranking within the top five states for fresh fruit production. The total state's acreage consists of both southern highbush (SHB) and rabbiteye (RE) blueberry types (USDA-NASS, 2019). To date, most research has focused on comparing physical and/or chemical instrumental analyses of cultivars within a type, or within and between two of these three types. Previous studies that were evaluated were focused on the blueberry physical and chemical characteristics. However, there has not been a reported study conducted comparing the major commercial cultivars within the three main types that currently best represent the overall blueberry market. In addition, there are limited amount of studies comparing instrumental analyses to consumer acceptability in blueberry.

Fruit quality characteristics, such as texture, appearance, flavor, aroma and nutritional benefits drive consumer overall acceptability, eating quality, and purchasing habits. Silva et al. (2005) suggested that although there is variation among NHB and RE quality measured by instrumental analyses. Phan et al. (2017) and Saftner et al. (2008) found that highbush were accepted by the majority of consumers because of their texture, flavor and sweetness compared

to rabbiteye. Gilbert et al. (2014) and Saftner et al. (2008) suggested that flavor was a predictor for an increased blueberry eating quality, followed by texture and appearance. Safter et al. (2008) also suggested that corresponding instrumental analyses were not indicators of consumer acceptability.

A larger assessment of early, mid and late harvested cultivars within each main commercial type needs to be conducted throughout multiple harvest seasons to assess quality conditions within and across years. Therefore, an assessment of eighteen and fourteen cultivars of the three main commercial types were evaluated in 2018 and 2019, respectively, with twelve cultivars in common between both years. The main objective of this study was to compare the physicochemical attributes among cultivars and types within a year and across years, using instrumental and consumer acceptability to determine whether NHB have superior fruit quality. This assessment will give a better understanding of which fruit quality traits consumers like by corresponding mean liking scores to instrumental analyses. Results may aid in future blueberry breeding using consumer-assisted selected traits, may reduce the subjective bias by the blueberry industry that NHB have superior fruit quality than SHB and RE, and may increase Georgia's profit share in the fresh fruit market.

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CHAPTER 2

LITERATURE REVIEW

INTRODUCTION

Blueberry industry overview

Blueberries, *Vaccinium* spp., are native to North America and were introduced into the food industry in 1916 (Gilbert et al., 2015). The United States is the largest in blueberry production, with 38 commercially producing states. In 2018, the top six fresh blueberry producing states were Oregon, California, Washington, Michigan, New Jersey and Georgia (USDA-NASS, 2019). From 2013 to 2015, production increased from 429 to 750.2 million pounds (Gilbert et al., 2015; U.S. Highbush Blueberry Council, 2016). In 2018, fresh cultivated blueberries were valued at approximately \$567.33 million (USDA-NASS, 2017). Georgia continues to be the top producing state in the southeastern U.S. Georgia's acreage as it is approximately 56% of the Southeastern US acreage. In 2018, Georgia produced approximately 32 million pounds of fresh cultivated fruit valued at approximately \$66.5 million (USDA-NASS, 2019). The overall increase in blueberry consumption has been associated with possible nutritional benefits (Saftner et al., 2008; USDA Economic Research Service, 2003; USDA National Agricultural Statistics Service, 2006).

The three main blueberry types commercially produced in the US are southern highbush (species complex of *V. corymbosum* L. and *V. darrowii* Camp), rabbiteye (*V. virgatum* Aiton)

and northern highbush (*V. corymbosum* L.). In 2016, the southeastern US, accounted for over 25% of 383 million pounds produced in North America (USDA-NASS, 2017). In Georgia, the two main types of commercially grown blueberries are southern highbush and rabbiteye, composing of approximately 60% and 40% of the commercial blueberry market in the state, respectively (Itle et al., 2018). Southern highbush cultivars require the least number of chill hours, approximately 100 to 500 hours, while rabbiteye cultivars require a moderate number of chill hours, approximately 300 to 650 hours. In Georgia, southern highbush are harvested from approximately mid-April to early June, and rabbiteye cultivars are harvested from approximately mid-June to early July. Northern highbush cultivars are not grown in Georgia as they require more chill hours, approximately 600 to 1000 hours, and are harvested from approximately July to August (Krewer et al., 2002; Krewer et al., 2006; Nesbitt et al., 2009) and compose the largest portion of the US blueberry market.

Growers in the Georgia industry grow both southern highbush and rabbiteye cultivars for the various advantages of both types. Southern highbush cultivars come onto the market first, and thereby demand a higher price as the main driver for price received for fruit is market timing throughout the blueberry industry. However, southern highbush are hand harvested, which costs approximately seven times that of machine harvesting. Additionally, the fruit are highly susceptible to yield losses because of late spring freezes from earlier flowering. Rabbiteye cultivars, however, ripen later which mitigates yield losses from spring freezes. Overall, rabbiteye are also more disease resistant, and are primarily machine harvested which is less expensive. However, the fruit quality of rabbiteye are often considered to be inferior to that of highbush types which can negatively affect the end price point received. In addition to the fruit quality consideration between southern highbush and rabbiteye, northern highbush cultivars are

considered to have the highest fruit quality over both southern highbush and rabbiteye cultivars. This can lead to reduced price points received for Georgia blueberry fruit. However, the fruit quality comparisons between the three blueberry types is largely subjectively based debated (Itle, 2018).

Fruit quality

One topic that has increased its popularity within the blueberry industry is fruit quality. Fruit quality is the combination of physical and chemical traits that determine the quality of the fruit. Quality and acceptance are determined by appearance, aroma, texture, flavor and nutritional value (Barrett et al., 2010). Preharvest and postharvest factors such as plant age, soil quality, growing location, harvesting methods, transportation, packaging and storage conditions may influence fruit quality traits and consumer acceptability (Itle et al., 2018).

Overall, blueberry breeding has largely focused on plant chilling requirement and general adaptability for a particular region, plant vigor, disease tolerance and resistance, and yield amount and uniformity, among other general horticultural traits. Originally, blueberry commercial production in the early 1900s and research and variety selection was primarily focused on cold hardiness, plant growth and development, soil pH requirements and pruning strategies (Mainland, 1998). In the late 1900s, Arlen Draper released several southern and northern highbush cultivars, ‘Duke’, ‘Elliott’, ‘Legacy’ and ‘Nelson’, which are still major cultivars grown by blueberry growers. Draper focused on breeding for fruit yield and physical traits, such as smaller pedicel scars, color and fruit firmness. Rabbiteye breeding began in 1939, followed by southern highbush breeding efforts in the following decades, with both focusing on physical traits such as overall appearance, color, size, skin toughness and fruit firmness (Hancock et al., 2008).

Breeding for blueberry fruit quality has mainly focused on traits that are easily identifiable and selectable in the field such as fruit size, steminess (ease of pedicel removal from the fruit when harvested), and stem scar size and dryness, among others. Blueberry breeders also evaluate fresh fruit traits such as firmness, skin toughness, seediness, fibrousness, outer skin color, wax content, and storability (Ballington et al., 1984; Itle and NeSmith, 2017a). Blueberry growers seek cultivars that produce superior fruit quality for fresh consumption, while maintaining high-density plantings, high fruit yield, and are pest and freeze tolerant. In addition, retailers want fruit that have excellent fruit quality and storability from the time they are harvested, until they are purchased by consumers. One fruit quality traits that commercial packers rely on is overall appearance, as it encourages initial purchasing habits, whereas flavor and texture influence continued purchasing habits (Slot, 2017). In addition to these standard fruit quality traits, there is a recent interest among growers, marketers, retailers and consumers alike to understand fruit quality traits in more detail. These traits include sugar, acid, anthocyanin and antioxidant content, among others. Additionally, there is a push in the blueberry industry to understand the actual fruit quality differences between the three commercial blueberry types, and between cultivars within a type, to help in fruit sale and marketing. There is also a growing interest to further understand the consumer sensory perception of these fruit quality traits within and between blueberry types. However, to date there have been few studies evaluating the variation of physicochemical fruit quality traits and their associated consumer sensory perception.

Consumer fruit quality characterization

Fruit quality, as determined by consumers, can be categorized as visual appeal (appearance and color), texture, overall flavor (taste and aroma by nose/mouth) and nutritional

value (Barrett et al., 2010). Overall appearance, size, glossiness, color, blemishes, and shape of the fruit influences whether or not the consumers will buy the product because of visual appeal (Barrett et al., 2010; Kramer, 1965). Once fruit are purchased, consumers determine the texture either with hand or mouthfeel, along with aroma and flavor. Texture characteristics may be perceived as smooth, crispy, mealy, gritty, etc., whereas flavor can be sweet, sour, bitter, fruity, floral, earthy, etc. Nutritional value, although unable to be perceived, has gained consumer appeal and influences consumption habits because of healthy lifestyle considerations (Barrett et al., 2010).

In one recent online study, participants were asked which fruit quality characteristics they desired in blueberries. The results suggested that purchasing habits may increase if blueberries had intense blue color, good shelf-life, sweetness and acidity balance, juiciness, firmness, crunchiness, and large size (Gilbert et al., 2014). Overall, very few published studies have been conducted on blueberry purchasing habits, especially those that coincide with blueberry consumer acceptability tests looking at the major commercial types produced in the U.S. In addition, there have been few studies on how blueberry appearance, flavor, texture, and aroma traits influence consumer sensory perception. No published study to date has examined a survey of the major commercial cultivars in the three main blueberry types for consumer acceptability.

INSTRUMENTAL EVALUATION OF FRUIT QUALITY

Instrumental evaluation can measure both physical and chemical traits of fruits, such as color, size, shape, firmness, flavor, and nutritional quality. These objective analyses are defined, precise and accurate. Instrumental evaluation may be able to detect differences in fruit quality that may not be able to be perceived by humans, such as nutritional compounds, and have been used as the main method to evaluate fruit quality traits in fruit and vegetable crops.

Texture

Fruit skin toughness and fruit firmness

Texture continues to be the main quality the commercial fruit industry and consumers seek for acceptability. Fruit texture is detected by consumers in several ways such as by touch, hand feel, and/or mouthfeel. One of the largest contributors to fruit texture is their insoluble solids (Barrett et al., 2010). Fruit development and ripening affect overall texture and firmness. Changes in fruit texture have been associated with turgor pressure loss, membrane composition degradation, and decreased cell wall strength and cell-to-cell adhesion. When these changes occur, fruit become less firm, and are less accepted by consumers (Goulao and Oliveira, 2008).

Instrumentally, there are three main methods for evaluating blueberry fruit texture. A puncture test examines skin strength/toughness of an individual berry by measuring the maximum force needed to pierce the fruit (Blaker et al., 2014; Itle and NeSmith 2017a; Silva et al., 2005). A Kramer shear test examines fruit firmness of a multiple berry sample by measuring the maximum force needed to shear the skin and the flesh (Itle and NeSmith 2017a; Silva et al., 2005), and a compression test examines fruit firmness of an individual berry by measuring the maximum force needed to deflect the fruit by 2 mm (Blaker et al., 2014).

Texture has been examined in blueberry fruit as it relates to numerous factors, as storage temperature and duration, cultivar, harvest maturity, harvest method, transportation, grading and packaging may all influence blueberry fruit softening (Maclean and NeSmith, 2011). Blueberry texture has been surveyed as it relates to cultivar (Saftner et al., 2008; Silva et al, 2005) and blueberry germplasm differences (Blaker et al., 2014; Ehlenfeldt et al., 2002). However, to date, there has been limited work done to compare the textural attributes of the main cultivars of the three main commercial blueberry types.

Textural traits that are debated among the three blueberry types are skin toughness, fruit firmness, seed content, and mealiness. Results have been varied for textural traits across blueberry types. Makus and Morris (1993) evaluated three northern highbush ('Collins', 'Bluecrop' and 'Herbert') and three rabbiteye cultivars ('Climax', 'Tifblue' and 'Menditoo') over three seasons for fruit quality traits. Results suggested that rabbiteye cultivars were approximately 1.5 times firmer than northern highbush cultivars. In another study examining three rabbiteye ('Climax', 'Premier' and 'Tifblue') and two northern highbush cultivars ('Bluecrop' and 'Jersey'), the results suggested that rabbiteye fruit had approximately 1.5 times tougher skin and approximately 2 times firmer fruit than northern highbush, respectively (Silva et al., 2005). Saftner et al. (2008) examined ten northern highbush cultivars ('Chanticleer', 'Duke', 'Hannah's Choice', 'Weymouth', 'Berkeley', 'Bluecrop', 'Coville', 'Elliott' and 'Lateblue') and two rabbiteye cultivars ('Coastal' and 'Montgomery'), results suggested that not all rabbiteye cultivars were firmer than northern highbush. The most recent study examining seven rabbiteye cultivars ('Alapaha', 'Brightwell', 'Ochlockonee', 'Powderblue', 'Premier', 'Tifblue' and 'Vernon') and seven southern highbush cultivars ('Camellia', 'Emerald', 'Farthing', 'Legacy', 'Meadowlark', 'Rebel' and 'Star'), researchers suggested that rabbiteye cultivars did not have tougher skins than southern highbush. Rabbiteye fruit were also found to be firmer than southern highbush (Itle and NeSmith, 2017b), which contradicts the subjective bias that rabbiteye have tougher skins than that of highbush types.

Overall, results from these studies do not support that rabbiteye have inferior fruit texture to highbush types. Additionally, due to either the limited number of cultivars evaluated, older cultivars that are currently of limited commercial importance, and/or evaluations conducted only

for one growing season, more thorough studies need to be conducted to further understand textural similarities and differences between the three blueberry types.

Seed content

Fruit texture is also highly influenced by seed and fiber. When compared to other fruit and berry crops, generally blueberry seeds are much smaller and not as noticeable during consumption. In general, seeds that are larger in size and number may be perceived as unfavorable to consumers. In addition, seeds are also known to have beneficial compounds such as a high content of polyunsaturated fatty acids (PUFAs), as well as a favorable n-3 to n-6 fatty acid ratio desirable for dietary intake compared to that of vegetable oils. Seeds also contain antioxidants and ascorbic acid (Hoed et al., 2009; Parker et al., 2003; Parry et al., 2005).

Numerous factors can affect seed amount in a berry fruit. These include unfavorable weather conditions during flower pollination and fruit set, which can include freezing temperatures that damage flower pistils preventing pollen from fertilizing embryos, and wet and cool weather that reduces pollen shed preventing adequate pollination, among others. Availability of pollinators and pollen from different cultivars can also have a large impact on seed and fruit set in blueberry as it is a highly self-incompatible and outcrossing crop (Itle, 2020).

Instrumentally, seeds are simply measured by extracting seed from the fruit, categorizing, counting, and weighing them. Blueberry seeds are found toward the center of the fruit. Fruit have approximately five carpels, five to ten locules, and five lignified placentae (Gough, 1994; Johnson et al., 2011). Around the placentae there are approximately 50 to 65 seeds (Blaker, 2014; Gough, 1994).

Overall, blueberry seed amount between the three blueberry types is debated, however it has been minimally investigated in the literature. At present, there is only one known study examining seed content between the blueberry types. Nine southern highbush genotypes ('Legacy', 'Meadowlark', 'Camellia', 'Emerald', 'Farthing', 'TH-1125', 'TH-1111' and 'Rebel') and seven rabbiteye cultivars ('Vernon', 'Premier', 'Alapaha', 'Tifblue' 'Brightwell', 'Powderblue' and 'Ochlockonee') were evaluated for number of plump and shriveled seeds, total seed weight and percent seed weight to berry weight. There were significant differences ($P \leq 0.05$) for overall plump seed number and total seed weight between southern highbush and rabbiteye types. However, southern highbush had 11% more shriveled seed and 7% more total seeds than rabbiteye cultivars. Rabbiteye also had twice the percent seed weight : berry weight than southern highbush (2.1% vs 1.1%) (Iltis and NeSmith, 2016b). Overall, results suggest that highbush types are not superior to rabbiteye for seed characteristics. More research is needed on the main commercial cultivars within each type to further understand the seed levels present across cultivars and types that represent the current commercial blueberry market.

Fiber content

Fruit fiber is composed of multiple components. Fruit cell walls contain cellulose, pectin, lignin, and hemicellulose, and these cell wall components greatly impact the overall texture (Silva et al., 2005). The mesocarp, contains an uneven size and total amount of stone cells, that are composed of more lignin than cellulose (Gough, 1993). Vascular bundles and stone cells contain fibers and sclereids that are lignified, and give support and structure to the fruit flesh. Additionally, the stone cells within a fruit can lead to a woody and gritty texture, and due to lignin composing most of the structure of stone cells, lignin may be used to examine this textural trait (Silva et al., 2005).

Overall fruit fiber content, found within the fruit cell wall and flesh structure, can be affected by the fruit growth and development. Environmental factors during the fruit development period such as temperature, soil moisture content, and humidity can all play a role in fruit development. These factors may negatively impact fruit overall, as well as their texture.

Fiber content can be determined instrumentally by measuring the neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin content. These components are measured using a multiple berry sample, drying the composite sample down, and using chemical extraction. From measuring these three, cellulose and hemicellulose content can be calculated (Silva et al., 2005).

Fibrous fruit is not considered to be a desirable textural trait in blueberry. It is often discussed as a negative fruit quality trait with differences between the blueberry type. Among the three types, rabbiteye are considered to have negative textural traits influenced, in part, by fiber content. Fruit fiber content has been compared between blueberry types in two studies. In the first study, three rabbiteye cultivars ('Climax', 'Premier' and 'Tifblue') were compared to two northern highbush cultivars ('Bluecrop' and 'Jersey') over one season. Results suggested that rabbiteye had a significantly higher amount of NDF, lignin, hemicellulose and cellulose. The two blueberry types were not significantly different for ADF and total pectin (Silva et al., 2005). The second study examined a larger number of cultivars, measuring fiber content in seven southern highbush cultivars ('Legacy', 'Meadowlark', 'Camellia', 'Emerald', 'Farthing' and 'Rebel') and in seven rabbiteye cultivars ('Vernon', 'Alapaha', 'Premier', 'Powderblue', 'Tifblue', 'Brightwell' and 'Ochlockonee') over two seasons. Rabbiteye were significantly higher than southern highbush for all fiber traits examined including NDF, ADF, lignin, hemicellulose and cellulose. Results from these studies suggest that rabbiteye may have more insoluble fiber content, which may contribute to negative subjective opinions and consumer taste

perception. However, these studies do not address fruit quality comparisons for fiber across the three blueberry types over multiple seasons. A more comprehensive study of fruit fiber would be beneficial to further understand fruit fiber content and the affect it may have on consumer acceptability.

Fruit size

Fruit appearance is influenced by physical characteristics (size, shape and morphology) and blemishes (bruises, skin cracking and spots), wax, and overall uniformity (Barrett et al., 2010; Mitcham et al., 1996). Fruit size, shape and appearance also determine whether or not a consumer will purchase them. Research has indicated, through sensory evaluation, that there is a greater preference for larger sized blueberry fruit (Donahue et al., 2000; Saftner et al., 2008). Fruit size variation may be associated with cell number. High cell counts have been associated with larger fruit in strawberry [*Fragaria x ananassa* (Cheng and Breen, 1992)], apple [*Malus x domestica* (Denne, 1960)], sweet cherry [*Prunus avium* (Olmstead et al., 2007)] and rabbiteye blueberry [*Vaccinium ashei* (Johnson et al., 2011)]. Cell number is determined by cell production in the ovary before bloom and during fruit growth through cell expansion. Cell expansion in the mesocarp has been associated with size, weight and diameter. In addition to the cell number and similar to textural traits, any factor that may affect fruit development and ripening may also affect the overall fruit size.

Blueberry fruit size is typically measured using weight of a subset of fruit harvested randomly and through the entire bush, as fruit size varies within a plant and cultivar. Weights, in both individual and composite measurements of a group of fruit (i.e. 10, 20, 50, etc. berry measurements) are typically done. Size measurements using calipers to measure fruit size

equatorially (berry diameter/width) and perpendicular to this along the stem to calyx portion of the fruit (berry height) is also done, although this is less common (Itle, 2020).

There have been a few recent studies that have examined fruit size variation between blueberry types. In one study, three rabbiteye cultivars ('Climax', 'Premier' and 'Tifblue') were compared to two northern highbush cultivars ('Bluecrop' and 'Jersey') for fruit weight, diameter, and height. Cultivars and types were not significantly different for weight or diameter, however, there were significant differences with rabbiteye having a larger height than northern highbush (Silva et al., 2005).

In another study, ten northern highbush cultivars ('Chanticleer', 'Duke', 'Hannah's Choice', 'Weymouth', 'Berkeley', 'Bluecrop', 'Bluegold', 'Coville', 'Elliott' and 'Lateblue') and two rabbiteye cultivars ('Coastal' and 'Montgomery') were evaluated using instrumental and consumer sensory acceptability of individual fruit weight and size. Fruit weight for 'Montgomery', 'Coastal' and 'Weymouth' were significantly lower than that of other cultivars. Additionally, smaller fruit were not as accepted by consumers compared to those of larger size. 'Coastal', 'Montgomery' and 'Weymouth' fruit sizes ranged from good to excellent scores, yet their overall eating quality were least liked, with 'Coastal' rating below acceptable eating quality (Saftner et al., 2008).

In one of the most recent studies comparing blueberry types (Itle and NeSmith, 2016a), fruit weight, diameter and height were among the fruit quality traits evaluated. Seven southern highbush ('Camellia', 'Emerald', 'Farthing', 'Legacy', 'Meadowlark' and 'Rebel') and seven rabbiteye ('Alapaha', 'Brightwell', 'Ochlochonee', 'Powderblue', 'Premier', 'Tifblue' and 'Vernon') were evaluated over two seasons. Southern highbush and rabbiteye weight and sizes were significantly different between cultivars and types. 'Meadowlark' had larger berry weight,

berry equator diameter and stem scar to calyx diameter, compared to that of other southern highbush and rabbiteye cultivars. ‘Alapaha’, ‘Brightwell’, ‘Ochlockonee’ and ‘Powderblue’ had smaller berry weight and diameters compared to other cultivars. Overall, rabbiteye fruit were smaller than southern highbush fruit (Itle and NeSmith, 2016a).

Overall, there have been few studies that have analyzed individual berry weight, diameter and height of the current commercial cultivars within the three main types. The majority of which evaluated a limited number of cultivars and/or types, a low sample size, and/or evaluated over only one season. Evaluating the main cultivars within each of the three major blueberry types over multiple years would allow for a better understanding of actual blueberry fruit size and shape variation.

Color

Fruit color develops during maturation and ripening. Blueberry natural pigmentation is because of the water-soluble anthocyanins, which determine whether the fruit are red, blue or purple (Barrett et al., 2010). Blueberry glossiness, a whitish wax that is also known as bloom, coats the outer layer of fruit skin and influences fruit color. It also can vary between cultivars (Albrigo et al., 1980; Retamales et al., 2012; Sapers et al., 1984). Waxes form when the parenchyma cells in the epidermis create a thick lipid layer of cuticle and coats the epicarp, also known as the fruit’s skin (Blaker et al., 2014). Epicuticular waxes (shapes varying from short, to amorphous, and to narrow rods) give the fruit a powdery blue appearance and can vary from berry to berry on a plant, and from cultivar to cultivar (Fava et al., 2006; Gough, 1994).

Blueberry wax may be affected by mechanical harvesting, moisture content, cold storage conditions, amount of wax content on the epidermis and postharvest handling (Barrett et al., 2010; Mitcham et al., 1996). Without bloom, fruit quality loss may occur due to water loss,

shrinking, and increased transpiration rate which may affect overall fruit visual appearance (Freeman et al., 1979; Loypimai et al. 2017). In one study where southern highbush fruit wax content was rubbed off and evaluated, Loypimai et al. (2017) saw that moisture loss, fruit firmness and berry weight were affected, corresponding to berry brightness, or hue. Moisture loss has also been associated to less wax content, observed in studies evaluating northern highbush (*V. corymbosum*) (Paniagua et al., 2013) and European plum (*Prunus domestica* L.) (Mukhtar et al., 2014). This may also be due to the wax layer providing a protection layer, which reflects the sun radiation (Bacher and Blanke 1999; Loypimai et al., 2017; Müller and Riederer, 2005).

Fruit color can be measured objectively using two main methods. First, comparisons to standardized color charts can be done using The Royal Horticultural Society Colour Chart (Voss, 2001). Second, color can be measured numerically using a colorimeter, which measures light reflectance to obtain color space values originating from and X, Y, Z chromaticity coordinate system. The most commonly used and reliable system for measuring numeric color values in fruit and vegetable crops is the CIE L*a*b* color space system. This method is considered to be more reliable as it does not rely on the human eye and factors that affect sight such as lighting, eye age and health, among others. L* measures the lightness or brightness of color (0=black, 100 = white), a* and b* are chromaticity coordinates (+a* = red, -a* = green; +b* = yellow, -b* = blue). Chroma, the saturation or vividness of color, and hue angle are calculated using a* and b* (HunterLab, 1996; Konica Minolta, 2019).

Fruit overall appearance, may be impacted by fruit color, and may affect consumer purchasing habits. Previous studies have used L* and b* values as estimates of wax levels on blueberries and have compared them to consumer preference (Makus and Morris, 1993) and fruit

eating quality (Saftner et al., 2008). In one study, three rabbiteye cultivars ('Climax', 'Tifblue' and 'Menditoo') were compared to three northern highbush cultivars ('Collins', 'Bluecrop' and 'Herbert'). Results suggested that rabbiteye had a larger hue angle, whereas northern highbush cultivars had larger L^* , a^* , b^* and chroma values (Makus and Morris, 1993). Silva et al. (2005) results suggested that L^* values did not differ between types and cultivars when evaluating three rabbiteye ('Climax', 'Premier' and 'Tifblue') and two northern highbush cultivars ('Bluecrop' and 'Jersey'). Northern highbush had a larger hue angle, more intense blue color and chroma, and lower a^* , b^* values than rabbiteye. Saftner et al. (2008) examined ten northern highbush cultivars ('Chanticleer', 'Duke', 'Hannah's Choice', 'Weymouth', 'Berkeley', 'Bluecrop', 'Bluegold', 'Coville', 'Elliott' and 'Lateblue') and two rabbiteye cultivars ('Coastal' and 'Montgomery') and the results suggested that northern highbush have larger L^* values, more intense (chroma) and lower a^* and b^* values. Results from these studies suggest that rabbiteye may have more bloom due to large L^* values and northern highbush have less bloom with a more intense blue color due to lower b^* and larger chroma values. A more thorough investigation into fruit color traits and consumer perception with the major cultivars across the three main commercial types would help to further understand fruit quality traits relating to appearance.

Sugar and acid content

Sugar and acid content are two traits that influence overall fruit quality. Fresh fruit is usually consumed by itself or added to other food to enhance flavors and sweetness. Most fruit are harvested before the optimal sweetness is reached, as sugars (soluble solids or °brix) increase as fruit ripens (Barrett et al., 2010). Blueberries are harvested when they turn blue in color, rather than waiting for the desired soluble solids (SS) content and total titratable acidity (TTA).

Additionally, environmental factors such as irrigation, precipitation, temperature, chill period, and crop load that have been shown to affect flavors, sugar, and acid content (Gilbert et al., 2015).

Overall, soluble solid content in fruit and vegetable crops is commonly measured using a refractometer, which can be handheld that can be taken to the field for quick evaluations or digital that can be used for more precise measurements in the lab. Refractometers measure the amount of light refraction, or refractive index, that passes through a juice sample. The higher the angle of refraction, the higher the total soluble solids in the juice solution, and the higher the estimate of overall sugar content. Total titratable acid content is commonly measured using an endpoint titration method, which can be done manually or using an autotitrator (Itle, 2020). Titrations measure the amount of a basic buffer solution that needs to be added to a juice sample to reach an endpoint titration. The original sample volume, buffer volume added to the sample, and the molecular weight of the most prominent acid in the fruit being tested are used to estimate the overall acid content (Mitcham et al., 1996). Both sugar and acid content can also be examined in more detail to measure individual sugars and acids using more precise methodology using high performance liquid chromatography (HPLC).

As sugar and acid content play a large role in blueberry fruit quality and taste, knowledge of blueberry type variation would aid fruit marketing. Overall, results have varied for sugar and acid content when comparing blueberry cultivars and types. Makus and Morris (1993) evaluated three rabbiteye cultivars ('Climax', 'Tifblue' and 'Menditoo') and three northern highbush cultivars ('Collins', 'Bluecrop' and 'Herbert') and identified significantly higher soluble solids in rabbiteye, and higher TTA in highbush, with approximately 70% more acid content. Silva et al. (2005) reported that there were not significant differences for soluble solids, TTA, or sugar acid

ratio between the cultivars and types for three rabbiteye cultivars ('Climax', 'Premier' and 'Tifblue') and two northern highbush cultivars ('Bluecrop' and 'Jersey'). In another study, Saftner et al. (2008) evaluated ten northern highbush cultivars ('Chanticleer', 'Duke', 'Hannah's Choice', 'Weymouth', 'Berkeley', 'Bluecrop', 'Bluegold', 'Coville', 'Elliott' and 'Lateblue') and two rabbiteye cultivars ('Coastal' and 'Montgomery') and results suggested that rabbiteye cultivars ranked among the northern highbush cultivars for SS, TTA and SSC : TTA. In a larger study, seven rabbiteye ('Alapaha', 'Austin', 'Brightwell', 'Briteblue', 'Centurion', 'Climax' and 'Premier') were compared to eleven southern highbush ('Bluecrisp', 'Farthing', 'Jewel', 'Millenia', 'O'Neal', 'Primadonna', 'Scintilla', 'Snowchaser', 'Springhigh', 'Sweetcrisp' and 'Windsor'). The two types were significantly different for soluble solids, but were not for sugar acid ratio. Results suggested that rabbiteye were higher in sugar content and southern highbush were higher in acid content (Gündüz et al., 2015). Results from another more recent study, suggested that rabbiteye ('Alapaha', 'Brightwell', 'Ochlochonee', 'Powderblue', 'Premier', 'Tifblue' and 'Vernon') had a higher soluble solid content and lower acid content when compared to southern highbush ('Camellia', 'Emerald', 'Farthing', 'Legacy', 'Meadowlark', 'Rebel' and 'Star' (Itle et al., 2015). Overall, there have been a limited number of studies evaluating soluble solid content, total titratable acids and sugar acid ratio between cultivars of the three main blueberry types, and current reports only examine one season. Knowledge of the major cultivars within each type and across seasons would help to further understand these fruit quality traits.

Anthocyanins

Anthocyanins are water-soluble pigments that give the red, purple, blue colors to the fruit, leaves and stems on a plant. There are six anthocyanins that are common in nature and are

found in fruit pulp and skins: cyanidin (50%), delphinidin (12%), malvidin (7%), pelargonidin (12%), peonidin (12%), and petunidin (7%) (Lohachoompol et al., 2008; Sellappan et al., 2002; You et al., 2010). Blueberries have high levels of anthocyanins, which may be associated with important human health benefits. In the past two decades, consumers have become more interested in and aware of health benefits and are beginning to seek out more nutritional food (Gilbert et al., 2014; Hu et al., 2009; Lohachoompol et al., 2008; You et al., 2010). Anthocyanins may aid in reducing elevated glucose levels (Blacker et al., 2012), cataracts formation and their risk, eye fatigue (Tsuda, 2012) and soreness due to exercise-induced muscle damage (McLeay et al., 2012), and aid in preventing heart disease (Cassidy et al., 2013). In addition, anthocyanins may promote cell protection with anti-oxidative and anti-carcinogenic effects on certain cancer cells (Bagchi et al., 2004; Bo et al., 2013; Feng et al., 2007; Mazza et al., 2002; Parry et al., 2006; Wolfe et al., 2008). As with the aforementioned fruit quality traits, environmental conditions that are either favorable or unfavorable to overall plant growth, fruit formation and development can have a positive or negative impact, respectively, on adequate pigment formation in the fruit.

Anthocyanin concentration can be measured in numerous ways ranging from an overall estimate of anthocyanin content to more detailed analyses involving solvent extractions, purifications, and profiling individual compounds. A pH differential method is most commonly used for an overall anthocyanin estimate. This method uses purified fruit juice that is added to two different buffers with two different pH levels, typically 1.0 and 4.5. A spectrophotometer is used to measure the Absorbance at two wavelengths, typically 700 and 520 nm due to the location of anthocyanin absorption within the visible spectra, within a defined timeframe for optimal measurement of the fruit sample's color change in solution. The method generally is

used to estimate cyanidin-3-glucoside equivalents per g, as this is the predominant anthocyanin found in nature. Individual anthocyanin can be measured and profiled using vacuum chromatography, HPLC with mass spectrometry (MS), HPLC electrospray ionization and time-of-flight mass spectrometry (HPLC–ESI–QTOF–MS), Fourier transform near-infrared spectroscopy (FT-NIR) (Routray and Orsat, 2011).

Previous studies have looked at the differences in individual anthocyanin and total anthocyanin content of cultivars and types. In one study, eight northern highbush cultivars ('Bluecrop', 'Duke', 'Spartan', 'Reka', 'Bluetta', 'Brigitta', 'Sunrise' and 'Berkeley') contained four types of anthocyanins: delphinidin, peonidin, petunidin and malvidin (Li et al., 2017). In another study, Lohachoompol et al. (2008) compared three southern highbush cultivars ('Star', 'Sharpe' and 'Crunchie') and three rabbiteye cultivars ('Powderblue', 'Brightwell' and 'Climax'). They found that southern highbush cultivars had larger concentrations of delphinidin and petunidin than that of rabbiteye and rabbiteye had larger concentrations of malvidin and cyanidin than that of southern highbush. Rabbiteye, specifically 'Climax', had larger total anthocyanin content compared to southern highbush cultivars. Similar results were found regarding total anthocyanin content when Prior et al. (1998) evaluated twelve northern highbush cultivars ('Bluecrop', 'Jersey', 'Croatan', 'Duke', 'Rancocaf', 'Rebel', 'O'Neal', 'Reveille', 'Blue Ridge', 'Cape Fear', 'Bladen' and 'Pender') and four rabbiteye cultivars ('Climax', 'Brightwell', 'Tifblue' and 'Little Giant') and Sellappan et al. (2002) evaluated rabbiteye genotypes ('Austin', 'Brightblue', 'Brightwell', 'Climax', 'FL 80-11', 'Premier', 'FL 81-156', 'T 460', 'Tifblue' and 'Woodard') and five southern highbush genotypes ('FL 86-19', 'TH 161', 'TH 440', 'TH 442' and 'Sharpblue'). In a recent study, Itle and Nesmith (2015) evaluated total monomeric anthocyanin content in seven rabbiteye cultivars ('Alapaha', 'Brightwell',

‘Ochlockonee’, ‘Powderblue’, ‘Premier’, ‘Tifblue’ and ‘Vernon’) and seven southern highbush cultivars (‘Camellia’, ‘Emerald’, ‘Farthing’, ‘Legacy’, ‘Meadowlark’, ‘Rebel’ and ‘Star’), and found no significant difference between the two types. Past studies indicated that anthocyanin content may be due to different structures of anthocyanins, total phenolic content, cultivar, types, environmental conditions, fruit maturity, irrigation and postharvest conditions (Conner et al, 2002; Kalt et al., 2003; Prior et al., 1998; Sellappan et al., 2002; You et al., 2010). As health benefits are growing in importance in blueberry and overall fruit consumption, knowledge of anthocyanin content of the major cultivars in the three main blueberry types would be extremely beneficial for use in sale, marketing, and development of value-added products to aid in increasing profits received by blueberry growers. Examination of anthocyanins across the three blueberry types over multiple growing seasons to date has not been reported.

CONSUMER SENSORY EVALUATION OF FRUIT QUALITY

Sensory evaluation is an effective methodology to understand fruit quality attributes and overall consumer acceptability of blueberry cultivars and types. One type of sensory evaluation is subjective testing. Subjective testing, is used to determine consumer preference or acceptability of a food product, using untrained panelists (Institute of Food Technologists, 1981). When analyzing food, consumers measure characteristics by sight, feel/touch, smell, taste and hearing. Taste is determined by gustatory mechanisms on the tongue to perceive whether or not something is bitter, salty, sour, sweet, or umami. Oral-somatosensation receptors measure the sense of texture of food and drink. Olfaction is the ability to detect and identify odors by sensory receptors that is sent to the brain. Humans differentiate between odors and their brains then recognize whether the odor is floral, sweet, dangerous, pungent, etc. (Taylor et al., 2004). Interpretations of consumer perception is difficult, with consumers highly accepting the first

food product they taste at the first position, therefore it is important to create a precise and accurate taste test design (Wang, 2015).

Consumer acceptability studies

Consumer acceptability is important in the fruit industry allowing growers and breeders to understand the consumer's preference of certain blueberry types and/or cultivars (Gilbert et al., 2014; Saftner et al., 2008). Samples are randomly assigned, monadically to panelists. Panelists will evaluate a set of samples in one session, usually using a 9-point hedonic liking scale. This allows consumers to evaluate how much they like or dislike different samples. A 1 on the scale, signifies that the consumer extremely dislikes a sample characteristic and a 9 signifies a consumer extremely likes the sample characteristic.

Common fruit quality traits consumers recognize are texture, taste, appearance and aroma. Few studies have compared blueberry cultivars and types across years. In one study, Silva et al. (2005) found that consumer mean liking scores were larger for northern highbush textural traits than rabbiteye. However, this study was conducted using trained panelists to rate the acceptability of the fruit, where such tests require participation of untrained panelists.

In 2011 and 2013, two online consumer surveys were made available based on consumers' blueberry consumption and purchasing habits (Gilbert et al., 2014). The survey consisted of questions where consumers rated favorability of fruit quality characteristics and likeliness of purchase (9-point hedonic scale). Consumers preferred berries that were sweet and did not require extra sugar, full of antioxidants, dark blue skin and pulp, and contained an intense blueberry flavor. Negative correlated characteristics included mushy, gritty, seedy, chewy and tough skins (Gilbert et al., 2015).

Color has a large impact on fruit appearance. Appearance (bright and colorful fruit) aids in consumer impulse purchases and is therefore important for the fresh fruit and processing market (Saftner et al., 2008). When purchasing fruit, consumers accept fruit with an even color. For blueberries, consumers accept fruit that have an even blue color, with an even gloss on the outside. Other studies reported that consumers preferred bright, less intense blue color and a berry with a 'dark blue outside, pale inside' and 'bright blue in color' (Gilbert et al., 2014; Saftner et al., 2008). In an online survey, men indicated that they would be more interested in a berry with a deep blue color, almost black color. In addition, consumers rated that berry size was more important than fruit color intensity (Saftner et al., 2008). No known studies have evaluated blueberry quality, consumption and purchasing behavior questions, in a proper controlled center location test (CLT) over multiple seasons.

Taste, overall flavor, sweetness, bitterness and acidity, determine whether a consumer will continue to purchase blueberries (Saftner et al., 2008). High acidity, bitterness, and sourness have been perceived as negative by consumers and bitter and sour fruit are more likely to be rejected (Barrett et al., 2010). As fruit develop, total titratable acid (TTA) tends to decrease. An increase in SS and decrease in TTA are favored by consumers. Research has shown that flavor related characteristics, such as sweetness, tartness and acidity balances, were more pertinent to consumers rather than textural or visual characteristics (Saftner et al., 2008). Although previous research has reported rabbiteye cultivars to have higher sugar content through instrumental analyses, it is not currently known if consumers like the sweetness of southern highbush, rabbiteye and northern highbush. In addition, no known study has compared the same cultivars over multiple harvest seasons using the same consumers in a CLT environment (Itle and NeSmith, 2017a; Silva et al., 2005).

Gender, age, income, ethnicity and residency may also influence the consumer's perception of fruit quality. Gilbert et al. (2014) reported that consumers between the ages of 35 to 50 were more interested in larger, crispier, antioxidants and fruit flavor than other age groups. Those who were between the ages of 18 to 24, were more interested in an intense blueberry flavor, while those between the ages of 25 to 34 were more interested in medium sized blueberries. Consumers from the southwest region of the U.S. favored berries full of antioxidants and juice, northeast region of the U.S. favored berries that were large and crisp, and southeast region of the U.S. favored berries that were so sweet they did not require sugar.

The focus of this study is to evaluate a representative group of cultivars from the three main blueberry types grown in U.S. to determine which fruit characteristics are associated with consumer preferences. In addition, this study will give the industry and growers a better understanding of whether or not northern highbush have superior fruit quality traits compared to southern highbush and rabbiteye. Although there have been studies done to evaluate blueberry quality using instrumental analyses, there have been few studies on that of consumer acceptability, such as appearance, flavor, texture, and aroma. This study will provide the blueberry industry with objective information to help prevent lowering of price points and cultivar and type purchase exclusions due to unfounded subjective biases (Itle, 2018).

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CHAPTER 3
INSTRUMENTAL ANALYSES AND CONSUMER ACCEPTABILITY OF BLUEBERRY
PHYSICAL FRUIT QUALITY ATTRIBUTES¹

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ABSTRACT

Blueberry production has significantly increased in the last two decades. Commercially, the blueberry industry has subjectively perceived northern highbush (*V. corymbosum* L.) to have superior fruit quality traits than southern highbush (species complex of *V. corymbosum* L. and *V. darrowii* Camp) and rabbiteye (*V. virgatum* Aiton) blueberries. Few studies have compared the quality attributes and consumer perception of these three main commercially grown types in the U.S. Our project characterized the physical quality traits of a representative number of cultivars from the three different types using instrumental analyses and consumer acceptability during the 2018 and 2019 harvest seasons. Skin toughness (puncture-in and puncture-out), fruit firmness (shear force), fruit size, seed traits (berry wt., diameter and height, plump seeds, shriveled seeds, total seeds, seed wt., seed wt. : berry wt. and percent seed wt. : berry wt.), and fiber traits (acid detergent fiber, neutral detergent fiber, lignin, hemicellulose and cellulose) were evaluated for eighteen and fourteen cultivars in 2018 and 2019, respectively. There were significant differences for all physical quality traits among types and cultivars ($P \leq 0.001$) for both years, except for 50 berry wt., berry wt. of those used for seed extraction, and total seed number in 2018. Physical traits varied among the same cultivars and types within a year ($P \leq 0.001$) and across years (twelve cultivars in common between years, $P \leq 0.05$). This may suggest an effect of genotype, environment and their interaction for physical traits. Among the types, the majority of consumers liked southern highbush texture and size, contrary to the blueberry industry's subjective perception.

INTRODUCTION

Blueberry production surpassed one million pounds in 2012. The U.S. fresh blueberry production from 2016 to 2018 was approximately 300 million pounds annually. Three main commercial types [southern highbush (species complex of *V. corymbosum* L. and *V. darrowii* Camp), rabbiteye (*V. virgatum* Aiton) and northern highbush (*V. corymbosum* L.)] are grown in the U.S. In Georgia, blueberries are within the top ten fruit commodities in Georgia (USDA NASS, 2019b) with an estimated production of 32 million pounds valued at \$66.54 million. This represented 69% of the Southeastern U.S. blueberry acreage. Georgia ranked sixth for fresh blueberry production in the U.S. (USDA NASS, 2019a).

Blueberry breeding in the early 1900s focused mainly on yield, disease resistance and superior plant growth and development. Recently blueberry breeding has focused on fruit quality traits, such as skin toughness, fruit firmness, size, pedicle scars and overall appearance. Consumer preference may increase industry profit and production (Gilbert et al., 2014; Hancock et al., 2008; Mainland, 1998). Understanding which fruit quality traits drive consumption and overall liking may lead to an increase in marketability and consumer acceptability.

Currently, the fresh blueberry industry perceives that northern highbush (NHB) have superior fruit quality traits compared to those of southern highbush (SHB) and rabbiteye (RE). This perception is based on subjective biases and no standardized research. This has led to a lower price point for SHB and RE, and rejection of specific cultivars within both types (Itle et al., 2020). Few studies have evaluated the physical trait differences of the current commercial cultivars across the major three commercial types. Most blueberry fruit quality research has focused on textural traits (puncture-in test and Kramer shear test). Puncture-in measures skin

toughness, while Kramer shear measures fruit firmness (Saftner et al., 2008; Silva et al., 2005; Itle and NeSmith, 2017a).

Another way to measure fruit textural traits is by using sensory evaluations. In past studies, researchers used trained panels to measure fruit quality, specifically texture, of NHB and RE cultivars. In one study, it was found that panelists preferred NHB texture over RE (Makus and Morris, 1993), while in other study, panelists did not find skin toughness differences among types (Silva et al., 2005). A larger study was conducted using untrained panelists for NHB and RE (Saftner et al., 2008). There were differences for consumer perception and instrumental analyses. NHB texture traits were preferred by most consumers for their quality than those of RE. These preferences influenced overall cultivar eating quality (Saftner et al., 2008).

Seed and fiber content influence components of fruit texture. Consumers tend to dislike seedier and grittier fruit. Researchers have assessed fiber content, seed content, and overall consumer acceptability (Saftner et al., 2008; Silva et al., 2005). Itle et al. (2016a), evaluated seed and fiber traits and found that a higher plump seed number corresponded to a higher percent neutral detergent fiber, acid detergent fiber, hemicellulose, and cellulose. In addition, in other studies, fruit with more fiber were liked by fewer consumers (Silva et al., 2005). However, there have been limitations to previous sensory tests comparing consumer acceptability to instrumental analyses. Silva et al. (2005) conducted tests for fruit using trained panelists for subjective testing instead untrained panelists and Saftner et al. (2008) did not indicate whether there was sample randomization to minimize first order effects, as well as booth partitioning and controlled center testing. Such test designs may influence how panelists scored their acceptability of the various observed fruit quality traits for types and cultivars.

Fruit quality is also determined by overall appearance, size and shape. Consumers initially purchase fruit for their appearance, whereas fruit texture and flavor lead repeated purchases (Barrett et al., 2010; Waldron, 2003). A combination of instrumental analyses and consumer acceptability will provide breeders with a better understanding of which traits drive consumer overall liking (Gilbert et al., 2014).

Few studies compared physical fruit quality traits using instrumental and consumer acceptability test methods (Phan et al., 2017; Saftner et al., 2008; Silva et al., 2005). There is no known research conducted using representative SHB, RE and NHB cultivars to understand their textural and appearance characteristics, and how they are associated with consumer acceptability. In addition, there are no known studies comparing the textural traits of these cultivars across two harvest seasons using the same consumer panels provides a unique opportunity. The objectives of this research were to determine whether NHB have superior physical fruit quality traits through 1) evaluation of type and cultivars differences using instrumental analyses and consumer acceptability tests and 2) consumer cultivar overall liking correspondence to such traits among and across harvest seasons. This study can allow growers, breeders and the fresh blueberry industry to have a better understanding of the inherit variation of type and cultivar differences for textural traits.

MATERIALS AND METHODS

Blueberry samples

Three blueberry types were collected in 2018 and 2019 from May through August, representing early, mid and late southern highbush, rabbiteye and northern highbush cultivars. In 2018, [seven SHB cultivars ('Camellia', 'Farthing', 'Keecrisp', 'Legacy' grown in Georgia and Michigan, 'Meadowlark', 'Star' and 'Suziblue'), five RE cultivars ('Alapaha', 'Austin',

‘Brightwell’, ‘Powderblue’ and ‘Vernon’) and six NHB cultivars (‘Aurora’, ‘Bluecrop’, ‘Draper’, ‘Elliott’, ‘Liberty’ and ‘Nelson’] were evaluated and in 2019 five SHB cultivars (‘Camellia’, ‘Farthing’, ‘Legacy’ grown in Georgia and Michigan, ‘Patrecia’, ‘Star’ and ‘Suziblue’), five RE cultivars (‘Alapaha’, ‘Brightwell’, ‘Powderblue’, ‘Premier’ and ‘Vernon’) and three cultivars NHB cultivars (‘Aurora’, ‘Elliott’ and ‘Liberty’)] were evaluated. NHB were harvested in Michigan and Canada and transported to commercial packing facilities in Alma, Georgia in lugs and packed in 1-pint clamshells in 2018. In 2019, SHB and RE were harvested in Alma, Georgia, and one southern highbush (‘Legacy’) harvested in Michigan. NHB were harvested in Michigan and Indiana, and were transported in ten-pound cardboard packing boxes in a refrigerated vehicle. All fruit from 2018 and 2019 were transported to the University of Georgia Griffin Campus Griffin, Georgia for evaluation.

Sample storage and preparation

Fruit were stored at 4 ± 1 °C one to three days prior to washing and sorting. Approximately three to five cultivars were evaluated per sample collection date. Fruit from four 1-pint clamshells were washed with tap water in strainers, placed on bread trays with paper towels, and sorted by commercial quality (overripe, underripe, damaged fruit, stems and leaves) and dried. For consumer panels, approximately 1 oz. of fruit per cultivar were placed in an individual 3 oz. Styrofoam cup with opaque plastic lids and labeled with a randomized three-digit code (Appendix H). Fruit were stored at 4 ± 1 °C, until all evaluations were conducted.

Consumer sensory protocol

The protocol used in this section was modified from Silva et al. (2005) and was approved by the University of Georgia’s Institutional Review Board (STUDY00003249).

In 2018, five acceptability tests were conducted with untrained panelists (n = 83) and in 2019, four acceptability tests were conducted with untrained panelists (n = 78) at the UGA Sensory Evaluation & Consumer Lab in Griffin, GA. Consumers were screened based off certain criteria (Appendix A): 1) no allergies of blueberries, 2) 18-75 years old, 3) must eat blueberries once a month or more, 4) interested in participating in the taste test and 5) can participate in all taste tests from May to August during the given year. Panelists were required to sign a consent form prior to participation and were given an hour to complete each test (Appendices B and E).

One hour prior to each taste test session, samples were taken out to reach room temperature 21 ± 1 °C. All tests were conducted in individual booths under incandescent lights at 21 ± 1 °C. Ballots (Appendices C and F) were presented to panelists, using the software Compusense Cloud (Guelph, Ontario, Canada). Samples were arranged using a Latin Square Design (Appendix H) for each panelist and taste test. Demographic questions were presented to panelists upon completion of the last sample's acceptability questionnaire (Appendices D and G). A spoon was given to consumers with each sample and water was used as a palate cleanser between samples. Consumer acceptability of fruit size, acidity, texture, skin toughness, fruit firmness, seediness, grittiness and overall liking were determined using a 9-point hedonic scale (1 = dislike extremely, 5 = neither liked or disliked, 9 = like extremely).

Texture measurements

Skin toughness was measured as puncture-in and puncture-out tests using a TMS-Pro Texture Analyzer (Food Corporation, Sterling, Virginia). Fruit were sorted and berries with similar size for each cultivar were selected. A total of twelve berries per replication and three replications per cultivar were evaluated. Fruit were processed one to two days after the consumer panel occurred. Puncture-in [max load (N)] and puncture-out [max load (N)] were measured for

each fruit. Puncture-in measured the force required for a 1.37 mm probe at a rate of 50 mm/min to break the skin of an individual fruit on its side. Puncture-out measured the force it took the same probe to break the fruit from the inside out (probe exiting the fruit in the other side of the fruit).

Fruit firmness was measured using a Kramer shear test in a TMS-Pro Texture Analyzer. Three samples (50 – 51 g) per replication and three replications per cultivar were evaluated three to four days after the consumer panel. Kramer shear measured the force [max load (N)] required to shear the fruit sample for a ten stainless-steel blades shear cell (3 x 7.1 x 12.6 mm) at a rate of 100 mm/min at a downward stroke. All fruit evaluated for skin toughness and fruit firmness, were brought to 21 ± 1 °C, for approximately one hour before each test (Itle and NeSmith, 2017a; Silva et al., 2005).

Fruit size

Individual fruit were weighed (g) using a benchtop balance (Eppendorf, Hamburg, Germany) and measured [berry equator diameter and height (mm)] prior to the puncture test using a caliper (Mitotoyu Corporation, Kawasaki, Japan). Twelve berries per replication and three replications per cultivar were evaluated. Fifty berry weight (g) were evaluated by randomly sampling 50 berries per sample, three samples per replication and three replications per cultivar (Itle and NeSmith, 2017a; Silva et al., 2005).

Seed and fiber traits

Fruit were frozen and held at -15 ± 1 °C for one to eight months, before seed and fiber trait evaluation. Three samples of five berries and three replications per cultivar were weighed (g) and measured [berry equator diameter and height (mm)]. Fruit were then cut equatorially and seeds and placentae were extracted onto a paper towel. Plump seed number, shriveled seed

number, total seed number, seed weight (g), seed weight to berry weight ratio, and percent seed weight to berry weight were recorded and calculated (Itle and NeSmith, 2016a).

Frozen fruit samples were stored in coolers with dry ice and transported to The University of Georgia's Agricultural and Environmental Services Laboratory in Athens, GA. Analyses were run for fiber traits: neutral detergent fiber (NDF) (Ankom Technology, 2017b), acid detergent fiber (ADF) (Ankom Technology, 2017a) and lignin following (Ankom Technology, 2016). Hemicellulose was calculated taking the difference between NDF and ADF and cellulose was calculated taking the difference between ADF and lignin (Itle and NeSmith, 2016a; Silva et al., 2015).

Data analyses

Analyses of variance (ANOVA) of instrumental tests and consumer acceptability data were conducted. Consumer panelists and replications acted as random effects using a general linear model (GLM) procedure (SAS 9.4; SAS Institute, Cary, NC). Post-hoc mean separation using Tukey HSD at 5% level of significance was used to detect differences among fresh blueberry types, cultivars and years, in addition to detect differences of cultivars and types across years. Principal Component Analyses (PCA) were conducted to determine the correspondence of cultivars, average consumer liking scores and instrumental traits using XLSTAT (ver. 2016.03; Addinsoft, New York, NY).

RESULTS AND DISCUSSION

Skin toughness and fruit firmness

Skin toughness and fruit firmness were evaluated for eighteen and fourteen fresh blueberry cultivars for the 2018 (Table 3.1) and 2019 (Table 3.2) seasons, respectively. Due to the blueberry industry primarily focusing on type comparisons, results hereafter, will include

both type and cultivar comparisons. There were significant differences when comparing types ($P \leq 0.001$) and cultivars ($P \leq 0.001$) for puncture-in, puncture-out and shear force within each season. Tougher skin may be due to skin thickness and cell wall components (hemicellulose, lignin and cellulose), as well as turgor pressure and water loss (Blaker et al., 2014; Dekazos, 1977; Gough, 1983; Silva et al., 2005).

SHB had higher skin toughness (puncture-in - $\bar{x} = 1.227$ N; puncture-out - $\bar{x} = 0.696$ N) values, followed by NHB (0.995 N; 0.505 N) and RE (0.757 N; 0.505 N) in 2018 (Table 3.1). In 2019, NHB skin were tougher and fruit were firmer than SHB and RE. There were no significant differences for SHB and RE skin toughness ($P > 0.05$) and RE and NHB fruit firmness ($P > 0.05$) (Table 3.2).

In 2018, skin toughness ranged from 0.631 N for ‘Powderblue’ to 1.514 N for ‘Keecrisp’ (puncture-in) and 0.414 N for ‘Powderblue’ to 0.983 N for ‘Draper’ (puncture-out). Fruit firmness varied from 236.76 N for ‘Alapaha’ to 460.56 N for ‘Draper’ and 490.23 N for ‘Meadowlark’ (Table 3.1). There were no significant differences for skin toughness for ‘Legacy’ GA (puncture-in - $\bar{x} = 1.001$; puncture-out - $\bar{x} = 0.548$ N) and ‘Legacy’ MI (0.918 N; 0.471 N). However, there were significant differences for fruit firmness for ‘Legacy’ GA (301.56 N) and ‘Legacy’ MI (345.48 N). ‘Legacy’ was harvested in May in Georgia, whereas it was harvested in August in Michigan. Differences among locations and harvest times may have had an effect in fruit firmness.

In 2019, ‘Aurora’ and ‘Star’ had tougher skins at puncture-in, whereas ‘Aurora’ and ‘Liberty’ had tougher skins at puncture-out. Cultivar puncture-in and puncture-out results were not consistent, except for ‘Alapaha’, ‘Brightwell’, and ‘Aurora’. ‘Aurora’ ($\bar{x} = 379.04$ N) were

firmer and required more than double the shear force than ‘Patrecia’ ($\bar{x} = 156.77$ N). ‘Legacy’ GA were firmer than Legacy’ MI (Table 3.2).

There was a total of twelve cultivars in common between 2018 and 2019 seasons (Table 3.3). Significant differences among cultivars ($P \leq 0.001$) and types ($P \leq 0.001$) for skin toughness and fruit firmness measurements within and across seasons were reported. In 2018, SHB skins were tougher than NHB and RE. SHB and NHB fruit were firmer than RE. In 2019, NHB skins were tougher and fruit were firmer than SHB and RE. NHB skin toughness and fruit firmness were similar for both years, whereas SHB skin toughness and fruit firmness decreased from 2018 to 2019. RE puncture-in were similar across years, but puncture-out and fruit firmness increased from 2018 and 2019. There were inconsistent trends for cultivars within a type for all traits, except for SHB.

All SHB cultivars puncture-in values decreased and the majority of SHB, except ‘Legacy’ GA and MI, puncture-out decreased from one year to the other. The majority of SHB cultivars, except ‘Camellia’, ‘Legacy’ GA and ‘Legacy’ MI, fruit firmness decreased. RE skin toughness values across years were not indicative to those found for individual cultivars across years. ‘Brightwell’ was the only RE with similar puncture-in values ($\bar{x}_{2018} = 0.72$ N; $\bar{x}_{2019} = 0.79$ N), whereas ‘Alapaha’ was the only RE with puncture-out values to increase across years ($\bar{x}_{2018} = 0.47$ N; $\bar{x}_{2019} = 0.61$ N). Similar to RE results found, NHB puncture-out and fruit firmness values were not indicative to those found for individual cultivars. ‘Aurora’ was the only NHB that had similar puncture-out values ($\bar{x}_{2018} = 0.62$ N; $\bar{x}_{2019} = 0.70$ N) and none of NHB fruit firmness were similar across years. These results indicate that cultivars and harvest seasons affect type fruit firmness and skin toughness. In addition, variation may be due to environmental factors (mechanical versus hand harvesting, harvest locations and sorting type).

The values presented above differed from those values reported by other researchers, that RE have tougher skins than HB (Makus and Morris, 1993; Silva et al., 2005) and that RE skin toughness did not significantly differ from SHB (Itle and NeSmith, 2017b). In 2018, HB fruit firmness (shear force) did not significantly differ ($P > 0.05$), however were higher than RE (Table 3.1). In 2019, RE and NHB fruit firmness were not significantly different from each other but were higher than SHB firmness (Table 3.2). These findings differed from Makus and Morris (1993) and Silva et al. (2005) who indicated RE had firmer fruit than NHB. Differences between results may be because of harvesting timing and location variation (environment influences on textural traits). Georgia RE harvest season is earlier compared to Mississippi and Arkansas. NHB, for our study, were harvested in Michigan and Canada, whereas Silva et al. (2005) harvested NHB in Michigan and Makus and Morris (1993) harvested NHB in Arkansas. Itle and NeSmith (2017b), indicated RE have firmer fruit than SHB. Our results were inconsistent, but overall suggest that RE do not have tougher skins and firmer fruits than HB. Among all cultivars within the three types, results are contrary to the blueberry market subjective idea that RE are firmer with tougher skin than HB. A decrease of SHB skin toughness and fruit firmness across years may be because of cultivar variation, harvest location, harvest seasons and hand harvested fruit (2018) versus machine harvested fruit (2019) and postharvest conditions (Ballington et al., 1984; Blaker et al., 2014; Ehlenfeldt and Martin, 2002; Itle and NeSmith, 2017b; Li et al., 2001; Paniagua et al., 2013; Saftner et al., 2008; Silva et al., 2005). In addition, results may vary from previous studies, since other researchers compared only two main commercial types, rather than the three main commercial types. Texture variation may be due to assessed cultivars within a type. Overall, skin toughness and fruit firmness were cultivar dependent rather than species

dependent. These results do not support the subjective bias that RE have tougher and firmer fruit than HB.

Fruit size

Individual fruit size, such as weight, berry equator diameter and height, were measured prior to conducting the skin toughness tests. In addition, a mean weight of 50 berries were evaluated (Tables 3.4 and 3.5). There were significant differences among types ($P \leq 0.001$) and cultivars ($P \leq 0.001$) for all variables in 2018 (Table 3.4) and 2019 (Table 3.5) seasons, respectively.

In 2018, there were no significant differences among types ($P > 0.05$) for 50 berry wt. SHB had a larger berry wt. (2.21 g) followed by RE (1.88 g) and NHB (1.58 g). SHB also had a larger berry equator (16.84 mm). However, there were no significant differences between NHB and RE berry equator (mm) and SHB and RE berry height (mm) (Table 3.4). In 2019, SHB individual berry wt. and 50 berry wt. were larger than NHB and RE. NHB weighed more than RE, but values were not significant. SHB berry equator diameter and height were larger than RE and NHB. RE had smaller berry diameter and a larger berry height than NHB. Results indicate SHB are larger than NHB and RE. Weight and berry height results were similar to those found by Silva et al. (2005), however berry equator diameter differed.

In 2018, 'Farthing' and 'Vernon' berry wt. and berry equator diameter were the largest, while 'Liberty' was the smallest. Berry equator diameter was larger for 'Farthing' and 'Vernon' and were smaller for 'Liberty'. Fifty berry wt. was larger for 'Legacy' GA and were smaller for 'Legacy' MI, 'Elliott' and 'Liberty'. There was a similar trend with 'Liberty' and 'Elliott' fruit having a smaller size than other cultivars (Table 3.4). In 2019, 'Patrecia' individual berry measurements and 50 berry wt. were larger than the other twelve cultivars. 'Alapaha' had

smaller berry wt., equator diameter and 50 berry weight while ‘Legacy’ GA and ‘Elliott’ had a smaller berry height. ‘Premier’ diameter values were similar to ‘Legacy’ MI, ‘Camellia’ and ‘Star’. ‘Legacy’ MI had a larger berry wt., equator and height than ‘Legacy’ GA, but there were no differences between the 50 berry wt. (Table 3.5).

Our results varied for cultivar and type, since three types and nineteen cultivars were examined. Johnson et al. (2011) indicated similar variation among RE, as ‘Vernon’ had larger fruit weight and diameter compared to ‘Brightwell’, ‘Powderblue’ and ‘Alapaha’. Berry wt. and diameter variation may be due to environmental factors, such as sorting and harvest period. ‘Legacy’ GA was sorted by hand, whereas ‘Legacy’ MI was mechanically sorted. Also, Alma, Georgia chilling hours decreased initiating an earlier flowering period and harvest period (three weeks earlier than last year) for SHB in 2019. The average temperature from December 2018 (12.03 °C) to March 2019 (15.1 °C) increased compared to last year average temperatures (11.11; 13.88 °C) (UGA CAES, 2019). Fresh fruit collection with consumer taste tests may have affected fruit size as they were the last fruit harvested from the ‘Legacy’ plants at the collection site for the 2019 harvest season (Allen, 2019).

There was a total of twelve cultivars in common between 2018 and 2019 seasons (Table 3.6 and 3.7). There were significant differences among types ($P \leq 0.001$) and cultivars ($P \leq 0.001$) for both years. SHB had larger individual berry wt. (2018 and 2019), diameter (2018) and berry height (2019) than RE and NHB. In 2018, RE had larger height than HB and in 2019, there were no differences between HB diameters. NHB, except for individual berry wt. (2019), fruit size was smaller than RE (Table 3.6). SHB and RE 50 berry wt. were larger than NHB in 2018, however in 2019, HB 50 berry wt. were larger than RE (Table 3.7). Fruit size variation may be dependent on cultivar fruit size variation. Makus and Morris (1993) reported that RE were larger

than NHB, Silva et al. (2005) reported no difference in NHB and RE fruit size and Itle et al. (2016a) reported SHB were larger than RE. Our results indicate inconsistent fruit size across years and no clear trends among types and cultivars.

SHB diameter and height were similar across years, however individual berry wt. and 50 berry wt. increased from 2018 to 2019. RE individual fruit size decreased and 50 berry wt. were similar, whereas NHB individual fruit size and 50 berry wt. increased from 2018 to 2019 (Tables 3.6 and 3.7). Our results indicate variation among types and cultivars may be because of harvest years, however cell number, cell size, genetic variation within a cultivar, pollination, water loss and storage conditions may also affect fruit size (Blaker et al., 2014; Cano-Medrano and Darnell, 1997; Johnson et al., 2011; Paniagua et al., 2013).

Seed traits

Berry data were taken prior to seed extraction (Tables 3.8 and 3.9). Individual berry wt., equator diameter, height, plump seeds, shriveled seeds, total seed number, seed wt., seed wt. : berry wt. and percent seed wt. : berry wt. within a cultivar were measured. There were no significant differences between types for berry wt. in 2018 ($P > 0.05$). Contrary, berry wt. between types were significantly different in 2019 ($P \leq 0.001$). SHB had larger berry wt., diameter and height than NHB and RE, similar results observed in Table 3.8. RE had larger berry wt. and height than NHB, but there were no differences between berry diameters. There were significant differences among cultivar berry wt. for both seasons ($P \leq 0.001$) (Tables 3.8 and 3.9). Type and cultivar berry equator diameter, height and seed traits significantly differed within both seasons (Tables 3.8, 3.9, 3.10, and 3.11).

In 2018, RE had larger berry height and more plump seeds, total seeds, total seed wt., seed wt. : berry wt. and percent seed wt. : berry wt. than HB. NHB had more shriveled seeds than

SHB and RE. Berry wt. varied from 0.96 to 2.47 g; ‘Legacy’ GA and ‘Nelson’ had a greater berry wt. and ‘Elliott’ had a lesser berry wt. and berry height.

In 2019, berry wt. ranged from 1.21 g for ‘Alapaha’ to 4.08 g for ‘Patrecia’. Berry equator diameter ranged from 12.55 mm for ‘Alapaha’ to 21.26 mm for ‘Patrecia’ and berry height ranged from 10.40 mm for ‘Aurora’ to 15.67 mm for ‘Patrecia’. Weight, height and diameter values differed from those reported by Makus and Morris (1993) and Silva et al. (2005). Makus and Morris (1993) reported that NHB had larger fruit weight and diameter than RE. Silva et al. (2005) reported that there were no differences between NHB and RE weights and diameters. Itle and Nesmith (2016a) compared SHB and RE fruit size and found that SHB berry weight, diameter and height were larger than RE. ‘Camellia’, ‘Farthing’, ‘Legacy’, ‘Star’ fruit size were larger than those we evaluated.

Within the 2018 harvest season, ‘Vernon’, ‘Austin’ and ‘Powderblue’ had more plump seeds, total seeds, total seed weight, seed wt. : berry wt. and percent seed wt. : berry wt. ‘Liberty’ had the highest number of shriveled seeds. ‘Liberty’, ‘Legacy’ MI and ‘Star’ had the smallest total seed wt., seed wt. : berry wt. and percent seed wt. : berry wt. The majority of RE may have a larger total seed wt. due to their larger percent plump seeds : total seeds (68.77%) compared to SHB (45.09%) and NHB (31.23%) (Table 3.10).

Blueberries have been known to contain several seeds –approximately 50 to 65 seeds (Gough, 1994). However, in our study, we found that fruit total seed number ranged from approximately 54.6 to 83.1, varying among types and cultivars. More plump seeds influenced total seed weight and percent seed wt. : berry wt. In addition, larger sized fruit did not contain more seeds compared to smaller sized fruit, which was suggested by Brewer and Dobson (1969) and Eaton (1967) that seed number may not be the only factor resulting in larger fruit. Blaker et

al. (2010) found that there were no significant differences between cultivars and seed wt. : berry wt. ranged from 0.0005% to 0.00149%, yet our results show that values varied from 0.005% to 0.023%. Results may vary as fruit for that study were only SHB and were harvested in Florida compared to HB and RE harvested in Georgia, Michigan and Canada.

In 2019, plump seeds ranged from 2.6 for ‘Aurora’ to 39.2 for ‘Vernon’. Shriveled seeds ranged from 23.5 for ‘Star’ to 86.9 for ‘Aurora’, and total seeds ranged from 39.3 for ‘Star’ to 89.5 for ‘Aurora’. Percent plump seeds : total seeds ranged from 3.67% for ‘Aurora’ to 51.09% for ‘Vernon’ and percent shriveled seeds : total seeds ranged from 48.91% for ‘Vernon’ to 96.33% for ‘Aurora’. Even though ‘Aurora’ had more seeds than other cultivars, the seed wt. : berry wt. was the smallest, which may be due to the percent shriveled seeds : total seeds. ‘Brightwell’ percent seed wt. : berry wt. was the highest among cultivars due to a larger total seed wt. (3.59 mg) and smaller berry wt. (1.56 g) (Tables 3.9 and 3.11).

There was a total of twelve cultivars in common between 2018 and 2019 seasons (Tables 3.12, 3.13, and 3.14). There were significant differences among types ($P \leq 0.001$) and cultivars ($P \leq 0.001$) for both years. Type fruit weights ranged from 1.20 g for NHB to 1.74 g SHB in 2018 and 1.43 g for NHB and 2.24 g for SHB in 2019. Fruit diameters ranged from 14.01 mm for RE to 15.51 mm for SHB in 2018 and 14.54 mm for RE to 16.83 mm for SHB in 2019. Fruit height varied from 10.68 mm for NHB to 13.28 mm for RE in 2018 and 10.88 mm for NHB to 13.13 mm for SHB in 2019. SHB and RE weights and diameters in 2018 and RE and NHB diameters in 2019 were not significantly different (Table 3.12). HB wt. and diameters and SHB height increased from 2018 to 2019. RE wt. and diameter and NHB height were similar across both years. Type weight and diameter of fruit used for seed extraction varied from those used for puncture across and among years (Tables 3.6 and 3.12).

Cultivar fruit wt. ranged from 0.96 g for ‘Liberty’ to 2.45 g for ‘Legacy’ GA in 2018 and 1.23 g for ‘Aurora’ to 3.12 g for ‘Farthing’ in 2019. Fruit diameters ranged from 13.20 mm for ‘Elliott’ to 17.94 mm for ‘Legacy’ GA in 2018 and 14.32 mm for ‘Brightwell’ and ‘Elliott’ to 18.95 mm for ‘Farthing’ in 2019. Fruit height varied from 10.15 mm for ‘Liberty’ to 13.37 mm for ‘Legacy’ GA in 2018 and 10.40 mm for ‘Aurora’ to 14.40 mm for ‘Farthing’ in 2019. For the majority of cultivar fruit size traits measured, there was variation across years. Across years, ‘Brightwell’ and ‘Powderblue’ fruit weights and diameters, ‘Aurora’ diameters and ‘Elliott’ height were similar. No trends were found among cultivar berry wt., diameters and height across years, suggesting that fruit size is not consistent within a cultivar (Itle and NeSmith, 2017b; Silva et al., 2005). Smaller fruit with larger seeds may negatively affect consumer overall and texture liking, as they may perceive fruit to be mealy.

There were significant differences for plump seeds, shriveled seeds, total seeds, percent plump seeds : total seeds, percent shriveled seeds : total seeds and percent seed wt. : berry wt. among cultivars in 2018 and 2019 (Tables 3.13, 3.14, 3.15). Plump seeds ranged from 6.3 for ‘Liberty’ to 62.6 for ‘Vernon’ in 2018 and 2.6 for ‘Aurora’ to 39.2 for ‘Vernon’ in 2019. Shriveled seeds ranged from 17.5 for ‘Alapaha’ to 65.2 for ‘Liberty’ in 2018 and 23.5 for ‘Star’ to 86.9 for ‘Aurora’ in 2019. Total seeds ranged from 57.9 for ‘Brightwell’ to 82.9 for ‘Vernon’ in 2018 and 46.4 for ‘Alapaha’ to 89.5 for ‘Aurora’ in 2019 (Table 3.13). Cultivar percent plump seeds : total seeds and percent shriveled seeds : total seeds across years, shown in Table 3.14, showed a similar trend to that of total plump seeds and shriveled seeds in Table 3.13. These results suggest that the majority of total seeds within ‘Vernon’ were plump, whereas the majority of ‘Liberty’ and ‘Aurora’ total seeds were shriveled. The majority of SHB and RE plump seeds decreased and shriveled seeds increased, however there were no differences for total seeds across

years. NHB plump seeds were similar across years, however shriveled and total seeds increased from 2018 to 2019. RE had more plump seeds and NHB had more shriveled seeds for both years. There were no differences for type total seeds in 2018, but in 2019, NHB had more seeds, followed by RE and SHB. Our results suggest that total seeds vary within a cultivar as well among cultivars and types. These results are not comparable to those reported by Gough (1994). Larger fruit size (weight, diameters and height) did not indicate a larger seed number (Tables 3.12 and 3.13) (Brewer and Dobson; 1969; Eaton, 1967). Results do not support the fresh market distributors' subjective idea that RE have more seeds than HB (Itle, 2018; Itle and NeSmith, 2016b).

Total seed weight, seed wt. : berry wt. and percent seed wt. : berry wt. significantly differed among cultivars and types for 2018 and 2019 (Table 3.15). Total seed weight ranged from 0.48 mg for 'Liberty' to 3.66 mg for 'Vernon' in 2018 and 0.35 mg for 'Aurora' to 3.81 mg for 'Vernon' in 2019. Seed wt. : berry wt. ranged from 0.00 for 'Legacy' MI, 'Star' and 'Liberty' to 0.02 for 'Powderblue' in 2018 and 0.00 for 'Aurora' to 0.02 for 'Brightwell' in 2019. Percent seed wt. : berry wt. ranged from 0.22% for 'Legacy' MI to 2.27% for 'Powderblue' in 2018 and 0.40% for 'Star' to 2.33% for 'Brightwell' in 2019. Overall, RE seed weight, seed wt. : berry wt. and percent seed wt. : berry wt. were larger (approximately two to three times more) than HB for both years and were consistent across years. SHB seed weight was larger than NHB in 2018, however HB seed weight were not different in 2019. HB seed wt. : berry wt. and percent seed wt. : berry wt. were not different for each year and across years. Although the majority of type fruit size and seed number varied across years, the majority of seed weight, seed wt. : berry wt. and percent seed wt. : berry wt. were consistent. RE large seed weight and percent seed wt. : berry wt. may be because they contain more plump seeds in 2018

and 2019 (Tables 3.13 and 3.15). Results were similar to those found by Itle and NeSmith (2016a and 2016b), but varied from those found by Blaker et al. (2014). Cultivar seed traits may vary because of harvest location, pollination style (self vs. cross pollination), and seeds ABA content (Blaker et al., 2010; Brewer and Dobson, 1969; Eaton, 1967; Ehlenfeldt and Martin, 2010).

Fiber traits

Fiber traits (NDF, ADF, lignin, hemicellulose and cellulose) were evaluated during the 2018 and 2019 harvest season (Tables 3.16 and 3.17). There were significant differences among types ($P \leq 0.001$) and cultivars ($P \leq 0.001$) for all fiber traits within each season (Tables 3.16 and 3.17). There was a similar trend for types for all traits. RE had more NDF, ADF, lignin (2018), hemicellulose (2018) and cellulose than HB. There were no differences among HB fiber traits ($P > 0.05$). There were no differences between RE and NHB lignin and hemicellulose in 2019.

In 2018, ‘Austin’ had higher fiber content than other cultivars. ‘Austin’ had a larger NDF (12.73%), whereas ‘Liberty’ had a smaller NDF (4.83%). ‘Austin’, ‘Brightwell’, ‘Powderblue’ and ‘Vernon’ had a larger ADF and ‘Liberty’ had a smaller ADF. Lignin ranged from 1.00% to 3.90% where ‘Legacy’ GA, ‘Meadowlark’, ‘Star’, ‘Draper’ and ‘Liberty’ had smaller values and ‘Austin’, ‘Brightwell’, ‘Powderblue’ and ‘Vernon’ had larger values. ‘Liberty’ hemicellulose and cellulose were smaller than other cultivars (Table 3.16).

In 2019, ‘Brightwell’ and ‘Powderblue’ had higher NDF and ADF than other cultivars. ‘Patrecia’, ‘Brightwell’, ‘Powderblue’ and ‘Premier’ had higher lignin and ‘Star’ had lower lignin. Hemicellulose and cellulose varied (1.16%; 1.14%) for ‘Patrecia’ and (1.36%; 1.34%) for ‘Brightwell’ (Table 3.17). Higher hemicellulose and cellulose have been associated with skin strength and fruit firmness, as they compose the majority of the primary and secondary cell walls (Blaker et al., 2014; Knox, 2008; Vermerris, 2008). ‘Patrecia’ lower hemicellulose and cellulose

may be an indicator of lower fruit firmness. Sclereids have a thick secondary wall, composed of lignin, and are found in clusters within blueberries, influencing fruit overall texture, skin toughness and fruit firmness (Blaker et al., 2014; Dekazos, 1977; Gough, 1983; Silva et al., 2005). Although a high lignin content is found in fruit skin, ‘Brightwell’, ‘Powderblue’ and ‘Premier’ skins were not tougher nor firmer (Table 3.2). Fruit endocarp and mesocarp contain parenchyma cells and vascular bundles, which contain a high lignin content. Their seeds and placentae are also highly lignified (Blaker et al., 2014; Gough, 1983). ‘Brightwell’, ‘Powderblue’ and ‘Premier’, had large percent seed wt. : berry wt. compared to ‘Star’, which may indicate a higher lignin content may be because of their plump seeds and total seed weight (Tables 3.11 and 3.17).

From our results, the majority of cultivars that had a larger fiber amount were within the RE type. Results indicate that although the majority of RE had more fiber, the variability of fiber content was due to cultivar variability and cell wall structure. Similar results were found in previous studies when comparing RE to HB (Itle and NeSmith, 2016a; Silva et al., 2005). Fruit cell walls are composed of primarily cellulose, hemicellulose and lignin. Lignin in the secondary cell wall allows for rigidity and structure of the fruit, affecting fruit firmness and skin toughness. In addition, lignin is found in the mesocarp, vascular bundles, seeds, and stone cells (Blaker et al., 2014; Dekazos, 1977; Gough, 1983; Gough, 1985; Silva et al., 2005). An increased amount of lignin may negatively affect the consumer overall mouthfeel, liking, texture, seediness and grittiness of the fruit.

There was a total of twelve cultivars in common between 2018 and 2019 seasons (Tables 3.18 and 3.19). There were significant differences among types ($P < 0.001$) and cultivars ($P < 0.001$) for fiber traits (NDF, ADF, lignin, hemicellulose and cellulose) during the 2018 and 2019

harvest seasons. There were also significant differences comparing type and cultivar across harvest seasons (Tables 3.18 and 3.19). NDF ranged from 4.83% for ‘Liberty’ to 19.67% for ‘Vernon’ in 2018 and 5.01% for ‘Star’ to 10.04% for ‘Brightwell’ in 2019. ADF ranged from 3.30% for ‘Liberty’ to 11.10% for ‘Vernon’ in 2018 and 3.95% for ‘Star’ to 7.36% for ‘Brightwell’ in 2019 (Table 3.18). Lignin ranged from 1.10% for ‘Liberty’ to 3.90% for ‘Vernon’ in 2018 and 3.27% for ‘Star’ to 5.50% for ‘Brightwell’ in 2019. Hemicellulose ranged from 1.57% for ‘Liberty’ to 8.57% for ‘Vernon’ in 2018 and 1.21% for ‘Suziblue’ to 1.36% for ‘Brightwell’ in 2019. Cellulose ranged from 2.20% for ‘Liberty’ to 7.23% for ‘Vernon’ in 2018 and 1.19% for ‘Aurora’ to 1.34% for ‘Brightwell’ in 2019 (Table 3.19). Overall, RE had more fiber content than HB for both years. There were no differences in HB fiber content for both years, except for 2018 cellulose and 2019 NDF. SHB had more cellulose and less NDF than NHB. SHB and RE NDF and ADF decreased across years. NHB NDF and ADF were consistent across years. HB and RE lignin decreased and hemicellulose and cellulose increased across years. Therefore, harvest seasons affect type and cultivar fiber content variation.

Blueberry endocarp and mesocarp contain a large amount of parenchyma cells and vascular bundles. Their fruit have also been found to have a large amount of seeds and five placentae (Blaker et al., 2014; Gough, 1983). Parenchyma cells, vascular bundles, seeds and placentae are composed of lignin. RE high values of lignin may be due to a larger plump seed content and total seed weight than HB. Our results were similar to those found by Itle and Nesmith (2016a) and Silva et al. (2005). Itle and Nesmith (2016a) found that RE larger plump seed number and seed weight highly correlated to larger lignin, hemicellulose, cellulose, NDF, and ADF than SHB. Hemicellulose and cellulose strengthen fruit skin increasing fruit firmness and skin toughness (Blaker et al., 2014; Dekazos, 1977; Gough, 1983; Silva et al., 2005).

Although RE had larger hemicellulose and cellulose values than HB, their fruit were not firmer nor were their skins tougher (Tables 3.3 and 3.19).

NDF, ADF, lignin, hemicellulose and cellulose are insoluble dietary fibers (IDF) and are important for human daily fiber intake. The US Department of Agriculture (USDA) (2010) and the Institute of Medicine (2005) recommend a total dietary fiber (TDF) intake of twenty-five to thirty-eight g/day. RE high fiber measurements may suggest that they are a better source of fiber intake than HB (Silva et al., 2005). Fiber traits may be cultivar dependent, environmental conditions (harvest year and location) and fruit composition (cell wall structure, xylem and sclerenchyma cells and seed type) (Blaker et al., 2014; Dekazos, 1977; Gough et al., 1994; Harker et al., 1997; Silva et al., 2005).

Consumer acceptability

The mean scores for consumer overall liking of textural traits are represented in Table 3.20 for 2018 season and in Table 3.21 for 2019 season. There were significant differences among types ($P \leq 0.001$) and cultivars ($P \leq 0.001$) for all acceptability textural traits (except size in 2019).

In 2018, the majority of consumers liked SHB over NHB and RE for all consumer acceptability attributes. Overall, 'Camellia', 'Legacy' and 'Farthing' had the higher acceptability scores. Overall, 'Elliott' was liked by fewer consumers (4.72) than other cultivars, however the fruit textural traits and size mean scores were not in the disliking range of the hedonic scale. Therefore, there may be other parameters that impact overall liking, such as chemical traits (sugars, acids, flavor, aroma and color).

In 2019, the majority of consumers liked SHB than RE and NHB. There were no differences between RE and NHB overall liking mean scores. NHB and RE skin toughness and

texture results were similar to those found by Saftner et al. (2008) and seediness results were similar to those found by Phan et al. (2017). There were also significant differences ($P \leq 0.001$) for all cultivar fruit quality traits. In general, 'Legacy' MI were liked by more consumers for their skin toughness, fruit firmness, seediness and grittiness. 'Alapaha', 'Vernon' and 'Elliott' were liked by less consumers because of their textural traits. 'Premier' was rated highest and 'Alapaha' was rated lowest for size. Several cultivars size and textural trait liking scores were not significantly different.

These results differed from those found by Silva et al. (2005), which may be due to the type of consumers recruited for the taste tests. When fruit were analyzed by a group of ten trained panelists, panelists liked NHB and RE skin toughness just as much. For acceptability tests, untrained panelists are recruited as they give their subjective acceptability of fruit, whereas trained panelists are trained for objective testing. Conducting acceptability tests using trained panelists may influence their fruit acceptability scores. However, results were similar to ours, when comparing RE and NHB seediness liking mean scores. This may suggest that RE have larger seeds than NHB, giving the fruit a gritty and mealy texture. Similar results were found when comparing SHB and RE. A majority of untrained panelists, overall liked 'Sweetcrisp', 'Legacy', 'Camellia', and 'Farthing' texture and fruit firmness, whereas few consumers liked RE textural traits (Phan et al., 2017). 'Vernon' was liked for their textural traits, yet our results show that the fruit were liked for their size rather than textural traits. Consumers may like fruit that are 'crisp and pop in their mouth', also seen as a desirable trait from a mass 2013 online survey (Gilbert et al., 2014).

Fruit texture determines whether or not consumers will continuously purchase them in the future (Barrett et al., 1984). Fruit texture is determined by cell wall structure, turgor pressure,

grittiness, seediness, mealiness, fiber content and cultivar parentage differences (Blaker et al., 2014; Ehlenfeldt and Martin, 2002; Gilbert et al., 2014; Phan et al., 2017; Saftner et al., 2008; Silva et al., 2005). For an overall assessment of consumer acceptability of the three main commercial blueberry types, the same twelve cultivars were harvested in 2018 and 2019. The same 54 consumers attended five panels in 2018 and four panels in 2019. Their acceptability mean scores for overall liking, overall texture, skin toughness, fruit firmness and seediness were compared among and across years (Tables 3.22 and 3.23). There were significant differences among cultivars ($P \leq 0.001$) and types ($P \leq 0.001$) for each fruit quality traits assessed among years. There were also significant differences among cultivars ($P \leq 0.05$) and types ($P \leq 0.05$) across years.

Overall, the majority of consumers liked SHB than RE and NHB for both years. There were no differences between RE and NHB overall liking for both years and texture in 2018. NHB texture was liked by more consumers than RE in 2019. Consumer overall liking ranged from 4.43 for ‘Elliott’ to 7.46 for ‘Farthing’ in 2018 and 5.13 for ‘Elliott’ to 7.56 for ‘Legacy’ MI. Consumer overall texture liking scores ranged from 5.17 for ‘Alapaha’ to 7.46 for ‘Farthing’ in 2018 and 5.19 for ‘Alapaha’ to 7.56 for ‘Legacy’ MI in 2019 (Table 3.21). The majority of consumers liked the texture of ‘Farthing’ in 2018 and ‘Legacy’ MI in 2019, which may influence consumer overall liking for specific cultivars. Few consumers liked ‘Alapaha’ and ‘Elliott’ textural traits which may be due their fruit firmness, skin toughness, and seediness.

More consumers liked SHB than NHB and RE for their skin toughness and fruit firmness in 2018 and 2019. SHB seediness was liked more in 2018 and in 2019 and there were no differences between HB seediness liking (Table 3.23). In 2018, more consumers liked ‘Farthing’ skin toughness and ‘Farthing’ and ‘Camellia’ fruit firmness and seediness. In 2019, more

consumers liked ‘Legacy’ MI skin toughness, fruit firmness and seediness. Few consumers liked the majority of RE and ‘Elliott’ for both years for their textural traits.

Although the majority of consumers liked SHB more than RE and NHB for both years, overall liking and texture scores decreased across years. Lower acceptability scores may be due to lower skin toughness (puncture-in) and fruit firmness (shear force) values across years (Table 3.3). RE and NHB skin toughness scores were similar across years, similar to results comparing their respective puncture-in results. Their fruit firmness scores decreased across years, contrary to their respective fruit firmness results (Tables 3.3 and 3.23). Fruit firmness scores of RE decreased and NHB were similar across years. This may suggest consumers liked fruit that had a moderate to high fruit firmness value. SHB and RE seediness scores decreased and NHB seediness scores were similar across years. SHB and RE plump seed number decreased, while NHB plump seeds were similar across years. There were no differences among type total seeds in 2018. NHB had more seeds in 2019 than in 2018. Type seed wt. : berry wt. and percent seed wt. : berry wt. were similar across years (Tables 3.13, 3.15, and 3.23). Instrumental analyses results suggested that larger plump seed number and total seed weight decreased consumers liking of fruit texture and seediness liking. In addition, they may negatively influence fruit overall liking. Consumer acceptability scores do not support the subjective bias from the fresh fruit industry that NHB have superior fruit quality than SHB and RE (Itle, 2018).

Correlation between instrumental analyses and consumer acceptability

Principal component analysis was conducted to identify why consumers overall liked certain cultivars. The mean liking score of 83 consumers of eighteen cultivars for overall liking, grittiness, seediness, fruit firmness and skin toughness and instrumental analyses are represented in Figures 3.1 and 3.2 for 2018 and 2019 seasons, respectively. Consumer acceptability average

scores (textural traits, size and overall liking) were represented as active variables and instrumental analyses (textural traits and size) were represented as supplementary variables. To understand which physical traits drive consumer overall liking, Pearson correlation was conducted using consumer acceptability and instrumental data.

In 2018, the first dimension (PC 1) represented 84.65% of variance and the second dimension (PC 2) represented 10.44% of variance for consumer acceptability traits and instrumental analyses. Consumer texture, fruit size and overall liking scores were represented on the right hand side, along with berry diameter, height and weight, puncture-in and –out, shear force and shriveled seeds. Seed weight, plump seeds, total seeds and all fiber traits were represented on the left hand side. Overall liking highly corresponded to overall texture, fruit firmness, skin toughness, grittiness liking and seediness liking ($r = 0.80$ to 0.93). Consumer overall liking moderately correlated ($r = 0.59$) with fruit size. Fruit wt., berry equator diameter and height highly corresponded ($r = 0.72$ to 0.82) and puncture-in highly correlated with fruit firmness ($r = 0.74$) and moderately correlated with skin toughness and seediness ($r = 0.66$ to 0.66). Percent seed wt. : berry wt., NDF, ADF, lignin, hemicellulose and cellulose negatively correlated with overall liking and seediness liking ($r = -0.70$ to -0.82) and grittiness and skin toughness liking ($r = -0.60$ to -0.68). Percent plump seeds : total seeds and percent shriveled seeds : total seeds were not included, as their correspondence to consumer texture, seediness and overall liking were weak and did give a better understanding of why consumers may dislike or like certain cultivars more than others. In addition, these parameters did not assist in reducing the model complexity and capturing the greater variance between instrumental analyses and consumer acceptability scores.

In general, the majority of consumers liked 'Farthing', 'Legacy' GA and MI and 'Camellia'. 'Legacy' MI and 'Camellia' were liked more for having more shriveled seeds than plump seeds, causing possible grittiness, and moderate skin toughness (267.3 to 345.5 N) (Tables 3.1 and 3.10 and Fig. 3.1). 'Legacy' GA and 'Farthing' were liked more because of their tougher berry skin and larger berry height and weight (Table 3.1 and 3.4, and Figure 3.1). 'Brightwell', 'Alapaha', 'Austin' and 'Vernon' were liked by fewer consumers because of their larger total seed weight, plump seeds, and fiber traits. These findings confirmed that textural traits drive consumer overall liking and SHB are liked by the majority of consumers followed by NHB and RE. These findings were also confirmed by Saftner et al. (2008) that NHB increased eating quality was because of an increased bursting energy and texture during chewing. This information is important for breeders for parental selection and for growers. Results suggest that the subjective bias that RE have tougher, firmer fruit and have more seeds than HB is invalid. Breeders should focus on improving blueberry texture that may be affected by genetics, environmental variables and postharvest conditions. Markets can possibly increase price point for certain cultivars with a good texture, as texture drives consumer liking.

In 2019, PC 1 represented 79.78% of variation and the PC 2 represented 14.78% variation of consumer acceptability and instrumental data. All consumer acceptability scores for fruit physical traits, berry size, puncture-in and -out and shriveled seeds were represented on the right hand side (Figure 3.2). Consumer liking of overall texture, fruit firmness, skin toughness, seediness and grittiness highly corresponded to overall liking ($r = 0.78$ to 0.93). There was a weak correspondence for fruit size liking and overall liking ($r = 0.41$). Larger fruit weight and diameter moderately to highly correlated with a higher size liking score ($r = 0.59$ to 0.70), whereas fruit height weakly correlated with size liking ($r = 0.45$). This suggests that consumers

like wider berries, however it may not influence consumer overall liking scores as much as textural traits (Gilbert et al., 2014). Puncture-in weakly correlated to consumer overall texture, fruit firmness, skin toughness and overall liking ($r = 0.15$ to 0.40). Shear force had a weak negative to positive correlation to consumer texture, skin toughness, fruit firmness and overall liking ($r = -0.02$ to 0.01). Results show that instrumental skin toughness and fruit firmness measurements may not be indicators of consumer texture liking. Consumer ballot wording may also influence consumer interpretation and enable them to differentiate individual textural traits to rate their acceptability. Rewording of consumer acceptability skin toughness and fruit firmness questions may create a positive clarification for panelists evaluating fruit (Blaker et al., 2014; Gilbert et al., 2014).

Consumer overall liking and fruit seediness and grittiness negatively correlated with plump seeds, total seeds and percent seed wt. : berry wt. ($r = -0.32$ to -0.78). Also, all fiber traits negatively associated with an increased consumer liking ($r = -0.01$ to -0.51). Both fiber traits and seed traits were represented on the left hand side of the PCA. Seediness and grittiness have been previously seen as negative traits by consumers (Gilbert et al., 2014; Makus and Morris, 1993). Similar to Figure 3.1, the majority of SHB were liked by consumers, in addition to ‘Powderblue’, ‘Aurora’ and ‘Liberty’ for their texture, shriveled seeds and smaller percent seed wt. : berry wt.

There was a total of twelve cultivars in common between 2018 and 2019 seasons. Principal component analysis was conducted to identify correlations between consumer mean liking scores (active data) and instrumental analyses mean values (supplementary data) and identify groups and possible outliers (Figure 3.3). Fruit quality traits, evaluated using instrumental analyses and consumer sensory liking scores, were chosen based off the correspondence with consumer overall liking in 2018 and 2019 (Figures 3.1 and 3.2). PC 1

explained 90.17% and PC 2 explained 5.74% of the variation among the twelve cultivar fruit quality traits evaluated in 2018 and 2019. On the right hand side, consumer liking of fruit texture, skin toughness, firmness, and seediness highly corresponded to overall liking ($r = 0.79$ to 0.94). Puncture-in weakly correlated to overall liking, texture and skin toughness ($r = 0.38$ to 0.49) and moderately correlated with fruit firmness ($r = 0.50$). Shear force weakly correlated to texture and fruit firmness ($r = 0.13$ to 0.14). Shriveled seeds positively correlated with consumer seediness liking, whereas it was the opposite for plump seeds. On the left hand side, total seeds, percent seed wt. : berry wt., ADF and lignin negatively correlated with consumer overall liking and textural traits. These results indicate that textural traits drive consumer overall liking of blueberries.

In general, the majority of consumers liked SHB textural traits more than NHB and RE. ‘Legacy’, ‘Farthing’ and ‘Camellia’ for both years were liked more for their textural traits than other cultivars. ‘Brightwell’, ‘Powderblue’ and ‘Elliott’ harvested in 2019 and ‘Vernon’ harvested both years were least liked because of their larger plump seed number, total seed number lignin and ADF and lower fruit firmness (shear force) and skin toughness (puncture-in) values. ‘Elliott’ and ‘Brightwell’ harvested in 2018, ‘Star’ harvested in 2019 and ‘Alapaha’ harvested both years, outliers, may have been liked by consumers for traits other than texture. Results suggest that harvest year affects cultivar fruit quality and consumer overall liking.

Using PCA, a large group corresponded to consumer liking of texture, specifically skin toughness and fruit firmness. Grouping of these traits may suggest that consumers cannot differentiate between skin toughness and fruit firmness. Fruit firmness scores corresponded more to puncture-in than to shear force. Amaral et al. (2019) and Blaker et al. (2014) also found textural traits highly corresponded to one another. Consumer acceptability of fruit texture is

highly complex and varies by individual consumer preferences. Using skin toughness and fruit firmness and fruit quality descriptors confusion and variation among consumers' responses (Blaker et al., 2014; Gilbert et al., 2014; Parker and Lessig, 1981).

CONCLUSIONS

Comparing instrumental analyses and consumer acceptability of blueberry physical fruit quality traits of the main commercial types grown in the US, may allow researchers to select and breed cultivars with superior traits. There was variation among types and cultivars physical traits, and across years. SHB were liked by the majority of consumers for their textural traits, contrary to the subjective idea that NHB fruit quality is superior to SHB and RE. Harvest year and other environmental conditions (location, sorting, storage time and harvesting methods) are believed to have influenced skin toughness, fruit firmness, fruit size, seed and fiber content.

Evaluation of both type and cultivar difference should continue to be conducted. Currently, blueberries have not been marketed by type or cultivar, as there are several limitations, such as cultivar fruit quality consistency year-to-year, variation among a cultivar and required time to market. Type evaluation using instrumental analyses and consumer acceptability may increase SHB and RE marketability and price point, specifically grown in the Southeast. Whereas, a cultivar assessment may allow breeders to select particular traits within the current commercial germplasm and breed fruit with desirable fruit quality.

Fruit quality continues to be essential to consumer consumption habits and increase of fresh fruit profitability. Texture, appearance and flavor have been associated with consumer increased eating quality and acceptability. However, researchers have yet to evaluate the correspondence of instrumental analyses of textural and flavor traits with consumer overall liking. Correspondence of consumer overall liking with chemical traits (color, sugars, acids,

flavor and aroma) is essential for breeders and growers to understand which traits drive consumption. Overall, results may increase consumer purchasing habits and allow growers to set premium price points for desired cultivars.

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Table 3.1 Skin toughness and fruit firmness mean values of eighteen cultivars and three blueberry types harvested in 2018.

Type	Cultivar	Skin toughness		Fruit firmness
		Puncture-in (N)	Puncture-out (N)	Shear force (N)
		***	***	***
SHB	'Camellia'	1.215 c ^{zy}	0.686 cd	267.25 g-i ^x
	'Farthing'	1.317 bc	0.770 bc	373.37 c
	'Keecrisp'	1.514 a	0.895 ab	367.85 c
	'Legacy' Georgia	1.001 d	0.548 d-g	301.56 e-g
	'Legacy' Michigan	0.918 d-f	0.471 fg	345.48 cd
	'Meadowlark'	1.428 ab	0.786 bc	490.23 a
	'Star'	0.992 d	0.556 d-f	310.52 d-f
	'Suziblue'	1.427 ab	0.851 ab	371.67 c
RE	'Alapaha'	0.696 h	0.465 fg	236.76 i
	'Austin'	0.795 e-h	0.599 d-f	371.54 c
	'Brightwell'	0.724 gh	0.539 e-g	326.86 de
	'Powderblue'	0.631 h	0.414 g	283.39 f-h
	'Vernon'	0.937 d-f	0.507 e-g	257.08 hi
NHB	'Aurora'	0.946 de	0.617 de	273.71 f-i
	'Bluecrop'	0.942 d-f	0.575 e-g	281.31 f-h
	'Draper'	1.430 ab	0.983 a	460.56 a
	'Elliott'	0.764 f-h	0.484 e-g	413.64 b
	'Liberty'	0.889 d-g	0.592 e-g	346.39 cd
	'Nelson'	0.998 d	0.596 e-g	304.88 e-g
	Type	***	***	***
SHB	1.227(0.0) a ^{wv}	0.696(0.0) a	353.49(8.1) a ^u	
RE	0.757(0.0) c	0.505(0.0) c	295.13(7.6) b	
NHB	0.995(0.0) b	0.641(0.0) b	346.75(10.0) a	

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 36 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$. *** Significant at $P \leq 0.001$, respectively.

^xN = 9 per cultivar

^wN = 288 for SHB; N = 216 for RE; N = 180 for NHB

^vValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^uN = 72 for SHB; N = 45 for RE; N = 54 for NHB

Table 3.2 Skin toughness and fruit firmness mean values of fourteen cultivars and three blueberry types harvested in 2019.

Type	Cultivar	Skin toughness		Fruit firmness			
		Puncture-in (N)	Puncture-out (N)	Shear force (N)			
		***	***	***			
SHB	'Camellia'	0.756	c ^{zy}	0.491	cd	270.93	d ^x
	'Farthing'	0.782	bc	0.533	b-d	266.24	d
	'Legacy' Georgia	0.727	cd	0.560	bc	368.58	ab
	'Legacy' Michigan	0.794	bc	0.492	cd	345.52	bc
	'Patrecia'	0.782	bc	0.455	c-e	156.77	f
	'Star'	0.499	e	0.268	f	180.74	ef
	'Suziblue'	0.946	a	0.515	b-d	205.22	e
RE	'Alapaha'	0.907	ab	0.609	ab	368.46	ab
	'Brightwell'	0.788	bc	0.551	bc	317.43	c
	'Powderblue'	0.741	cd	0.443	de	329.42	c
	'Premier'	0.582	e	0.428	de	276.32	d
	'Vernon'	0.600	de	0.480	cd	280.55	d
NHB	'Aurora'	1.013	a	0.696	a	379.04	a
	'Elliott'	0.520	e	0.369	ef	340.67	bc
	'Liberty'	0.927	ab	0.708	a	321.38	c
Type	***	***	***	***	***	***	
SHB	0.755(0.0)	b ^{wv}	0.473(0.0)	b	256.29(9.8)	b ^u	
RE	0.724(0.0)	b	0.502(0.0)	b	314.44(5.6)	a	
NHB	0.820(0.0)	a	0.591(0.0)	a	347.03(5.9)	a	

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 36 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$. ***Significant at $P \leq 0.001$, respectively.

^xN = 9 per cultivar

^wN = 252 for SHB; N = 180 for RE; N = 108 for NHB

^vValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^uN = 63 for SHB; N = 45 for RE; N = 27 for NHB

Table 3.3 Skin toughness and fruit firmness mean values of the same blueberry cultivars and types harvested in 2018 and 2019.

Type	Cultivar	Skin toughness				Fruit firmness	
		Puncture-in (N)		Puncture-out (N)		Shear force (N)	
		2018	2019	2018	2019	2018	2019
SHB	'Camellia'	1.21 bA ^{zy}	0.76 dB	0.69 bcA	0.49 cdB	267.2 ghA ^x	270.9 dA
	'Farthing'	1.32 abA	0.78 cdB	0.77 abA	0.53 b-dB	373.4 bA	266.2 dB
	'Legacy' Georgia	1.00 cA	0.73 deB	0.55 d-fA	0.56 bcA	301.6 d-fB	368.6 aA
	'Legacy' Michigan	0.92 cdA	0.79 b-dB	0.47 e-gA	0.49 cdA	345.5 bcA	345.5 bcA
	'Star'	0.99 cA	0.50 fB	0.56 d-fA	0.27 fB	310.5 deA	180.7 eB
	'Suziblue'	1.43 aA	0.95 aB	0.85 aA	0.51 b-dB	371.7 bA	205.2 eB
RE	'Alapaha'	0.70 fB	0.91 a-cA	0.47 fgB	0.61 abA	236.8 hB	368.5 abA
	'Brightwell'	0.72 efA	0.79 b-dA	0.54 d-gA	0.55 bcA	326.9 cdA	317.4 cA
	'Powderblue'	0.63 fB	0.74 deA	0.41 gA	0.44 deA	283.4 e-gB	329.4 cA
	'Vernon'	0.94 cdA	0.60 efB	0.51 d-gA	0.48 cdA	257.1 ghB	280.6 dA
NHB	'Aurora'	0.95 cA	1.01 aA	0.62 cdA	0.70 aA	273.7 fgB	379.0 aA
	'Elliott'	0.76 d-fA	0.52 fB	0.48 e-gA	0.37 efB	413.6 aA	340.7 bcB
	'Liberty'	0.89 c-eA	0.93 abA	0.59 c-eB	0.71 aA	346.4 bcA	321.4 cB
SHB		1.15(0.0) aA ^{wv}	0.75(0.0) bB	0.65(0.0) aA	0.48(0.0) cB	328.3(6.3) aA ^u	272.9(9.7) cB
RE		0.75(0.0) cA	0.76(0.0) bA	0.48(0.0) cB	0.52(0.0) bA	276.0(6.1) bB	324(6.0) bA
NHB		0.87(0.0) bA	0.82(0.0) aA	0.56(0.0) bA	0.59(0.0) aA	344.6(11.7) aA	347(5.9) aA

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 36 per cultivar

^yDifferent lowercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different uppercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^xN = 9 per cultivar

^wN = 216 for SHB; N = 144 for RE; N = 108 for NHB

^vValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^uN = 54 for SHB; N = 36 for RE; N = 27 for NHB

Table 3.4 Individual berry weight, diameters and 50 berry weight mean values of eighteen cultivars and three blueberry types harvested in 2018.

Type	Cultivar	Berry wt. (g)		Berry equator diameter (mm)		Berry height (mm)		50 berry wt. (g)	
		***		***		***		***	
SHB	'Camellia'	2.42	c ^{zy}	17.34	c	14.33	a	102.89	c ^x
	'Farthing'	2.92	a	19.01	a	14.16	ab	100.44	c
	'Keecrisp'	2.05	d	16.07	e	13.59	cd	85.45	e
	'Legacy' Georgia	2.63	b	18.17	b	14.02	a-c	117.40	a
	'Legacy' Michigan	1.26	j	13.88	gh	10.73	g	51.77	i
	'Meadowlark'	2.33	c	17.69	bc	13.60	b-d	81.01	e-g
	'Star'	1.79	e-g	15.78	e	12.15	ef	70.80	h
	'Suziblue'	2.29	c	16.77	d	14.23	a	78.54	g
RE	'Alapaha'	1.67	gh	14.79	f	13.65	b-d	72.38	h
	'Austin'	1.42	ij	13.77	h	12.54	e	75.25	gh
	'Brightwell'	1.55	hi	14.43	fg	13.39	d	76.47	gh
	'Powderblue'	1.70	f-h	14.69	f	13.27	d	84.98	ef
	'Vernon'	3.07	a	19.14	a	14.25	a	109.52	b
NHB	'Aurora'	2.27	c	17.32	cd	12.57	e	101.49	c
	'Bluecrop'	1.89	de	16.19	e	12.07	ef	93.01	d
	'Draper'	1.66	gh	15.62	e	11.64	f	79.30	fg
	'Elliott'	1.06	k	13.19	i	10.26	g	53.06	i
	'Liberty'	0.73	l	11.67	j	9.03	h	55.89	i
	'Nelson'	1.86	ef	16.00	e	12.15	ef	104.41	bc
Type		***		***		***		NS	
SHB		2.21(0.0)	a ^{wv}	16.84(0.1)	a	13.35(0.1)	a	86.04(0.3) ^u	
RE		1.88(0.1)	b	15.36(0.2)	b	13.42(0.1)	a	83.72(2.1)	
NHB		1.58(0.0)	c	15.00(0.1)	b	11.29(0.1)	b	81.19(2.8)	

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 36 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$.

NS, ***Nonsignificant or significant at $P \leq 0.05$ or $P \leq 0.001$, respectively.

^xN = 9 per cultivar

^wN = 288 for SHB; N = 216 for RE; N = 180 for NHB

^vValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^uN = 72 for SHB; N = 45 for RE; N = 54 for NHB

Table 3.5 Individual berry weight, diameters and 50 berry weight mean values of fourteen cultivars and three blueberry types harvested in 2019.

Type	Cultivar	Berry wt. (g)		Berry equator diameter (mm)		Berry height (mm)		50 berry wt. (g)	
		***		***		***		***	
SHB	'Camellia'	2.08	e ^{zy}	15.99	f	12.43	ef	117.39 ^x	c
	'Farthing'	3.37	b	19.40	b	14.58	b	141.57	b
	'Legacy' Georgia	1.90	ef	15.35	g	11.68	g	95.74	e
	'Legacy' Michigan	2.06	e	16.51	d-f	12.38	ef	96.28	e
	'Patrecia'	3.89	a	20.50	a	15.18	a	190.15	a
	'Star'	2.09	e	16.09	ef	13.28	cd	100.25	e
	'Suziblue'	2.92	c	18.07	c	15.20	a	108.30	d
RE	'Alapaha'	1.25	g	12.94	i	11.92	fg	50.68	h
	'Brightwell'	1.71	f	14.75	h	12.85	de	66.30	g
	'Powderblue'	1.92	e	15.22	gh	13.39	c	61.90	g
	'Premier'	2.48	d	16.48	d-f	13.01	cd	122.62	c
	'Vernon'	2.35	d	16.61	de	13.20	cd	122.23	c
NHB	'Aurora'	2.07	e	17.01	d	12.00	fg	100.52	e
	'Elliott'	2.02	e	16.82	d	11.62	g	89.27	f
	'Liberty'	2.03	e	16.84	d	12.02	fg	95.75	e
Type	***		***		***		***		
SHB	2.61(0.1)	a ^{wv}	17.41(0.1)	a	13.53(0.0)	a	121.39(4.1)	a ^u	
RE	1.94(0.1)	b	15.20(0.1)	c	12.87(0.0)	b	84.75(4.7)	b	
NHB	2.04(0.1)	b	16.89(0.1)	b	11.88(0.0)	c	95.18(1.1)	b	

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 36 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$.

*** Significant at $P \leq 0.001$, respectively.

^xN = 9 per cultivar

^wN = 252 for SHB; N = 180 for RE; N = 108 for NHB

^vValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^uN = 63 for SHB; N = 45 for RE; N = 27 for NHB

Table 3.6 Individual berry size (weight, equator diameter, and height) mean values of the same blueberry cultivars and types harvested in 2018 and 2019.

Type	Cultivar	Berry wt. (g)		Berry diameter equator (mm)		Berry height (mm)	
		2018	2019	2018	2019	2018	2019
SHB	'Camellia'	2.42 cA ^{zy}	2.08 dB	17.34 cA	15.99 eB	14.33 aA	12.43 efB
	'Farthing'	2.92 aB	3.37 aA	19.01 aA	19.40 aA	14.16 abB	14.58 bA
	'Legacy' Georgia	2.63 bA	1.90 dB	18.17 bA	15.35 fB	14.02 abA	11.68 hB
	'Legacy' Michigan	1.26 fB	2.06 dA	13.88 gB	16.51 c-eA	10.73 eB	12.38 e-gA
	'Star'	1.79 dB	2.09 dA	15.78 eA	16.09 deA	12.15 dB	13.28 cdA
	'Suziblue'	2.29 cB	2.92 bA	16.77 dB	18.07 bA	14.23 aB	15.20 aA
RE	'Alapaha'	1.67 deA	1.25 fB	14.79 fA	12.94 hB	13.65 bcA	11.92 ghB
	'Brightwell'	1.55 eB	1.71 eA	14.43 fB	14.75 gA	13.39 cA	12.85 deB
	'Powderblue'	1.70 deB	1.92 dA	14.69 fB	15.22 fgA	13.27 cA	13.39 cA
	'Vernon'	3.07 aA	2.35 cB	19.14 aA	16.61 cdB	14.25 aA	13.20 cdB
NHB	'Aurora'	2.27 cA	2.07 dB	17.32 cA	17.01 cB	12.57 dA	12.00 f-hB
	'Elliott'	1.06 gB	2.02 dA	13.19 hB	16.82 cA	10.26 eB	11.62 hA
	'Liberty'	0.73 hB	2.03 dA	11.67 iB	16.84 cA	9.03 fB	12.02 f-hA
SHB		2.22(0.0) aB ^{xw}	2.40(0.0) aA	16.82(0.1) aA	16.90(0.1) aA	13.27(0.1) bA	13.26(0.1) aA
RE		2.00(0.1) bA	1.80(0.0) cB	15.76(0.2) bA	14.88(0.1) bB	13.64(0.1) aA	12.84(0.1) bB
NHB		1.36(0.1) cB	2.04(0.0) bA	14.06(0.2) cB	16.89(0.1) aA	10.62(0.2) cB	11.88(0.1) cA

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 36 per cultivar

^yDifferent lowercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different uppercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^x Values within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 216 for SHB; N = 144 for RE; N = 108 for NHB

Table 3.7 Mean values of 50 berry weight mean values of the same blueberry cultivars and types harvested in 2018 and 2019.

Type	Cultivar	50 berry wt. (g)			
		2018		2019	
SHB	'Camellia'	102.89	cB ^{zy}	117.39	bA
	'Farthing'	100.44	cB	141.57	aA
	'Legacy' Georgia	117.40	aA	95.74	dB
	'Legacy' Michigan	51.77	hB	96.28	dA
	'Star'	70.80	gB	100.25	dA
	'Suziblue'	78.54	eB	108.30	cA
RE	'Alapaha'	72.38	fgA	50.68	gB
	'Brightwell'	76.47	efA	66.30	fB
	'Powderblue'	84.98	dA	61.90	fB
	'Vernon'	109.52	bB	122.23	bA
NHB	'Aurora'	101.49	cA	100.52	dA
	'Elliott'	53.06	hB	89.27	eA
	'Liberty'	55.89	hB	95.75	dA
SHB		86.97(3.1)	aB ^{xw}	109.92(2.3)	aA
RE		85.84(2.5)	aA	75.28(4.7)	cA
NHB		70.14(4.4)	bB	95.18(1.1)	bA

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 9 per cultivar

^yDifferent lowercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different uppercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^x Values within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 54 for SHB; N = 36 for RE; N = 27 for NHB

Table 3.8 Berries', used for seed extraction, weight, diameter and height mean values of eighteen cultivars and three blueberry types harvested in 2018.

Type	Cultivar	Berry wt. (g)	Berry diameter equator (mm)	Berry height (mm)
		***	***	***
SHB	'Camellia'	1.57 fg ^{zy}	14.90 f-h	12.60 a-c
	'Farthing'	2.14 bc	16.99 bc	12.87 a-c
	'Keecrisp'	1.69 d-f	15.34 e-g	12.96 a-c
	'Legacy' Georgia	2.45 a	17.94 ab	13.37 a
	'Legacy' Michigan	1.19 h-j	13.76 i-k	10.86 ef
	'Meadowlark'	1.73 d-f	15.88 d-f	12.47 bc
	'Star'	1.36 g-i	14.37 g-j	11.39 e
	'Suziblue'	1.72 d-f	15.08 fg	12.89 a-c
RE	'Alapaha'	1.66 e-g	14.75 g-i	13.20 ab
	'Austin'	1.45 f-h	14.04 h-k	12.73 a-c
	'Brightwell'	1.53 fg	14.62 g-j	13.36 a
	'Powderblue'	1.59 e-g	14.54 g-j	13.22 ab
	'Vernon'	1.97 cd	16.10 c-e	13.33 ab
NHB	'Aurora'	1.57 fg	15.20 e-g	11.58 de
	'Bluecrop'	2.33 ab	17.93 ab	12.87 a-c
	'Draper'	1.89 c-e	16.47 cd	12.29 cd
	'Elliott'	0.96 j	13.20 k	10.31 f
	'Liberty'	1.08 ij	13.61 jk	10.15 f
	'Nelson'	2.47 a	18.18 a	12.94 a-c
Type	NS	***	***	
SHB	1.73(0.0) ^{xw}	15.53(0.1) a	12.43(0.1) b	
RE	1.64(0.0)	14.81(0.1) b	13.17(0.1) a	
NHB	1.71(0.1)	15.77(0.2) a	11.69(0.1) c	

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 15 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$.

NS, *** Nonsignificant or significant at $P \leq 0.05$ or $P \leq 0.001$, respectively.

^x Values within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 120 for SHB; N = 75 for RE; N = 90 for NHB

Table 3.9 Berries¹, used for seed extraction, weight and diameter mean values of fourteen cultivars and three blueberry types harvested in 2019.

Type	Cultivar	Berry wt. (g)		Berry diameter equator (mm)		Berry height (mm)	
		***		***		***	
SHB	'Camellia'	1.73	f ^z y	15.82	e	11.68	f
	'Farthing'	3.12	b	18.95	b	14.40	b
	'Legacy' Georgia	1.81	ef	16.03	de	12.12	ef
	'Legacy' Michigan	2.16	de	16.97	c-e	12.94	de
	'Patrecia'	4.08	a	21.26	a	15.67	a
	'Star'	2.34	cd	16.68	c-e	13.67	b-d
	'Suziblue'	2.29	cd	16.54	c-e	13.95	bc
RE	'Alapaha'	1.21	g	12.55	g	11.96	f
	'Brightwell'	1.56	fg	14.32	f	12.30	de
	'Powderblue'	1.51	fg	14.16	f	12.18	ef
	'Premier'	2.62	c	17.79	bc	13.92	bc
	'Vernon'	2.44	cd	17.14	cd	13.47	cd
NHB	'Aurora'	1.23	g	14.48	f	10.40	g
	'Elliott'	1.26	g	14.32	f	10.58	g
	'Liberty'	1.80	ef	16.27	de	11.66	f
Type	***		***		***		
SHB	2.50(0.1)	a ^{xw}	17.46(0.2)	a	13.49(0.1)	a	
RE	1.87(0.1)	b	15.19(0.3)	b	12.76(0.1)	b	
NHB	1.43(0.1)	c	15.02(0.2)	b	10.88(0.1)	c	

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 15 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$. ***Significant at $P \leq 0.001$, respectively.

^x Values within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 105 for SHB; N = 75 for RE; N = 45 for NHB

Table 3.10 Seed trait mean values of eighteen cultivars and three blueberry types harvested in 2018.

Type Cultivar	Plump seed no.	Shriveled seed no.	Total seed no.	Plump seeds : total seeds (%)	Shriveled seeds : total seeds (%)	Total seed wt. (mg)	Seed wt. : berry wt.	Seed wt. : berry wt. (%)
	***	***	***	***	***	***	***	***
SHB 'Camellia'	33.2 e-c ^{zy}	35.0 c-g	68.2 a-e	43.00 e-g	57.00 d-f	1.03 g-i	0.01 fg	0.66 ef
'Farthing'	47.9 b-c	34.4 d-g	82.3 a-c	58.36 a-e	41.64 f-j	1.31 fg	0.01 fg	0.61 ef
'Keecrisp'	43.3 c	32.4 e-h	75.7 a-d	56.93 b-e	43.07 f-i	2.32 c-e	0.01 de	1.37 cd
'Legacy' GA	40.5 c	23.7 f-h	64.1 b-e	62.86 a-d	37.14 g-j	2.41 b-d	0.01 ef	0.98 de
'Legacy' MI	8.7 fg	58.2 ab	66.9 a-e	13.48 ij	86.52 ab	0.39 i	0.00 g	0.22 f
'Meadowlark'	17.1 fg	46.5 b-e	63.6 c-e	27.32 g-i	72.68 b-d	0.96 g-i	0.01 fg	0.55 ef
'Star'	19 e-f	35.6 c-g	54.6 e	32.62 f-h	67.38 c-e	0.51 hi	0.00 g	0.38 f
'Suziblue'	43.9 bc	22.5 gh	66.3 a-e	66.14 a-c	33.86 h-j	2.09 c-f	0.01 e	1.24 d
RE 'Alapaha'	46.7 bc	17.5 h	64.3 a-e	72.81 ab	27.19 ij	2.41 b-d	0.01 c-e	1.42 cd
'Austin'	58.9 ab	24.2 f-h	83.1 a	71.09 a-c	28.91 h-j	3.17 ab	0.02 ab	2.20 ab
'Brightwell'	38.4 cd	21.3 gh	59.7 de	62.58 a-d	37.42 g-j	2.69 bc	0.02 b-d	1.76 bc
'Powderblue'	47.3 a-c	33.5 d-g	80.8 a-c	58.34 a-e	41.66 g-j	3.57 a	0.02 a	2.27 a
'Vernon'	62.6 a	20.3 gh	82.9 ab	75.51 a	24.49 j	3.66 a	0.02 a-c	1.84 a-c
NHB 'Aurora'	15.8 fg	57.1 ab	72.9 a-e	20.09 h-j	79.91 a-c	1.02 g-i	0.01 fg	0.60 ef
'Bluecrop'	34.3 c-e	38.3 c-f	72.5 a-e	46.90 d-f	53.10 e-g	1.54 e-g	0.01 fg	0.66 ef
'Draper'	23.6 d-f	48.1 b-d	71.7 a-e	32.90 f-h	67.10 c-e	1.16 g-i	0.01 fg	0.63 ef
'Elliott'	16.3 fg	50.5 a-c	66.8 a-e	24.27 h-j	75.73 a-c	1.20 gh	0.01 de	1.28 d
'Liberty'	6.3 g	65.2 a	71.5 a-e	9.03 j	90.97 a	0.48 hi	0.00 g	0.44 f
'Nelson'	37.6 cd	32.2 e-h	69.8 a-e	54.21 c-e	45.79 f-h	1.67 c-g	0.01 fg	0.67 ef
Type	***	***	***	***	***	***	***	***
SHB	31.7(1.7) b ^{xw}	36.0(1.5) b	67.7(1.7) b	45.09(2.1) b	54.91(2.1) b	1.38(0.0) b	0.01(0.0) b	0.75(0.0) b
RE	50.8(1.8) a	23.4(1.4) c	74.2(1.8) a	68.07(1.8) a	31.93(1.8) c	3.10(0.0) a	0.02(0.0) a	1.9(0.1) a
NHB	22.3(1.5) c	48.6(1.6) a	70.9(2.0) ab	31.23(2.0) c	68.77(2.0) a	1.18(0.0) b	0.01(0.0) b	0.71(0.0) b

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 15 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$.

*** Significant at $P \leq 0.001$, respectively.

^x Values within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 120 for SHB; N = 75 for RE; N = 90 for NHB

Table 3.11 Seed traits mean values of fourteen cultivars and three blueberry types harvested in 2019.

Type	Cultivar	Plump seed	Shriveled	Total seed no.	Plump seeds :	Shriveled	Total seed	Seed wt. :	Seed wt. :
		no.	seed no.		total seeds	seeds : total	wt. (mg)	berry wt.	berry wt. (%)
		***	***	***	***	***	***	***	***
					(%)	seeds (%)			
SHB	'Camellia'	7.0 gh ^{zy}	45.3 c-f	52.3 f-h	14.00 ef	86.00 ab	1.02 g-i	0.01 f-h	0.59 e-h
	'Farthing'	29.1 bc	58.1 b-d	87.2 a-c	33.26 b-d	66.74 c-e	2.37 cd	0.01 e-g	0.76 d-g
	Legacy' GA	19.1 de	30.5 fg	49.6 gh	38.45 ab	61.55 ef	1.62 e-g	0.01 ef	0.92 de
	Legacy' MI	14.7 e-g	52.7 c-e	67.3 d-g	22.27 de	77.73 bc	1.06 gh	0.00 gh	0.49 f-h
	'Patrecia'	13.7 e-g	41.1 d-g	54.8 e-h	24.09 c-e	75.91 b-d	1.14 gh	0.00 h	0.28 h
	'Star'	15.8 e-g	23.5 g	39.3 h	39.70 ab	60.30 ef	0.93 hi	0.00 gh	0.40 gh
	'Suzibblue'	31.3 a-c	38.0 e-g	69.3 c-f	44.98 ab	55.02 ef	1.86 d-f	0.01 e-g	0.81 d-f
RE	'Alapaha'	15.5 e-g	30.9 fg	46.4 h	33.45 b-d	66.55 c-e	1.36 f-h	0.01 de	1.12 d
	'Brightwell'	34.0 a-c	47.0 c-f	81.0 a-d	42.33 ab	57.67 ef	3.59 ab	0.02 a	2.33 a
	'Powderblue'	27.3 cd	46.2 c-f	73.5 a-d	37.63 a-c	62.37 d-f	2.90 bc	0.02 b	1.93 b
	'Premier'	37.7 ab	47.5 c-f	85.3 a-d	44.87 ab	55.13 ef	3.93 a	0.02 cd	1.52 c
	'Vernon'	39.2 a	37.5 e-g	76.7 a-d	51.09 a	48.91 f	3.81 a	0.02 bc	1.60 bc
NHB	'Aurora'	2.6 h	86.9 a	89.5 a	3.67 f	96.33 a	0.35 i	0.00 h	0.28 h
	'Elliott'	18.6 d-f	70.8 ab	89.4 ab	21.36 de	78.64 bc	2.07 de	0.02 bc	1.66 bc
	'Liberty'	8.9 f-h	62.5 bc	71.4 b-e	12.98 ef	87.02 ab	0.86 hi	0.00 gh	0.46 f-h
Type		***	***	***	***	***	***	***	***
SHB		18.7(1.1) b ^{xw}	41.3(1.6) b	60.0(1.9) c	30.96(1.5) b	69.04(1.5) b	1.43(0.0) b	0.01(0.0) b	0.61(0.0) b
RE		30.8(1.5) a	41.8(1.5) b	72.6(2.1) b	41.87(1.6) a	58.13(1.6) c	3.12(0.0) a	0.02(0.0) a	1.70(0.1) a
NHB		10.0(1.2) c	73.4(3.4) a	83.4(3.1) a	12.67(1.4) c	87.33(1.4) a	1.10(0.0) b	0.01(0.0) b	0.80(0.1) b

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 15 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$.

*** Significant at $P \leq 0.001$, respectively.

^x Values within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 105 for SHB; N = 75 for RE; N = 45 for NHB

Table 3.12 Fruit, used for seed extraction, weight, equator diameter and height mean values of the same blueberry cultivars and types harvested in 2018 and 2019.

Type	Cultivar	Berry wt. (g)		Berry diameter equator (mm)		Berry height (mm)	
		2018	2019	2018	2019	2018	2019
SHB	‘Camellia’	1.57 deB ^{zy}	1.73 dA	14.90 dB	15.82 cA	12.60 aA	11.68 eB
	‘Farthing’	2.14 abB	3.12 aA	16.99 abB	18.95 aA	12.87 aB	14.40 aA
	‘Legacy’ Georgia	2.45 aA	1.81 cdB	17.94 aA	16.03 bcB	13.37 aA	12.12 deB
	‘Legacy’ Michigan	1.19 fgB	2.16 bcA	13.76 e-gB	16.97 bcA	10.86 bcB	12.94 cdA
	‘Star’	1.36 efB	2.34 bA	14.37 d-fB	16.68 bcA	11.39 bB	13.67 a-cA
	‘Suziblue’	1.72 cdB	2.29 bA	15.08 cdB	16.54 bcA	12.89 aB	13.95 a-cA
RE	‘Alapaha’	1.66 deA	1.21 eB	14.75 deA	12.55 eB	13.20 aA	11.96 eB
	‘Brightwell’	1.53 deA	1.56 deA	14.62 d-fA	14.32 dA	13.36 aA	12.30 deB
	‘Powderblue’	1.59 deA	1.51 deA	14.54 d-fA	14.16 dA	13.22 aA	12.18 deB
	‘Vernon’	1.97 bcB	2.44 bA	16.10 bcB	17.14 bA	13.33 aA	13.47 bcA
NHB	‘Aurora’	1.57 deA	1.23 eB	15.20 cdA	14.48 dA	11.58 bA	10.40 fB
	‘Elliott’	0.96 gB	1.26 eA	13.20 gB	14.32 dA	10.31 cA	10.58 fA
	‘Liberty’	1.08 fgB	1.80 cdA	13.61 fgB	16.27 bcA	10.15 cB	11.66 eA
SHB		1.74(0.1) aB ^{xw}	2.24(0.1) aA	15.51(0.2) aB	16.83(0.2) aA	12.33(0.1) bB	13.13(0.1) aA
RE		1.69(0.0) aA	1.68(0.1) bA	15.00(0.1) aA	14.54(0.3) bA	13.28(0.1) aA	12.47(0.1) bB
NHB		1.20(0.1) bB	1.43(0.1) cA	14.01(0.2) bB	15.02(0.2) bA	10.68(0.2) cA	10.88(0.1) cA

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 15 per cultivar

^yDifferent lowercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different uppercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^xValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 90 for SHB; N = 60 for RE; N = 45 for NHB

Table 3.13 Plump seed, shriveled seed and total seed mean values of the same blueberry cultivars and types harvested in 2018 and 2019.

Type	Cultivar	Plump seed no.		Shriveled seed no.		Total seed no.	
		2018	2019	2018	2019	2018	2019
SHB	‘Camellia’	33.2 bcA ^{zy}	7.0 fgB	35.0 c-eA	45.3 c-eA	68.2 abA	52.3 deA
	‘Farthing’	47.9 abA	29.1 bB	34.4 c-eB	58.1 bcA	82.3 aA	87.2 a-cA
	‘Legacy’ Georgia	40.5 bA	19.1 cdB	23.7 c-eB	30.5 efA	64.1 abA	49.6 eB
	‘Legacy’ Michigan	8.7 dA	14.7 d-fA	58.2 aA	52.7 c-eA	66.9 abA	67.3 cdA
	‘Star’	19.0 cdA	15.8 d-fA	35.6 bcA	23.5 fB	54.6 bA	39.3 eB
	‘Suziblue’	43.9 bA	31.3 abB	22.5 c-eB	38.0 d-fA	66.3 abA	69.3 cdA
RE	‘Alapaha’	46.7 bA	15.5 d-fB	17.5 eB	30.9 efA	64.3 abA	46.4 eB
	‘Brightwell’	38.4 bA	34.0 abA	21.3 c-eB	47.0 c-eA	59.7 bB	81 a-cA
	‘Powderblue’	47.3 bA	27.3 bcB	33.5 c-eB	46.2 c-eA	80.8 aA	73.5 a-cA
	‘Vernon’	62.6 aA	39.2 aB	20.3 deB	37.5 d-fA	82.9 aA	76.7 a-cA
NHB	‘Aurora’	15.8 dA	2.6 gB	57.1 aB	86.9 aA	72.9 abB	89.5 aA
	‘Elliott’	16.3 dA	18.6 c-eA	50.5 abB	70.8 abA	66.8 abB	89.4 aA
	‘Liberty’	6.3 dA	8.9 e-gA	65.2 aA	62.5 bcA	71.5 abA	71.4 bcA
SHB		32.2(2.0) bA ^{xw}	19.5(1.2) bB	34.9(1.8) bB	41.4(1.8) bA	67.1(2.0) aA	60.9(2.1) cA
RE		48.8(2.1) aA	29.0(1.7) aB	23.2(1.7) cB	40.4(1.7) bA	71.9(2.1) aA	69.4(2.3) bA
NHB		12.8(1.4) cA	10.0(1.2) cA	57.6(2.0) aB	73.4(3.4) aA	70.4(2.1) aB	83.4(3.1) aA

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 15 per cultivar

^yDifferent lowercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different uppercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 90 for SHB; N = 60 for RE; N = 45 for NHB

Table 3.14 Percent plump seeds : total seeds and percent shriveled seeds : total seeds mean values of the same blueberry cultivars and types harvested in 2018 and 2019.

Type	Cultivar	Plump seeds : total seeds (%)		Shriveled seeds : total seeds (%)	
		2018	2019	2018	2019
SHB	‘Camellia’	43.00 cdA ^{zy}	14.00 deB	57.00 cdB	86.00 abA
	‘Farthing’	58.36 bcA	33.26 bcB	41.64 deB	66.74 cdA
	‘Legacy’ GA	62.86 abA	38.45 abB	37.14 efB	61.55 deA
	‘Legacy’ MI	13.48 fA	22.27 cdA	86.52 aA	77.73 bcA
	‘Star’	32.62 deA	39.70 abA	67.38 bcA	60.30 deA
	‘Suziblue’	66.14 abA	44.98 abB	33.86 efB	55.02 deA
RE	‘Alapaha’	72.81 abA	33.45 bcB	27.19 efB	66.55 cdA
	‘Brightwell’	62.58 abA	42.33 abB	37.42 efB	57.67 deA
	‘Powderblue’	58.34 bcA	37.63 abB	41.66 deB	62.37 deA
	‘Vernon’	75.51 abA	51.09 abB	24.49 fB	48.91 eA
NHB	‘Aurora’	20.09 efA	3.67 eB	79.91 abB	96.33 aA
	‘Elliott’	24.27 efA	21.36 cdA	75.73 abA	78.64 bcA
	‘Liberty’	9.03 fA	12.98 deA	90.97 aA	87.02 abA
SHB		46.08(2.4) bA ^{xw}	32.11(1.7) bB	53.92(2.4) bB	67.89(1.7) bA
RE		67.31(2.2) aA	41.13(1.8) aB	32.69(2.2) cB	58.87(1.8) cA
NHB		17.80(1.8) cA	12.67(1.4) cB	82.20(1.8) aB	87.33(1.4) aA

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 15 per cultivar

^yDifferent lowercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different uppercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$. ^xValues within parentheses indicate type Standard Error (SE).

^wN = 90 for SHB; N = 60 for RE; N = 45 for NHB

Table 3.15 Seed weight, seed weight : berry weight, and seed weight : berry weight (%) mean values of the same blueberry cultivars and types harvested in 2018 and 2019.

Type	Cultivar	Total seed wt. (mg)		Seed wt. : berry wt.		Seed wt. : berry wt. (%)	
		2018	2019	2018	2019	2018	2019
SHB	‘Camellia’	1.03 deA ^{zy}	1.02 f-hA	0.01 efA	0.01 d-fA	0.66 efA	0.59 d-gA
	‘Farthing’	1.31 cdB	2.37 bcA	0.01 efA	0.01 c-eA	0.61 efB	0.76 c-fA
	‘Legacy’ Georgia	2.41 bA	1.62 d-fB	0.01 deA	0.01 c-eA	0.98 deA	0.92 c-fA
	‘Legacy’ Michigan	0.39 eB	1.06 fgA	0.00 fB	0.00 efA	0.22 fB	0.49 e-gA
	‘Star’	0.51 deB	0.93 ghA	0.00 fA	0.00 efA	0.38 fA	0.40 fgA
	‘Suziblue’	2.09 bcA	1.86 c-eA	0.01 cdA	0.01 c-eB	1.24 deA	0.81 c-eB
RE	‘Alapaha’	2.41 bA	1.36 e-gB	0.01 b-dA	0.01 cA	1.42 b-dA	1.12 cA
	‘Brightwell’	2.69 bB	3.59 aA	0.02 bcB	0.02 aA	1.76 bcB	2.33 aA
	‘Powderblue’	3.57 aB	2.90 bA	0.02 aA	0.02 abA	2.27 aA	1.93 bA
	‘Vernon’	3.66 aA	3.81 aA	0.02 abA	0.02 bA	1.84 abA	1.60 bA
NHB	‘Aurora’	1.02 deA	0.35 hB	0.01 efA	0.00 fB	0.60 efA	0.28 gB
	‘Elliott’	1.20 deB	2.07 cdA	0.01 cdA	0.02 bA	1.28 cdA	1.66 bA
	‘Liberty’	0.48 eB	0.86 ghA	0.00 fA	0.00 efA	0.44 fA	0.46 e-gA
SHB		1.29(0.0) bA ^{xw}	1.48(0.0) bB	0.01(0.0) bA	0.01(0.0) bA	0.68(0.0) bA	0.66(0.0) bA
RE		3.08(0.0) aA	2.91(0.0) aA	0.02(0.0) aA	0.02(0.0) aA	1.82(0.1) aA	1.75(0.1) aA
NHB		0.90(0.0) cA	1.10(0.0) bA	0.01(0.0) bA	0.01(0.0) bA	0.77(0.1) bA	0.80(0.1) bA

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 15 per cultivar

^yDifferent lowercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different uppercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^xValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 90 for SHB; N = 60 for RE; N = 45 for NHB

Table 3.16 Fiber traits mean values of eighteen cultivars and three blueberry types harvested in 2018.

Type	Cultivar	Neutral	Acid	Lignin (%)	Hemi-	Cellulose (%)
		detergent fiber (%)	detergent fiber (%)		cellulose (%)	
		***	***	***	***	***
SHB	'Camellia'	7.63 e ^{zy}	5.00 d	1.37 de	2.60 ij	3.66 f
	'Farthing'	7.97 e	4.90 d	1.70 b-e	3.00 g-j	3.24 f
	'Keecrisp'	11.93 c	7.73 b	2.10 b-d	4.20 d-f	5.63 cd
	'Legacy' Georgia	8.70 e	5.03 d	1.27 e	3.67 fg	3.74 f
	'Legacy' Michigan	7.93 e	5.00 d	1.67 b-e	2.97 g-j	3.29 f
	'Meadowlark'	7.73 e	4.77 d	1.13 e	2.97 g-j	3.60 f
	'Star'	7.23 e	4.57 de	1.28 e	2.67 h-j	3.29 f
	'Suziblue'	11.13 cd	7.33 b	2.20 bc	3.80 e-g	5.11 d
RE	'Alapaha'	12.73 c	7.60 b	2.37 b	5.13 d	5.20 d
	'Austin'	20.47 a	10.73 a	3.23 a	9.70 a	7.53 a
	'Brightwell'	17.50 b	10.30 a	3.47 a	7.17 c	6.85 ab
	'Powderblue'	18.17 ab	9.67 a	3.23 a	8.50 b	6.41 bc
	'Vernon'	19.67 ab	11.10 a	3.90 a	8.57 b	7.23 ab
NHB	'Aurora'	7.43 e	4.77 d	1.47 c-e	2.67 h-j	3.29 f
	'Bluecrop'	9.23 de	5.70 cd	1.63 b-e	3.60 f-h	4.03 ef
	'Draper'	7.10 ef	4.60 de	1.00 e	2.50 jk	3.60 f
	'Elliott'	11.90 c	7.07 bc	2.33 b	4.73 de	4.75 de
	'Liberty'	4.83 f	3.30 e	1.10 e	1.57 k	2.20 g
	'Nelson'	8.77 e	5.27 d	1.70 b-e	3.53 f-i	3.55 f
Type		***	***	***	***	***
SHB		8.78(0.4) b ^{xw}	5.54(0.3) b	1.59(0.1) b	3.23(0.1) b	3.94(0.2) b
RE		17.71(0.7) a	9.88(0.3) a	3.24(0.1) a	7.81(0.4) a	6.64(0.2) a
NHB		8.21(0.5) b	5.12(0.3) b	1.54(0.1) b	3.10(0.2) b	3.57(0.2) b

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 3 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$. *** Significant at $P \leq 0.001$, respectively.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 24 for SHB; N = 15 for RE; N = 18 for NHB

Table 3.17 Fiber traits mean values of fourteen cultivars and three blueberry types harvested in 2019.

Type	Cultivar	Neutral detergent fiber (%) ***	Acid detergent fiber (%) ***	Lignin (%) ***	Hemi-cellulose (%) ***	Cellulose (%) ***
SHB	'Camellia'	7.27 b-e ^{zy}	5.74 b-d	4.80 ab	1.27 bc	1.20 de
	'Farthing'	6.18 d-f	4.99 c-e	4.15 a-c	1.24 cd	1.21 c-e
	'Legacy' Georgia	7.52 b-e	6.03 a-d	4.93 ab	1.25 b-d	1.23 cd
	'Legacy' Michigan	5.84 ef	4.57 de	3.50 bc	1.28 bc	1.32 ab
	'Patrecia'	6.63 c-f	5.72 b-d	5.03 a	1.16 e	1.14 e
	'Star'	5.01 f	3.95 e	3.27 c	1.27 bc	1.21 c-e
	'Suziblue'	6.07 d-f	5.01 c-e	4.07 a-c	1.21 de	1.24 b-d
RE	'Alapaha'	7.92 b-d	6.22 a-c	4.83 ab	1.27 bc	1.29 a-c
	'Brightwell'	10.04 a	7.36 a	5.50 a	1.36 a	1.34 a
	'Powderblue'	8.67 ab	6.71 ab	5.36 a	1.30 b	1.26 a-d
	'Premier'	8.27 a-c	6.56 a-c	5.26 a	1.26 b-d	1.25 a-d
	'Vernon'	7.58 b-e	5.92 a-d	4.68 a-c	1.28 bc	1.26 a-d
NHB	'Aurora'	6.63 c-f	5.24 b-e	4.38 a-c	1.27 bc	1.19 de
	'Elliott'	7.36 b-e	5.69 b-d	4.50 a-c	1.29 b	1.27 a-d
	'Liberty'	6.91 b-e	5.59 b-d	4.65 a-c	1.24 cd	1.20 de
Type	***	***	***	***	***	
SHB	6.36(0.2) b ^{xw}	5.15(0.2) b	4.25(0.2) b	1.24(0.0) b	1.22(0.0) b	
RE	8.50(0.3) a	6.55(0.2) a	5.13(0.1) a	1.30(0.0) a	1.28(0.0) a	
NHB	6.97(0.1) b	5.51(0.1) b	4.51(0.1) ab	1.27(0.0) ab	1.22(0.0) b	

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 3 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$. *** Significant at $P \leq 0.001$, respectively.

^xValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 21 for SHB; N = 15 for RE; N = 9 for NHB

Table 3.18 Fiber traits (neutral detergent fiber (NDF) and acid detergent fiber (ADF) mean values of the same blueberry cultivars and types harvested in 2018 and 2019.

Type	Cultivar	Neutral detergent fiber (%)		Acid detergent fiber (%)	
		2018	2019	2018	2019
SHB	‘Camellia’	7.63 dA ^{zy}	7.27 b-dA	5.00 dA	5.74 b-dA
	‘Farthing’	7.97 dA	6.18 c-eB	4.90 dA	4.99 c-eA
	‘Legacy’ Georgia	8.70 dA	7.52 b-dA	5.03 dA	6.03 a-dA
	‘Legacy’ Michigan	7.93 dA	5.84 deA	5.00 dA	4.57 deA
	‘Star’	7.23 dA	5.01 eA	4.57 deA	3.95 eA
	‘Suziblue’	11.13 cA	6.07 c-eB	7.33 cA	5.01 c-eA
RE	‘Alapaha’	12.73 cA	7.92 bcB	7.60 cA	6.22 a-cB
	‘Brightwell’	17.50 bA	10.04 aB	10.30 abA	7.36 aB
	‘Powderblue’	18.17 abA	8.67 abB	9.67 bA	6.71 a-cB
	‘Vernon’	19.67 aA	7.58 b-dB	11.10 aA	5.92 a-dB
NHB	‘Aurora’	7.43 dA	6.63 c-eA	4.77 dA	5.24 b-eA
	‘Elliott’	11.90 cA	7.36 b-dB	7.07 cA	5.69 b-dB
	‘Liberty’	4.83 eB	6.91 b-dA	3.30 eB	5.59 b-dA
SHB		8.43(0.4) bA ^{xw}	6.32(0.3) cB	5.31(0.2) bA	5.05(0.2) bA
RE		17.02(0.8) aA	8.55(0.3) aB	9.67(0.4) aA	6.55(0.2) aB
NHB		8.06(1.0) bA	6.97(0.1) bA	5.04(0.6) bA	5.51(0.1) bA

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 3 per cultivar

^yDifferent lowercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different uppercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^xValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 18 for SHB; N = 12 for RE; N = 9 for NHB

Table 3.19 Fiber traits (lignin, hemicellulose and cellulose) mean values of the same blueberry cultivars and types harvested in 2018 and 2019.

Type	Cultivar	Lignin (%)		Hemicellulose (%)		Cellulose (%)	
		2018	2019	2018	2019	2018	2019
SHB	‘Camellia’	1.37dB ^{zy}	4.80a-cA	2.60eA	1.27b-dB	3.66cA	1.20cdB
	‘Farthing’	1.70b-dB	4.15a-cA	3.00deA	1.24cdB	3.24cA	1.21 cdB
	‘Legacy’ Georgia	1.27dB	4.93a-cA	3.67dA	1.25b-dB	3.74cA	1.23b-dB
	‘Legacy’ Michigan	1.67b-dA	3.50bcA	2.97deA	1.28bcB	3.29cA	1.32abB
	‘Star’	1.28dB	3.27cA	2.67eA	1.27bcB	3.29cA	1.21 cdB
	‘Suziblue’	2.20bcA	4.07a-cA	3.80dA	1.21 dB	5.11bA	1.24b-cB
RE	‘Alapaha’	2.37bB	4.83abA	5.13cA	1.27bcB	5.20bA	1.29a-cB
	‘Brightwell’	3.47aB	5.50aA	7.17bA	1.36aB	6.85aA	1.34aB
	‘Powderblue’	3.23aB	5.36aA	8.50aA	1.30bB	6.41aA	1.26a-dB
	‘Vernon’	3.90aB	4.68a-cA	8.57aA	1.28bcB	7.23aA	1.26a-dB
NHB	‘Aurora’	1.47cdB	4.38a-cA	2.67eA	1.27b-dB	3.29cA	1.19dB
	‘Elliott’	2.33bB	4.50a-cA	4.73cA	1.29bcB	4.75bA	1.27a-dB
	‘Liberty’	1.10dB	4.65a-cA	1.57fA	1.24cdA	2.20dA	1.20cdB
SHB		1.58(0.1)bB ^{xw}	4.12(0.2)bA	3.12(0.1)bA	1.25(0.0)bB	3.72(0.2)bA	1.23(0.0)bB
RE		3.24(0.2)aB	5.09(0.2)aA	7.34(0.4)aA	1.30(0.0)aB	6.42(0.2)aA	1.29(0.0)aB
NHB		1.63(0.2)bB	4.51(0.1)bA	2.99(0.5)bA	1.27(0.0)bB	3.41(0.4)cA	1.22(0.0)bB

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 3 per cultivar

^yDifferent lowercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different uppercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^xValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 18 for SHB; N = 12 for RE; N = 9 for NHB

Table 3.20 Consumer acceptability mean values of eighteen cultivars and three blueberry types harvested in 2018.

Type	Cultivar	Overall Liking ***	Size ***	Overall texture ***	Skin toughness ***	Fruit firmness ***	Seediness ***	Grittiness ***
SHB	'Camellia'	7.17 ^{a^{zy}}	7.06 ^{a-e}	7.20 ^{ab}	7.17 ^{ab}	7.55 ^a	6.99 ^a	6.87 ^a
	'Farthing'	7.39 ^a	7.70 ^{ab}	7.35 ^a	7.36 ^a	7.52 ^{ab}	7.00 ^a	6.51 ^{ab}
	'Keecrisp'	6.52 ^{a-c}	7.54 ^{ab}	6.69 ^{a-d}	6.67 ^{a-c}	6.84 ^{a-e}	6.63 ^{ab}	6.36 ^{a-c}
	'Legacy' GA	7.30 ^a	7.77 ^a	7.17 ^{ab}	7.02 ^{ab}	7.05 ^{a-e}	6.95 ^a	6.72 ^{ab}
	'Legacy' MI	7.08 ^{ab}	6.65 ^{de}	7.00 ^{a-c}	6.83 ^{ab}	6.92 ^{a-e}	6.95 ^a	6.82 ^a
	'Meadowlark'	6.58 ^{a-c}	7.63 ^{ab}	6.89 ^{a-c}	6.88 ^{ab}	7.31 ^{a-c}	6.89 ^a	6.48 ^{ab}
	'Star'	6.46 ^{a-c}	6.99 ^{b-e}	6.18 ^{c-f}	6.41 ^{b-e}	6.23 ^{e-g}	6.46 ^{a-c}	6.06 ^{a-e}
	'Suziblue'	6.13 ^{b-d}	7.47 ^{a-c}	6.40 ^{b-f}	6.42 ^{b-d}	6.65 ^{b-f}	6.39 ^{a-c}	6.10 ^{a-d}
RE	'Alapaha'	5.12 ^{ef}	6.53 ^e	5.22 ^g	5.17 ^f	4.88 ^h	5.24 ^e	4.92 ^f
	'Austin'	5.93 ^{c-e}	6.75 ^{c-e}	5.87 ^{d-g}	5.54 ^{ef}	5.46 ^{gh}	5.43 ^{de}	5.20 ^{ef}
	'Brightwell'	5.47 ^{d-f}	6.63 ^{de}	5.61 ^{e-g}	5.42 ^f	5.19 ^h	5.64 ^{c-e}	5.42 ^{d-f}
	'Powderblue'	6.87 ^{a-c}	7.34 ^{a-d}	6.55 ^{a-d}	6.41 ^{b-e}	6.33 ^{d-g}	5.82 ^{b-e}	6.05 ^{a-e}
	'Vernon'	5.37 ^{d-f}	7.53 ^{ab}	5.53 ^{fg}	5.87 ^{c-f}	5.58 ^{gh}	5.19 ^e	5.05 ^f
NHB	'Aurora'	5.96 ^{c-e}	7.51 ^{a-c}	6.45 ^{b-e}	6.60 ^{a-c}	6.48 ^{c-f}	6.61 ^{ab}	6.43 ^{ab}
	'Bluecrop'	6.78 ^{a-c}	7.34 ^{a-d}	6.69 ^{a-d}	6.69 ^{a-c}	6.90 ^{a-e}	6.49 ^{a-c}	6.17 ^{a-d}
	'Draper'	5.98 ^{c-e}	7.33 ^{a-d}	6.61 ^{a-d}	6.73 ^{a-c}	7.18 ^{a-d}	6.60 ^{ab}	6.23 ^{a-d}
	'Elliott'	4.72 ^f	5.55 ^f	5.59 ^{e-g}	5.65 ^{d-f}	5.53 ^{gh}	5.69 ^{c-e}	5.55 ^{c-f}
	'Liberty'	5.89 ^{c-e}	5.47 ^f	6.12 ^{c-f}	5.92 ^{c-f}	5.77 ^{f-h}	6.23 ^{a-d}	5.95 ^{b-e}
	'Nelson'	7.02 ^{ab}	7.59 ^{ab}	7.00 ^{a-c}	6.99 ^{ab}	6.93 ^{a-e}	6.80 ^a	6.53 ^{ab}
Type		***	***	***	***	***	***	***
SHB		6.83(0.1) ^{a^{xw}}	7.35(0.1) ^a	6.86(0.1) ^a	6.85(0.1) ^a	7.01(0.1) ^a	6.78(0.1) ^a	6.49(0.1) ^a
RE		5.75(0.1) ^c	6.95(0.1) ^b	5.76(0.1) ^c	5.68(0.1) ^c	5.49(0.1) ^c	5.47(0.1) ^c	5.33(0.1) ^c
NHB		6.06(0.1) ^b	6.80(0.1) ^b	6.41(0.1) ^b	6.43(0.1) ^b	6.47(0.1) ^b	6.40(0.1) ^b	6.14(0.1) ^b

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush.

Fruit were evaluated by consumers using a 9-point hedonic scale: 9 = extremely like 5 = neither dislike/like and 1 = extremely dislike.

^zN = 83 (83 consumers attended all five consumer panels throughout the harvest season)

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$.

*** Significant at $P \leq 0.001$, respectively.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 664 for SHB; N = 415 for RE; N = 498 for NHB

Table 3.21 Consumer acceptability mean values of fourteen cultivars and three blueberry types harvested in 2019.

	Overall Liking	Size	Overall texture	Skin toughness	Fruit firmness	Seediness	Grittiness
Type Cultivar	***	***	***	***	***	***	***
SHB 'Camellia'	7.28 ab ^{zy}	7.09 b-d	7.29 ab	7.03 ab	7.40 ab	6.74 a-c	6.73 a-c
'Farthing'	6.44 b-d	7.53 ab	6.71 bc	6.78 a-c	6.96 bc	6.44 a-d	6.27 a-d
'Legacy' Georgia	6.86 a-c	6.26 e	6.68 bc	6.54 b-d	6.81 bc	6.54 a-d	6.36 a-c
'Legacy' Michigan	7.51 a	7.74 ab	7.63 a	7.42 a	7.78 a	7.12 a	6.99 a
'Patrecia'	7.14 ab	7.60 ab	7.12 ab	7.03 ab	7.06 a-c	7.09 ab	6.86 ab
'Star'	5.81 d-f	6.44 de	5.58 ef	5.99 d	5.37 f	6.28 b-e	5.97 c-f
'Suziblue'	5.94 d-f	6.71 c-e	6.22 c-e	6.36 b-d	6.42 c-e	6.10 c-e	6.04 b-e
RE 'Alapaha'	5.36 ef	5.14 f	5.38 f	4.99 e	5.21 f	5.53 ef	5.31 e-g
'Brightwell'	6.14 c-e	7.17 a-c	5.86 d-f	5.90 d	6.37 c-e	5.50 e-g	5.28 e-g
'Powderblue'	6.67 a-d	6.77 c-e	6.67 bc	6.41 b-d	6.69 bc	5.88 d-f	6.04 b-e
'Premier'	5.79 d-f	7.82 a	6.10 c-f	6.08 cd	5.88 d-f	5.27 fg	5.17 fg
'Vernon'	5.50 ef	7.59 ab	5.59 ef	5.78 d	5.69 ef	4.69 g	4.90 g
NHB 'Aurora'	5.86 d-f	6.76 c-e	6.50 b-d	6.27 b-d	6.55 cd	6.47 a-d	6.24 a-d
'Elliott'	5.21 f	6.56 c-e	5.65 ef	5.78 d	5.56 f	5.62 ef	5.45 d-g
'Liberty'	6.41 b-d	7.18 a-c	6.74 bc	6.40 b-d	6.76 bc	6.64 a-d	6.50 a-c
Type	***	NS	***	***	***	***	***
SHB	6.71(0.1) a ^{xw}	7.05(0.1)	6.75(0.1) a	6.73(0.1) a	6.83(0.1) a	6.62(0.1) a	6.46(0.1) a
RE	5.89(0.1) b	6.90(0.1)	5.92(0.1) c	5.83(0.1) c	5.97(0.1) c	5.37(0.1) c	5.34(0.1) c
NHB	5.82(0.1) b	6.83(0.1)	6.30(0.1) b	6.15(0.1) b	6.29(0.1) b	6.24(0.1) b	6.06(0.1) b

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

Fruit were evaluated by consumers using a 9-point hedonic scale: 9 = extremely like 5 = neither dislike/like and 1 = extremely dislike.

^zN = 78 (78 consumers attended all four consumer panels throughout the harvest season)

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$.

NS, *** Nonsignificant or significant at $P \leq 0.05$ or $P \leq 0.001$, respectively.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 546 for SHB; N = 390 for RE; N = 234 for NHB

Table 3.22 Consumer acceptability mean scores for overall liking and overall texture of the same blueberry cultivars and types harvested in 2018 and 2019.

Type	Cultivar	Overall liking		Overall texture	
		2018	2019	2018	2019
SHB	‘Camellia’	7.26 abA ^{zy}	7.11 abA	7.31 abA	7.09 abA
	‘Farthing’	7.46 aA	6.63 a-cB	7.46 aA	6.72 a-cB
	‘Legacy’ Georgia	7.35 abA	6.72 a-cB	7.19 abA	6.50 b-dB
	‘Legacy’ Michigan	6.96 a-cB	7.56 aA	6.81 a-cB	7.56 aA
	‘Star’	6.54 a-dA	5.78 c-eB	6.30 b-eA	5.56 e-gB
	‘Suziblue’	6.30 b-eA	5.81 c-eA	6.46 a-dA	6.11 c-gA
RE	‘Alapaha’	5.11 fgA	5.15 eA	5.17 fA	5.19 gA
	‘Brightwell’	5.46 d-gA	5.93 c-eA	5.63 d-fA	5.63 d-gA
	‘Powderblue’	6.83 a-cA	6.43 bcA	6.43 a-dA	6.48 b-eA
	‘Vernon’	5.33 e-gA	5.33 deA	5.37 efA	5.46 fgA
NHB	‘Aurora’	6.00 c-fA	5.74 c-eA	6.39 b-eA	6.30 b-fA
	‘Elliott’	4.43 gB	5.13 eA	5.44 d-fA	5.70 d-gA
	‘Liberty’	5.89 c-fA	6.33 b-dA	6.11 c-fB	6.65 a-cA
SHB		6.98(0.1) aA ^{xw}	6.60(0.1) aB	6.92(0.1) aA	6.59(0.1) aB
RE		5.69(0.1) bA	5.71(0.1) bA	5.65(0.1) bA	5.69(0.1) cA
NHB		5.44(0.2) bA	5.73(0.2) bA	5.98(0.1) bA	6.22(0.1) bA

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

Fruit were evaluated by consumers using a 9-point hedonic scale 9 = extremely like 5 = neither dislike/like and 1 = extremely dislike.

^zN = 54 of the same panelists that attended the nine panels

^yDifferent lowercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different uppercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 324 for SHB; N = 216 for RE; N = 162 for NHB

Table 3.23 Consumer acceptability mean liking scores for textural traits (skin toughness, fruit firmness and seediness) of the same blueberry cultivars and types harvested in 2018 and 2019.

Type Cultivar	Skin toughness		Fruit firmness		Seediness	
	2018	2019	2018	2019	2018	2019
SHB ‘Camellia’	7.09 a-cA ^{zy}	6.78 abA	7.54 aA	7.20 abA	7.02 aA	6.33 a-cB
‘Farthing’	7.44 aA	6.69 abB	7.72 aA	6.96 a-cB	7.02 aA	6.22 a-cB
‘Legacy’ Georgia	7.06 a-cA	6.31 bcB	7.13 abA	6.63 bcA	6.89 abA	6.31 a-cB
‘Legacy’ Michigan	6.74 a-cA	7.26 aA	6.70 a-cB	7.72 aA	6.78 abA	6.98 aA
‘Star’	6.39 b-dA	5.94 bcA	6.11 b-eA	5.26 fB	6.56 a-cA	6.07 a-dA
‘Suziblue’	6.31 b-eA	6.24 bcA	6.74 a-cA	6.26 c-eA	6.31 a-dA	5.83 b-eA
RE ‘Alapaha’	5.04 fA	4.57 dA	4.78 fA	4.91 fA	5.33 deA	5.19 d-fA
‘Brightwell’	5.33 efA	5.57 cA	5.07 efB	6.26 c-eA	5.70 c-eA	5.00 efB
‘Powderblue’	6.54 a-cA	6.07 bcA	6.20 b-dA	6.54 b-dA	5.89 b-eA	5.41 c-eA
‘Vernon’	5.83 c-fA	5.59 cA	5.41 d-fA	5.65 d-fA	5.19 eA	4.43 fB
NHB ‘Aurora’	6.54 a-cA	5.96 bcB	6.33 b-dA	6.39 b-eA	6.56 a-cA	6.30 a-cA
‘Elliott’	5.50 d-fA	5.74 cA	5.43 d-fA	5.59 efA	5.41 deA	5.43 c-eA
‘Liberty’	5.96 c-fA	6.19 bcA	5.72 c-fB	6.70 bcA	6.11 a-eA	6.48 a-cA
SHB	6.84(0.1) aA ^{xw}	6.54(0.1) aB	6.99(0.1) aA	6.67(0.1) aB	6.76(0.1) aA	6.29(0.1) aB
RE	5.69(0.1) bA	5.45(0.1) cA	5.37(0.1) cB	5.84(0.1) bA	5.53(0.1) cA	5.00(0.1) bB
NHB	6.00(0.1) bA	5.96(0.1) bA	5.83(0.1) bB	6.23(0.1) bA	6.02(0.1) bA	6.07(0.1) aA

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

Fruit were evaluated by consumers using a 9-point hedonic scale 9 = extremely like 5 = neither dislike/like and 1 = extremely dislike.

^zN = 54 of the same panelists that attended the nine panels

^yDifferent lowercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different uppercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 324 for SHB; N = 216 for RE; N = 162 for NHB

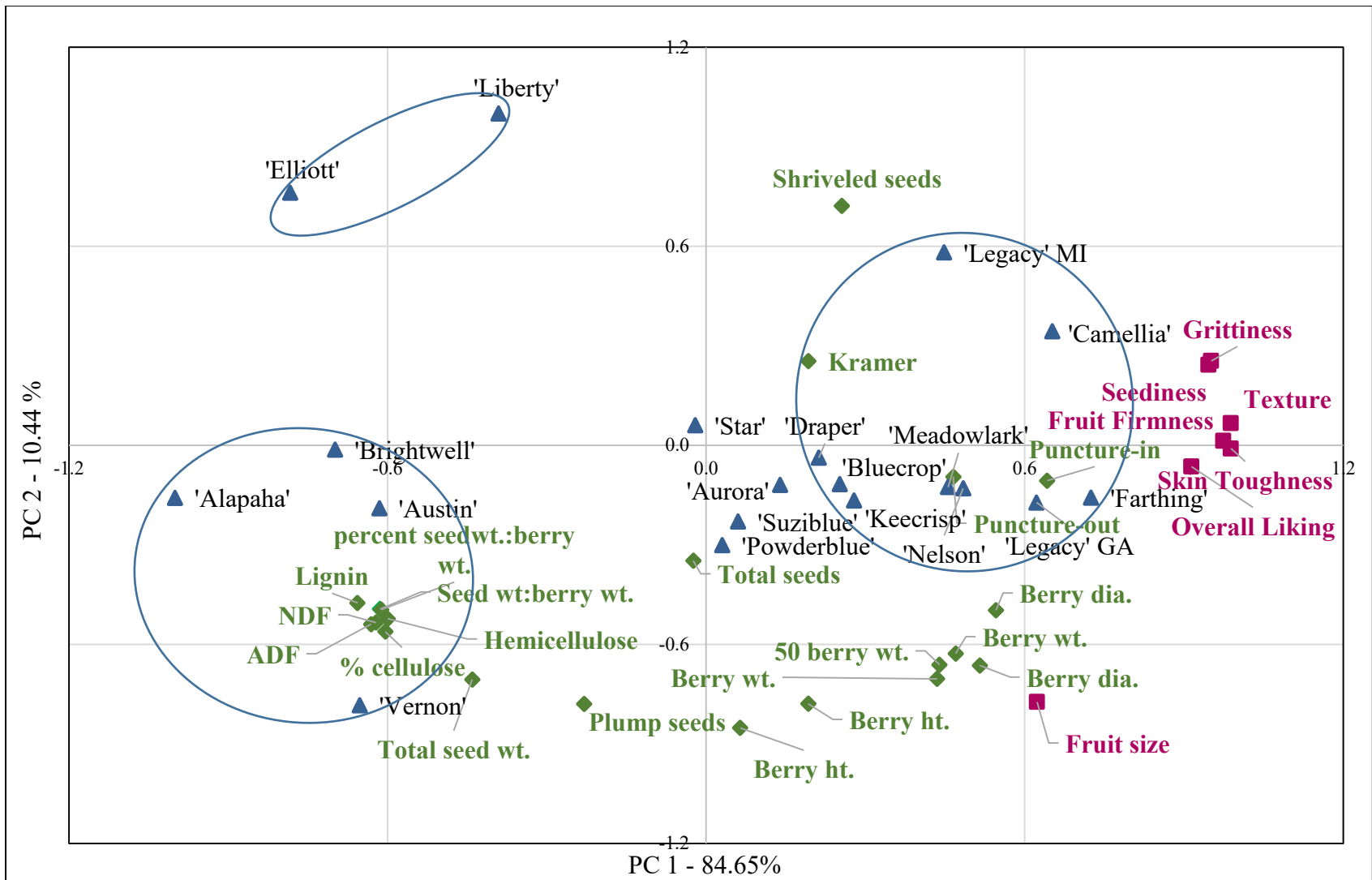


Fig. 3.1 Principal component analysis (PCA) of physical traits of nineteen cultivars (represented by triangle shapes) during the 2018 harvest season. PCA shows the correspondence of consumer mean liking scores (represented by square shapes) to instrumental analyses mean values (represented by diamond shapes).

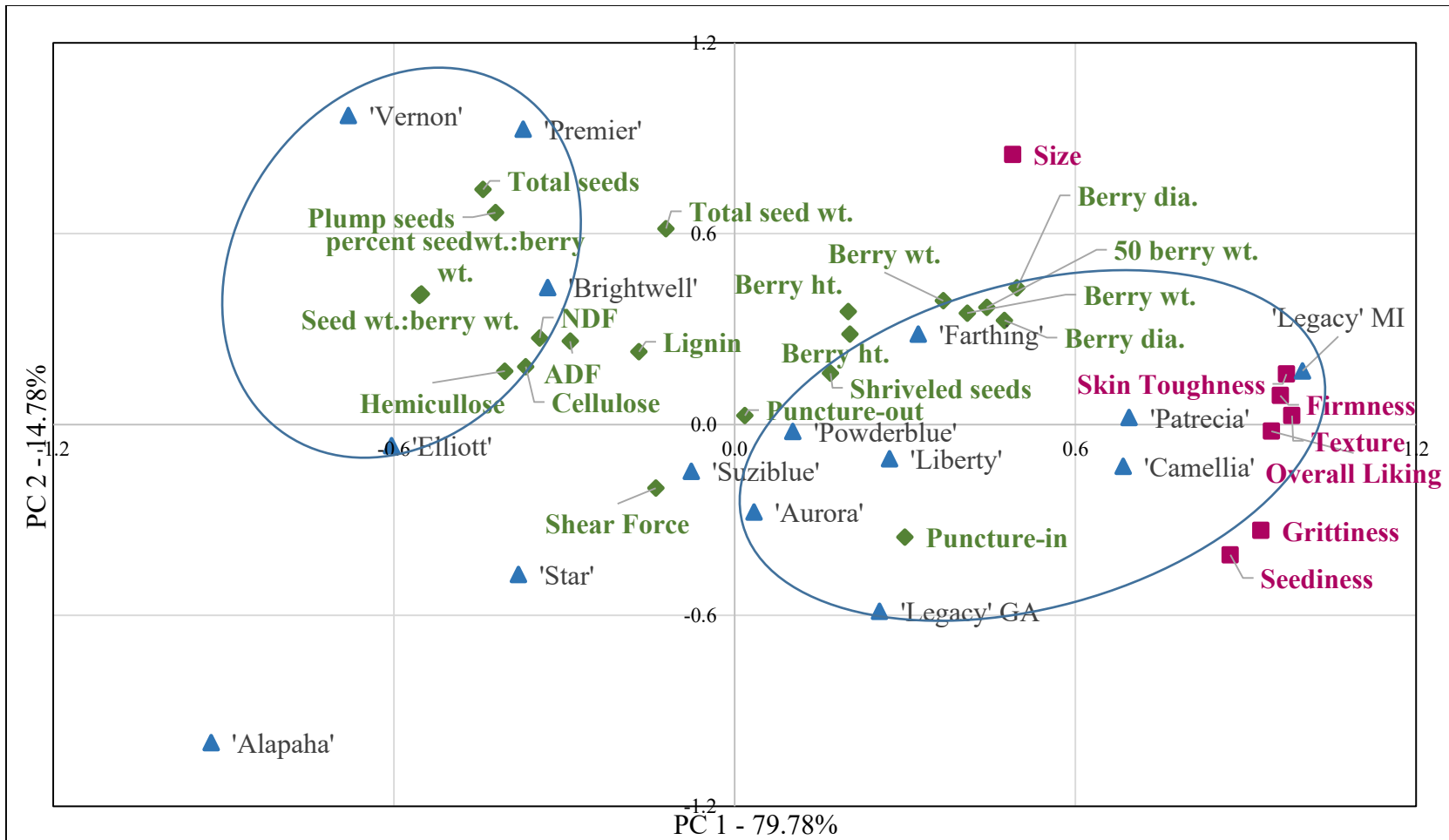


Figure 3.2 Principal component analysis (PCA) of physical traits of fourteen cultivars (represented by triangle shapes) during the 2019 harvest season. PCA shows the correspondence of consumer mean liking scores (represented by square shapes) to instrumental analyses mean values (represented by diamond shapes).

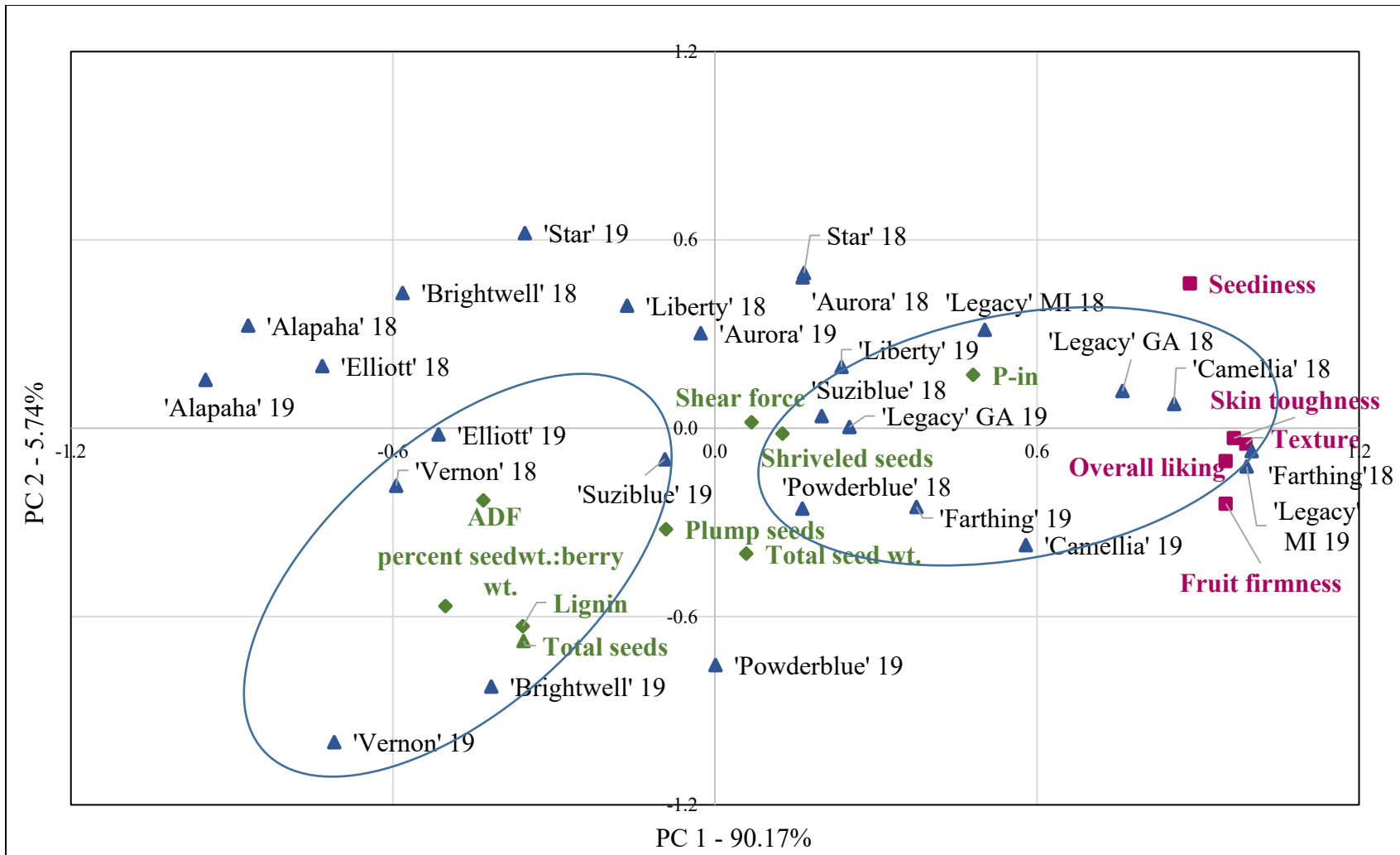


Figure 3.3 Principal component analysis (PCA) of physical traits of twelve cultivars (represented by triangle shapes) during the 2018 and 2019 harvest season. Harvest year is indicated by the '18' or '19' at the end of the cultivar name. PCA shows the correspondence of consumer mean liking scores (represented by square shapes) to instrumental analyses mean values (represented by diamond shapes).

CHAPTER 4
INSTRUMENTAL ANALYSES AND CONSUMER ACCEPTABILITY OF BLUEBERRY
CHEMICAL TRAITS²

²Amaral, K.S., K. Adhikari, J. Kim, R.M. Allen, D.J. Chavez, D.S. NeSmith, and R.A. Itle. To be submitted to *HortScience*.

ABSTRACT

There are three main commercial blueberries types grown in the US: southern highbush (SHB), rabbiteye (RE) and northern highbush (NHB). Georgia's fresh blueberry market comprises of two of these types, SHB and RE. Georgia in the past decade, has continued to be one of the top fresh blueberry producing states in the U.S. Within each type, there are several cultivars that are commercially grown, all containing different fruit quality attributes. Eighteen and fourteen cultivars were evaluated in 2018 and 2019 (with twelve cultivars in common between years) for soluble solid content (SSC), total titratable acidity (TTA), SSC : TTA, color values (L^* , a^* , b^* , hue and chroma), and monomeric anthocyanin content (concentration cyanidin-3-glucoside $\text{mg}\cdot\text{L}^{-1}$), respectively. To understand consumer acceptability and overall liking of these fruit quality traits, consumers sampled all cultivars in 2018 ($n = 83$) and 2019 ($n = 78$), of which 54 of the consumers attended sessions for both years. Consumers evaluated fruit sweetness, acidity, color, aroma and flavor. There were significant differences between cultivars and types for all traits within and across years ($P \leq 0.05$). SHB had larger SSC : TTA, whereas NHB had larger TTA and anthocyanin content. Across years, consumer overall liking positively correlated with consumer liking of fruit flavor ($r = 0.95$), sweetness ($r = 0.91$), acidity ($r = 0.90$) and color ($r = 0.59$). The majority of consumers liked SHB for all traits compared to RE and NHB. SHB SSC : TTA ratio were more consistent when observing year-to-year comparisons. Consumers liked fruit with a deeper blue color compared to those with more of a brighter waxy fruit skin. From this assessment, results have shown that flavor may be one of the main attributes that influences consumer overall liking. Results have also demonstrated that although there is variation among cultivars within the three main commercial types, the majority of SHB were liked by consumers for their sugar and acid content and color values.

INTRODUCTION

In the U.S., there are three main commercial blueberry types grown for fresh consumption: southern highbush (species complex of *V. corymbosum* L. and *V. darrowii* Camp), rabbiteye (*V. virgatum* Aiton), and northern highbush (*V. corymbosum* L.). Southern highbush (SHB) and rabbiteye (RE) grow in warmer climates, whereas northern highbush (NHB) grow in cooler climates (Krewer and Nesmith, 2006). There are more than twenty cultivars within a commercially grown type, and each cultivar's fruit marketability ranges from one to three weeks. Fruit quality variation among blueberries (color, sugars, acids, antioxidants, aroma, and flavor) can be attributed to blueberries' genetic makeup, environmental effects on fruit quality, harvest conditions and differences between years, etc. Blueberry acreage has greatly increased over the past decade due to consumers' perception of blueberry nutritional benefits (Gilbert et al., 2014; Saftner et al., 2008; USDA-NASS, 2017). To increase SHB and RE share in the fresh blueberry market, it is important to understand consumer acceptability of fruit quality characteristics. Comparing instrumental analyses with consumer acceptability for all three commercial blueberry types within a harvest season have not been previously documented.

Consumer perception is important to understand specific fruit traits that drive their overall liking (Gilbert et al., 2014; Saftner et al., 2008). An increased overall liking may increase blueberry consumption. Consumer acceptability tests are widely used to identify which traits, such as appearance, flavor and/or aroma lead to an increased acceptability of a food product (Lawless and Civille, 2013; Saftner et al., 2008). Previous blueberry sensory research has been conducted using trained and untrained panelists to determine blueberry fruit quality (Makus and Morris, 1993; Phan et al., 2017; Saftner et al., 2008; Silva et al., 2005). However, a large

assessment of cultivars within the three main commercial types using the same consumers throughout the harvest season has not been established.

The three main commercial blueberry types were represented by eighteen and fourteen early-, mid- and late- harvested cultivars harvested in 2018 and 2019, respectively, for this project. The objectives of this study were to determine whether NHB chemical fruit quality traits are superior than SHB and RE by 1) evaluating cultivars and types within a year and across years, 2) comparing consumer acceptability scores to instrumental analyses, and 3) understanding which traits correspond to consumer overall liking.

MATERIALS AND METHODS

Blueberry samples

Three blueberry types were collected and evaluated from May through August in 2018 [seven SHB cultivars ('Camellia', 'Farthing', 'Keecrisp', 'Legacy' grown in Georgia and Michigan, 'Meadowlark', 'Star' and 'Suziblue'), five RE cultivars ('Alapaha', 'Austin', 'Brightwell', 'Powderblue' and 'Vernon') and six NHB cultivars ('Aurora', 'Bluecrop', 'Draper', 'Elliott', 'Liberty' and 'Nelson')] and in 2019 [five SHB cultivars ('Camellia', 'Farthing', 'Legacy' grown in Georgia and Michigan, 'Patrencia', 'Star' and 'Suziblue'), five RE cultivars ('Alapaha', 'Brightwell', 'Powderblue', 'Premier' and 'Vernon') and three cultivars NHB cultivars ('Aurora', 'Elliott' and 'Liberty')]. SHB and RE were harvested in Alma, Georgia and NHB were harvested in Michigan, Indiana and Canada. Early, mid, and late cultivars within the three blueberry types represented current main commercial cultivars harvested for fresh consumption. There were five collections and four collections during the 2018 and 2019 harvest seasons. In 2018, all fruit were hand harvested, whereas in 2019, only NHB and 'Legacy' grown in Michigan were hand harvested and the remaining cultivars were machine harvested. NHB and

'Legacy' grown in Michigan, in 2018, were transported in lugs to commercial packing facilities in Alma, Georgia, whereas in 2019, fruit were transported in ten-pound cardboard packing boxes. Fruit held at commercial packing facilities were packed in 1-pint clamshells. All fruit were then transported to the University of Georgia Griffin Campus Griffin, Georgia for evaluation. Fruit were stored in open plastic bags over ice in coolers during transportation.

Sample storage and preparation

Fruit were stored at 4 ± 1 °C for one to three days prior to sorting and washing. Four 1-pint clamshells of fruit were gently washed with tap water in strainers, placed on plastic bread trays lined with paper towels, sorted by commercial standards (including the removal of underripe, overripe, and damaged fruit) and air dried. Approximately 1 oz. of fruit for each cultivar were placed in 3 oz. Styrofoam cups with opaque plastic lids for consumer tests. Styrofoam cups were labeled with a randomized three-digit code per cultivar (Appendix H). Consumers received an individual cup containing one cultivar and given a new spoon for each set of evaluation questions pertaining to the corresponding binding code on the questionnaire. Fruit for sensory and instrumental evaluation were stored at 4 ± 1 °C, until all fruit quality evaluations were completed.

Consumer sensory protocol

The protocol was adapted for the method used by Silva et al. (2005) and was approved by the University of Georgia's Institutional Review Board (STUDY00003249).

Five acceptability taste tests were conducted with untrained panelists in 2018 ($n = 83$), and four acceptability taste tests were conducted in 2019 ($n = 78$) at the UGA Sensory Evaluation & Consumer (SEC) Lab in Griffin, GA. For both years, 54 of the same panelists attended all nine taste tests. Panelists were recruited using a screener test that was sent out to

those on an existing consumer database established by the UGA SEC Lab (Appendix A). Consumers must 1) not be allergic to blueberries, 2) be eighteen years old or over, 3) eat blueberries once or more a month, 4) be interested in participating in the taste test 5) and be able to attend all taste tests from May to August during the given harvest season. Panelists were required to sign consent forms prior to participation and were given approximately an hour to complete each test (Appendices B and E).

One hour prior to each test session, samples were held at benchtop to reach room temperature (21 ± 1 °C). Sensory tests were conducted in partitioned booths under incandescent lights at 21 ± 1 °C. Samples were served to consumers in sequential order, using Latin Square Design (Appendices D and G), with a corresponding ballot using Compusense (Guelph, Ontario, Canada). Consumers were instructed to consume individual samples with a new spoon and cleanse their palate with water between samples. Consumer acceptability of fruit quality was determined using a 9-point hedonic scale (1 = dislike extremely, 5 = neither liked or disliked, and 9 = like extremely).

Juice preparation

Three replications of fresh blueberries per cultivar were weighed (60.00 to 61.00 g) and stored in freezer-safe Ziploc bags at -23 ± 1 °C in a walk-in freezer. Fruit were thawed at 21 ± 1 °C for approximately one hour. Samples were weighed (55.00 to 56.00 g) and pureed for approximately one minute using a Ninja Ultima™ Blender BL810 30 series (Balance Inc., Cleveland, OH) until samples were homogenized. Three replications per cultivar were weighed (40.00 to 41.00 g) and poured into 50 mL oak ridge Nalgene centrifuge tubes (Thermos Scientific, Waltham, MA). Samples were centrifuged in a 5810R centrifuge (Eppendorf), for twenty minutes at 12,100 rpm and 5 °C. Supernatant was filtered through a pre-cut, four-layered

cheesecloth in two 15 mL VWR® SuperClear™ Ultra High Performance Centrifuge Tubes (Radnor, PA). Juice extracts were kept at -23 ± 1 °C for later analyses.

Sugar and acid measurements

Juice samples in the 15 mL centrifuge tubes were thawed at 21 ± 1 °C for approximately one hour and vortexed prior to analyses. SSC was measured by dispensing 300 μ L of supernatant on the PR-32 palette digital hand-held refractometer (Atago, Bellevue, WA). TTA was measured using a solution of 6 mL of supernatant diluted in 50 mL of deionized water and 0.1 N NaOH titrant with the Easy PRO, Easy plus™ titrator (Mettler Toledo, Columbus, OH). Initial pH, volume (mL) of titrant visual end point (VEP) and R% (TTA) were calculated using an endpoint titration pH of 8.2 and acid miliequivalent factor of 0.064 for citric acid. Three replications and two subreplications per cultivar were evaluated for both SSC and TTA.

Color measurements

Fresh fruit skin color was measured five days after consumer panels using a MiniScan XE colorimeter (HunterLab, Reston, VA). Sample measurements were evaluated using a 3.5 cm diameter ocular lens. L^* , a^* and b^* values were measured in the $C/2^\circ$ color-space coordinates. L^* ranged from 0 (black) to 100 (white), a^* ranged from negative (green) to positive (red) and b^* ranged from negative (blue) to positive (yellow). The colorimeter was calibrated using a white and MiniScan reference tile (X 78.56, Y 83.52, Z 88.46, L^* 93.24, a^* -1.30 and b^* 0.84 for D65/10°). Fruit were weighed (50.00 to 51.00 g) per replication and held at 21 ± 1 °C for approximately one hour. Nine samples, three replications of three subreplications, per cultivar were evaluated.

Monomeric anthocyanin content

Monomeric anthocyanins (cyanidin-3-glucoside equivalents) were measured based on a modified method from Lee et al. (2005). Frozen prepared juice samples in 15 mL centrifuge tubes, at -23 ± 1 °C, were thawed for approximately one hour at 21 ± 1 °C. For each sample, 1.2 mL of juice was pipetted into 1.5 mL snap cap low retention microcentrifuge tubes (Thermo Fisher Scientific, Waltham, MA) and centrifuged in a LSE™ high speed microcentrifuge (Corning, Corning, NY) for 25 min at 12,000 rpm and 20 °C. A dilution factor was experimentally determined using 5 parts dilution factor (1-part sample, 4-parts buffer) for two buffers for each test sample. It should be noted that if samples were highly pigmented, a serial dilution was conducted during sample preparation. Two Falcon 5 mL round bottom polystyrene test tubes were prepared for the test solutions: 500 µL of test sample was added to 2 mL pH 1.0 buffer (0.0025 M KCl) and 500 µL of test sample was added to 2 mL pH 4.5 buffer (0.4 M CH₃CO₂NA·3H₂O). Diluted test solutions in pH 1.0 and 4.5 buffers were vortexed and 200 µL of each test solution were pipetted in a DYNATECH IMMULON 96-well flat top plate. Absorbance was read within 20 to 50 min of preparation at 520 and 700 nm wavelength. Test solutions absorbance was corrected with blank wells filled with distilled water. Cyanidin-3-glucoside equivalents (mg·L⁻¹ L) were calculated using Eq. [1].

$$\text{Anthocyanin pigment concentration} = \frac{A \times MW \times DF \times 10^3}{\epsilon \times \text{pathlength of individual wells}} \quad [1]$$

Where A = (corrected A_{520nm} – corrected A_{700nm}) pH 1.0 - (corrected A_{520nm} – corrected A_{700nm}) pH 4.5; MW = 449.2 g/mol for cyanidin-3-glucoside; DF = 5; pathlength in cm for each well with test sample; $\epsilon = 26,900 \text{ L} \cdot \text{mol}^{-1} \cdot \text{cm}^{-1}$ molar extinction coefficient. Three replications of two diluted test solutions in pH 1.0 and 4.5 buffers were evaluated per cultivar.

Data analyses

Analysis of variance (ANOVA) was conducted with consumer panelists and replications as random effects using the general linear model (GLM) procedure (SAS 9.4; SAS Institute, Cary, NC) to determine differences between among cultivars and types instrumental and consumer sensory within a year. Differences were also determined comparing the same cultivars and types across years. Differences were detected using post-hoc mean separation (Tukey HSD) test at a 5% level of significance. Principal component analyses (PCA) were performed using XLSTAT (ver. 2016.03; Addinsoft, New York, NY) to determine the relationship between cultivar chemical trait instrumental analyses and consumer liking scores.

RESULTS AND DISCUSSION

Soluble solid content and total titratable acidity

SSC, TTA and SSC : TTA were measured for eighteen and fourteen cultivars in 2018 and 2019, with 12 cultivars in common across years. These represented the three main commercial blueberry types. Since the blueberry industry primarily discuss type fruit quality traits, hereafter, a general type comparison was evaluated, although there were high and low values for individual cultivars within a type. Results within each year and across years were separately analyzed (Tables 4.1 to 4.3). Results significantly differed ($P \leq 0.001$) among cultivars and types in 2018 and 2019 for all traits. In 2018, SSC ranged from 10.33% for ‘Aurora’ to 19.65% for ‘Austin’. TTA ranged from 0.23% for ‘Meadowlark’ to 1.02% for ‘Elliott’. SSC : TTA ranged from 15.02 for ‘Elliott’ to 74.95 for ‘Austin’. The majority of NHB had larger SSC and TTA, whereas SHB and RE had larger SSC : TTA. No differences between SHB and RE for TTA and SSC : TTA were observed (Table 4.1). In 2019, SSC varied from 9.28% for ‘Liberty’ to 17.83% for ‘Alapaha’. TTA varied from 0.29% for ‘Alapaha’ to 0.98% for ‘Aurora’. SSC : TTA varied from

11.81 for ‘Elliott’ to 61.96 for ‘Alapaha’. Overall, RE had higher SSC, NHB had higher TTA, and SHB and RE had higher SSC : TTA. There were no differences between SHB and RE TTA and SSC: TTA and HB SSC (Table 4.2).

When comparing SSC, TTA and SSC : TTA of the same twelve cultivars and three types across years, there were significant differences ($P \leq 0.05$) for all traits. In 2018, ‘Farthing’ had the highest SSC (15.90%) and ‘Aurora’ had the lowest (10.33%), whereas in 2019 ‘Alapaha’ had the highest (17.83%) and ‘Liberty’ had the lowest (9.28%) (Table 4.3). TTA ranged from 0.27% for ‘Camellia’ to 1.02% for ‘Elliott’ in 2018 and 0.29% for ‘Alapaha’ to 0.98% for ‘Aurora’ in 2019. SSC : TTA varied from 15.02 for ‘Elliott’ to 45.54 for ‘Camellia’ in 2018 and 11.81 for ‘Elliott’ to 61.96 for ‘Alapaha’ in 2019. NHB had higher SSC in 2018, whereas RE had higher SSC in 2019. NHB had higher TTA and RE had higher SSC : TTA for both years. SHB sugar and acid content were consistent between both harvest seasons, whereas only RE SSC : TTA and NHB SSC were consistent.

RE SSC values in 2018 were similar to those reported by Saftner et al. (2008) and Itle et al. (2015), however varied for SSC values in 2019. RE SSC values, reported in 2019, were similar to those found by Makus and Morris (1993) with a range from 14.8% to 16.4% (Tables 4.2 and 4.3). Our NHB SSC values were larger than those found by Saftner et al. (2008) and Makus and Morris (1993) for both years, with a broader range for SSC in 2019. Bremer et al. (2008) and Itle et al. (2015) reported variation among SHB with a range of 11.8% to 12.9% and 10.6% to 13.1%, respectively. However, our results demonstrated a higher SSC for SHB and RE, which may be because of ‘Farthing’ harvested in 2018 and ‘Legacy’ GA, ‘Alapaha’ and ‘Vernon’ harvested in 2019 (Table 4.3). SHB TTA for both years were lower and SSC : TTA were higher than those found by Bremer et al. (2008) and Itle et al. (2015). RE and NHB TTA

were similar to those reported by Gündüz et al. (2014), Itle et al. (2015) and Saftner et al. (2008) (Table 4.1 to 4.3). The variability of SSC, TTA and SSC : TTA from year-to-year have been previously reported in blueberries and may be because of the differences caused by location, plant age, cultivar variation (genetic), variation within a cultivar, and environmental effects (Bremer et al., 2008; Gündüz et al., 2015; Itle et al., 2015; Lobos et al., 2013; Lobos et al., 2014).

Skin color

L^* , a^* , b^* , hue and chroma values were measured for eighteen and fourteen cultivars and three types for the 2018 and 2019 harvest seasons. Skin color values significantly differed among cultivars and types for each year ($P \leq 0.001$) (Tables 4.4 and 4.5). In 2018, L^* and b^* cultivar variation was the greatest (Table 4.4). L^* ranged from 15.99 for 'Keecrisp' to 24.16 for 'Powderblue', a^* ranged from -0.22 for 'Bluecrop' to 0.74 for 'Suziblue' and b^* ranged from -5.23 for 'Nelson' to -2.10 for 'Brightwell'. Chroma ranged from 3.04 for 'Austin' to 5.23 for 'Nelson' and hue ranged from 267.13 for 'Aurora' to 288.09 for 'Brightwell'. 'Nelson' and 'Powderblue' were whiter and 'Brightwell' had a lighter blue color. NHB had higher L^* and chroma values and RE had higher a^* , b^* and hue values. There were no significant differences between SHB and RE a^* , b^* , chroma and hue values and RE and NHB L^* values. Color values also varied in 2019 (Table 4.5). L^* ranged from 25.08 for 'Aurora' to 31.05 for 'Powderblue', a^* ranged from 0.12 for 'Legacy' GA to 0.72 for 'Patrecia', and b^* ranged from -6.09 for 'Elliott' to -2.11 for 'Suziblue'. 'Legacy' GA had lower chroma and hue values (2.53 and 271.91, respectively), 'Elliott' had the highest chroma value (6.15) and 'Patrecia' had the highest hue value (279.35). When comparing types, SHB had the highest b^* value, RE had the highest L^* value and NHB had the highest a^* , chroma and hue values. There were no significant differences between RE and NHB L^* , b^* and chroma values and SHB and RE a^* and hue values.

Skin color values, L*, a*, b*, hue and chroma, were measured for the same twelve cultivars and three types in 2018 and 2019 (Tables 4.6 and 4.7). There were significant differences among cultivars and types within each year ($P \leq 0.001$) and across both years ($P \leq 0.05$). ‘Suziblue’ had smaller L* values (17.27; 15.72) while ‘Powderblue’ had larger L* values (24.16; 31.05) year-to-year. In 2018, a* values ranged from -0.08 for ‘Legacy’ MI to 0.74 for ‘Suziblue’ and 0.12 for ‘Legacy’ GA to 0.84 for ‘Elliott’ in 2019. ‘Powderblue’ had the lowest b* values (-4.54; -6.02) for both years, whereas ‘Brightwell’ had the highest in 2018 (-2.10) and ‘Suziblue’ had the highest in 2019 (-2.11). Chroma values varied from 2.24 for ‘Brightwell’ to 4.55 for ‘Powderblue’ in 2018 and 2.12 for ‘Suziblue’ to 6.15 for ‘Elliott’ in 2019. Hue values ranged from 267.13 for ‘Aurora’ to 288.09 for ‘Brightwell’ in 2018 and 271.91 for ‘Legacy’ GA to 279.05 for ‘Star’ in 2019. In general, cultivars were not consistent for all skin color value traits across years.

There were differences among types for each year, except for 2018 b* and chroma values. RE had the highest L* values in 2018 and 2019, and chroma value in 2019. SHB had the highest b* value in 2019 and NHB had the highest a* and hue values in 2019. There were no significant differences among 2018 and 2019 SHB and RE a* values and 2018 hue values. When comparing types across years, SHB, with the exception of L* values, was the only type with consistent skin color trait values. RE and NHB L*, a* and chroma values increased and b* values decreased from 2018 to 2019. RE hue values were consistent across years and NHB hue values increased from 2018 to 2019.

Blueberry color development, associated to anthocyanin content, is known to occur during maturation and ripening. Anthocyanins give blueberries their red, purple and blue color, which can be read using color space values (L*, a*, b*, chroma and hue). NHB in 2018, had a

more negative b^* , whereas in 2019, RE and NHB b^* values did not differ. When comparing the same cultivars year-to-year, there were no differences among all three types in 2018 and no difference among NHB and RE in 2019 (Tables 4.4 to 4.7). These results indicate variation is dependent on the cultivars within a type. In addition, a bluer color may be affected by harvest year, growing location, variation within a cultivar, and amount of bloom on the skin surface (Albrigo et al., 1980; Makus and Morris, 1993; Sapers et al., 1984; Retamales et al., 2014). Bloom gives blueberries a glossy and white surface, coating the epicarp, increasing the L^* values (Blaker et al., 2014). Gough (1994) and Fava et al. (2006) found that color values are more dependent on cultivar rather than type, also seen with results found in Tables 4.4 to 4.5. All our color value traits differ from previous studies conducted (Makus and Morris, 1993; Saftner et al., 2008; Silva et al., 2005). Although there was variation across years, SHB color values have been more consistent than RE and NHB, with the exception of their L^* values. RE may have more bloom than HB because of their higher L^* values. Silva et al. (2005) and Saftner et al. (2008) found that NHB have a more intense (SI) color, however, results in Table 4.6 suggest that NHB do not. Anthocyanin content may also influence blueberry a^* , b^* and hue values.

Monomeric Anthocyanin Content

The amount of total monomeric anthocyanin content was measured using the pH differential method for cultivars harvested in 2018 and 2019. In 2018, there were significant differences between cultivars and types ($P \leq 0.001$) (Table 4.8). Cyanidin-3-glucoside content ranged from 105.95 $\text{mg}\cdot\text{L}^{-1}$ for ‘Alapaha’ to 923.54 $\text{mg}\cdot\text{L}^{-1}$ for ‘Elliott’. NHB cyanidin-3-glucoside content was higher than SHB and RE, however there was no significant difference ($P > 0.05$) between SHB and RE. In 2019, there were significant differences among cultivars and types ($P \leq 0.001$) (Table 4.9). Cyanidin-3-glucoside content varied from 9.34 $\text{mg}\cdot\text{L}^{-1}$ for

'Patrecia' to 728.01 mg·L⁻¹ for 'Aurora'. NHB cyanidin-3-glucoside content was higher than SHB and RE. There was no significant difference ($P > 0.05$) between SHB and RE cyanidin-3-glucoside concentration.

When comparing the same cultivars and types evaluated during both harvest seasons there were also differences ($P \leq 0.05$) (Table 4.10). 'Alapaha' had the lowest cyanidin-3-glucoside concentration in 2018, whereas in 2019, 'Legacy' MI and 'Star' had the lowest. Half of the cultivars' concentrations reported a decrease, while the other cultivars' concentrations were similar across years. The majority of SHB values decreased, whereas the majority of RE and NHB values were similar across years. For both years, NHB had higher concentrations than SHB and RE. Itle et al. (2015) also reported no difference between SHB and RE concentrations. In Table 4.8, cyanidin-3-glucoside concentration of 'Camellia', 'Premier' and 'Powderblue' were higher and 'Star' was lower than those found by Itle et al (2015). Type and cultivar concentrations were also not similar to those found by Lohachoompol et al. (2008), Prior et al. (1998) and Sellappan et al. (2002). Previous research has shown that earlier harvested cultivars contain a larger content of anthocyanins, whereas cultivars harvested in mid- to late- summer have a smaller content due to unstable molecules (Lohachoompol et al., 2008). When comparing cultivars and types over two harvest seasons, our results have shown that cultivars harvested earlier than others within a type did not have more anthocyanin content than others. In addition, SHB were harvested earlier within the season and they did not contain more anthocyanin content than RE or NHB. Our results have shown that although there is no difference between SHB and RE, there is variation among cultivars. Anthocyanin content is more cultivar dependent rather than type dependent (Connor et al., 2002; Cho et al., 2004; Itle et al., 2015; Kalt et al., 1999; Prior et al., 1998).

The majority of anthocyanin content is found in the fruit skin; however, it may also be found in the pulp. At the early stages of fruit development, when fruit are still green, a study has shown no present anthocyanin content in both the skin and pulp. At 25% red, SHB anthocyanin was solely found in the skin, whereas their pulp contained anthocyanins at 100% red to blue (Kalt et al., 2003; Prior et al., 1998; Ribera et al., 2010; Wang and Lin, 2000). Ribera et al. (2010) reported variation among anthocyanin content in the mesocarp of individual SHB, therefore influencing the total anthocyanin content of the fruit. ‘Aurora’, ‘Elliott’, ‘Liberty’, ‘Camellia’ and ‘Powderblue’ had larger anthocyanin content and skins’ colors were bluer and redder (Tables 4.7 and 4.9). Yet, when these cultivars were equatorially sliced, a red to purple pigmentation was found within the fresh fruit pulp (Figure 4.1). Results suggest that cultivar anthocyanin content may be influenced not only by fruit skin, but also pulp. Although NHB contained more anthocyanin content than SHB and RE, there were no differences between types. Results are contrary to the blueberry industry perception that SHB have more anthocyanins than RE (Itle, 2018).

Consumer Acceptability

The mean consumer liking scores of sweetness, acidity, color, aroma, flavor and overall liking are shown in Tables 4.10 to 4.12. There were significant differences ($P \leq 0.001$) among cultivars and types in 2018 (Table 4.11). Overall liking scores ranged from 4.72 for ‘Elliott’ to 7.39 for ‘Farthing’. The highest overall liking scores were for ‘Farthing’, ‘Camellia’ and ‘Legacy’ GA. ‘Farthing’ and ‘Legacy’ MI had higher sweetness liking scores, ‘Farthing’ had higher flavor liking score, ‘Legacy’ MI had higher acidity liking score, and ‘Meadowlark’ had a higher color liking score. ‘Powderblue’ had higher aroma scores. ‘Elliott’ had higher sweetness, acidity, color and flavor scores. SHB were highly liked for their sweetness, acidity, color and

flavor. RE were liked by the majority of consumers for their aroma. There were no significant differences ($P > 0.05$) between RE and NHB sweetness, acidity, color and flavor liking scores and HB aroma liking scores.

There were also significant differences between cultivar and type liking scores in 2019 Table 4.12. ‘Legacy’ MI was characterized by its highest sweetness, acidity, color and flavor liking scores. ‘Farthing’, ‘Patrecia’, and ‘Premier’ had the highest color liking scores. The aroma of ‘Camellia’, ‘Farthing’, ‘Star’, ‘Alapaha’, ‘Brightwell’, ‘Powderblue’, ‘Premier’, ‘Vernon’ and ‘Liberty’ were preferred by the majority of consumers. Similar to a previous study, few consumers liked ‘Elliott’ for its sweetness, acidity, color and flavor (Saftner et al., 2008). SHB were liked more by consumers than RE and NHB for all traits, except aroma. RE were liked more than HB for their aroma. NHB were liked by fewer consumers for their sweetness and acidity.

When the same cultivars and types harvested in 2018 and 2019 were compared, there were significant differences, except for 2018 mean color liking scores (Tables 4.13 and 4.14). There were no consistent trends across years for overall liking of the same consumers ($n = 54$) that tasted the same cultivars during both harvest seasons. In 2018, ‘Farthing’ received high flavor, sweetness and acidity mean liking scores and ‘Powderblue’ received a high aroma mean liking score. In 2019, ‘Legacy’ MI received a high flavor, sweetness and acidity mean liking scores, ‘Farthing’ for its color mean liking score and ‘Vernon’ for its aroma mean liking score. For both years, ‘Elliott’ sweetness and acidity and ‘Star’ for its flavor.

When comparing results to those of previous studies, there were few similarities among consumer acceptability and eating quality of blueberries. Saftner et al. (2008) reported that the majority of consumers, liked SHB for all chemical traits and least liked the overall appearance

and color of RE compared to NHB. Silva et al. (2005) found that consumers could not distinguish a difference between NHB and RE color, similar to our results. These results suggest that color acceptability may be more cultivar dependent, where more variability is shown. Saftner et al. (2008) reported that consumers preferred NHB than RE sweetness, tart, sweet/tart balance, flavor and overall eating quality, contrary to our results. NHB overall liking, sweetness and acidity scores were higher than RE. RE sweetness acceptability scores were higher than NHB for both years. As seen in other studies, fruit may be liked by fewer consumers, because of their very tart, acidic taste and flavor (Barrett et al., 2010). Results suggest that consumers, depending on region, may prefer more or less sweet fruit (Gilbert et al., 2014).

Correlation between instrumental analyses and consumer sensory

Principal component analyses were conducted to understand the relationship between consumer mean liking scores (active data) and instrumental analyses (supplementary data) of blueberry chemical traits for individual harvest years (Figures 4.2 to 4.4). Pearson correlation was used to determine the correspondence of the active and supplementary data to the mean consumer overall liking score. In Figure 4.2, PC 1 explained 72.30% and PC 2 explained 20.45% variation among the 18 cultivars. All chemical traits observed by consumers positively correlated to consumer overall liking. Overall liking scores highly corresponded to flavor, sweetness, and acidity ($r = 0.90$ to 0.96), moderately corresponded to color ($r = 0.63$) and weakly correlated to aroma ($r = 0.13$). Consumers also liked fruit with a more intense blue color. Color liking score positively correlated to chroma ($r = 0.41$) and negatively correlated to cyanidin-3-glucoside ($r = -0.55$), L^* ($r = -0.11$), a^* ($r = -0.13$), b^* ($r = -0.41$), and hue ($r = -0.26$). Consumers overall liking may be associated to fruit taste rather than the initial appearance and smell. An increased flavor liking score may be associated with increased sweetness and acidity liking scores ($r = 0.95$ to

0.99). Consumer flavor liking score negatively corresponded to TTA ($r = -0.34$) and positively correlated to SSC : TTA ($r = 0.11$). Consumer acidity liking score negatively associated with TTA ($r = -0.50$) and positively associated with SSC : TTA ($r = 0.27$). When comparing the instrumental analyses to consumer acceptability scores, the majority of consumers liked fruit that did not have larger SSC, TTA or SSC: TTA. Cultivars with a large TTA and smaller SSC : TTA were least liked by consumers. Results show that consumers may like all cultivar and type skin color, although there were differences in color when instrumentally evaluated. There was also less variation among cultivar sweetness mean liking scores, however cultivars that contained a large TTA and smaller SSC : TTA values, were liked by few consumers. This may suggest consumers may not like fruit that are more acidic.

In Figure 4.3, PC 1 explained 68.04% and PC 2 explained 17.89% of the variation among the fourteen cultivars in 2019. On the right hand side, consumer overall liking highly corresponded to consumer sweetness, acidity and flavor liking ($r = 0.88$ to 0.96) and moderately correlated to color liking ($r = 0.53$). Consumer flavor liking scores highly corresponded to sweetness and acidity liking scores ($r = 0.95$ to 0.99), weakly corresponded to SSC : TTA ($r = 0.12$) and negatively correlated to SSC and TTA ($r = -0.14$ to -0.41). When comparing consumer acceptability of sweetness and acidity to SSC, TTA and SSC : TTA, fewer consumers liked fruit with a larger SSC and TTA, similar to results seen in Figure 4.1. Traits on the left hand side of the PCA, represent traits that negatively corresponded to consumer overall liking. Consumer liking of color, weakly correlated with a^* , b^* and hue ($r = 0.15$ to 0.33) and negatively correlated with cyanidin-3-glucoside content, L^* and chroma ($r = -0.32$ to -0.20).

The majority of SHB were liked by consumers for their color. SHB had smaller L^* and chroma values and larger b^* and hue values, indicating that consumers may have liked darker

fruit with less bloom. Fruit with larger anthocyanin content, a^* , b^* and hue values, such as ‘Elliott’ and ‘Aurora’, were liked by fewer consumers. Gilbert et al. (2014) reported that a “deep blue, almost black color” and “berries are dark blue throughout” positively affected consumer liking, whereas fruit with a “waxy white coating” negatively affected their liking. Although NHB had a larger chroma value and anthocyanin content and a smaller b^* value, the majority of consumer acceptability may be influenced by the amount of bloom rather than the actual skin color and anthocyanin content. Although there are other cultivars with high anthocyanin content, such as ‘Camellia’ and ‘Powderblue’, they are displayed on the right hand side of the PCA because the majority of consumers liked their sweetness, acidity, and flavor.

Similar results were found when the same twelve cultivars were evaluated in 2018 and 2019 (Figure 4.3). The same consumers’ ($n = 54$) mean liking scores for overall liking, flavor, aroma, sweetness, acidity and color (active variables) were compared to mean instrumentally measured fruit quality traits (supplementary variables). PC 1 represented 68.04% and PC 2 represented 17.89% of the variation among the variables. As seen in Figures 4.1 and 4.2, consumer overall liking highly corresponded to flavor, acidity and sweetness ($r = 0.90$ to 0.95) and flavor highly corresponded to sweetness and acidity liking ($r = 0.96$ to 0.98). From the instrumental measurements SSC : TTA was the only chemical trait that positively correlated ($r = 0.11$ to 0.32) with sweetness, acidity and overall liking scores. TTA negatively corresponded ($r = -0.52$) to sweetness, acidity and overall liking scores suggesting that the majority of consumers prefer fruit with a smaller TTA. Consumer color liking scores also moderately correlated to overall liking scores. However, all color value traits (L^* , a^* , b^* , hue and chroma) and cyanidin-3-glucoside negatively corresponded to consumer color and overall liking. Fruit that were darker and bluer were liked by the majority of consumers. In general, SHB such as ‘Legacy’ GA and

MI, 'Camellia' and 'Farthing' evaluated in 2018 and 2019 were liked for their flavor, sweetness, acidity and color. 'Liberty' and 'Brightwell' evaluated in 2019 and 'Powderblue' evaluated in 2018 and 2019 were liked for their aroma. Similar to other studies, our results suggest that flavor may be one of the main fruit quality traits that associates to consumer blueberry overall liking, besides texture (Gilbert et al., 2014; Saftner et al., 2008). In addition, the majority of consumers liked SHB for their sweetness, acidity and flavor and RE for their aroma. Overall, results are contrary to industry's subjective bias that NHB have superior fruit quality traits than SHB and RE.

CONCLUSIONS

An assessment of fruit quality of various cultivars within the major commercial blueberry types grown, may allow researchers, growers and breeders to select cultivars for their desired traits. In addition to type-to-type variation, there was cultivar-to-cultivar and year-to-year variation for chemical traits observed. These results suggest that environmental factors, such as harvest location, fruit maturity when harvested, storage time, and harvesting methods, may affect overall fruit quality. Although there was variation, SHB SSC, TTA, SSC : TTA, a*, b*, chroma and hue were consistent across years. Overall, SHB were liked by the majority of consumers for both years for their sweetness, acidity, color, aroma and flavor. RE were either liked as much or more than NHB for their chemical traits. Flavor may be an important fruit quality trait for consumer overall liking, when comparing it to chemical traits' liking scores. Aroma was found to negatively correspond to overall liking. Evaluation of fruit traits prior to consumption, such as aroma, may not influence consumer acceptability of blueberries in comparison to taste, however further research is required. Research to evaluate profiles of sugars, acids, antioxidants and consumer purchase and behavior are the next steps in understanding desired fruit quality traits.

Evaluation of cultivar differences may assist breeders in selecting specific cultivars with desired chemical fruit quality traits for cross selections and type differences may increase Georgia's share in the fresh blueberry market.

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Table 4.1 Soluble solid content (SSC), total titratable acidity (TTA) and SSC : TTA mean values of eighteen and three blueberry types harvested in 2018.

Type	Cultivar	Soluble Solid Content (SSC)	Total Titratable	SSC : TTA
		(%)	Acids (TTA) (%)	
		***	***	***
SHB	'Camellia'	11.83 e-g ^{zy}	0.27 ij	45.54 b
	'Farthing'	15.90 b-d	0.49 e-g	33.50 c-e
	'Keecrisp'	10.67 g	0.42 f-h	25.27 d-g
	'Legacy' Georgia	11.07 fg	0.45 f-h	25.65 d-g
	'Legacy' Michigan	11.67 fg	0.40 f-i	30.13 c-f
	'Meadowlark'	16.60 a-c	0.23 j	73.93 a
	'Star'	13.98 c-f	0.53 d-f	26.75 d-f
	'Suziblue'	11.67 fg	0.42 f-h	27.84 d-f
RE	'Alapaha'	12.42 e-g	0.30 h-j	41.27 bc
	'Austin'	19.65 a	0.26 ij	74.95 a
	'Brightwell'	13.23 d-g	0.46 e-g	28.75 d-f
	'Powderblue'	13.02 d-g	0.38 f-i	34.15 c-e
	'Vernon'	12.68 d-g	0.37 g-j	34.66 b-d
NHB	'Aurora'	10.33 g	0.69 c	15.24 g
	'Bluecrop'	14.98 b-e	0.60 c-e	24.75 c-g
	'Draper'	17.97 ab	0.85 b	21.66 fg
	'Elliott'	15.10 b-e	1.02 a	15.02 g
	'Liberty'	15.78 b-d	0.38 f-i	41.41 bc
	'Nelson'	15.02 b-e	0.65 cd	23.21 e-g
Type		***	***	***
SHB		12.92(0.3) b ^{xw}	0.40(0.0) b	36.08(2.4) a
RE		14.20(0.6) ab	0.36(0.0) b	42.75(3.3) a
NHB		14.86(0.5) a	0.70(0.0) a	23.55(1.6) b

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 6 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$. *** Significant at $P \leq 0.001$, respectively.

^xValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 48 for SHB; N = 30 for RE; N = 36 for NHB

Table 4.2 Soluble solid content (SSC), total titratable acidity (TTA) and SSC : TTA mean values of fourteen and three blueberry types harvested in 2019.

Type	Cultivar	Soluble Solid Content	Total Titratable	SSC : TTA
		(SSC) (%)	Acids (TTA) (%)	
		***	***	***
SHB	'Camellia'	14.37 b-d ^{zy}	0.59 cd	24.49 fg
	'Farthing'	11.70 d-f	0.41 fg	28.79 d-f
	'Legacy' Georgia	15.00 a-c	0.39 f-h	38.88 bc
	'Legacy' Michigan	13.48 b-e	0.44 ef	30.69 d-f
	'Patrecia'	13.33 c-e	0.30 hi	44.92 b
	'Star'	13.47 b-e	0.52 de	25.98 ef
	'Suziblue'	10.85 ef	0.33 g-i	33.78 c-e
RE	'Alapaha'	17.83 a	0.29 i	61.96 a
	'Brightwell'	13.25 c-e	0.39 f-h	34.62 cd
	'Powderblue'	14.93 a-c	0.52 de	28.69 d-f
	'Premier'	16.52 ab	0.51 de	32.70 c-e
	'Vernon'	17.55 a	0.64 bc	27.53 d-f
NHB	'Aurora'	16.00 a-c	0.98 a	16.43 gh
	'Elliott'	11.30 d-f	0.97 a	11.81 h
	'Liberty'	9.28 f	0.73 b	12.64 h
Type		***	***	***
SHB		13.17(0.2) b ^{xw}	0.43(0.0) b	32.51(1.2) a
RE		16.02(0.5) a	0.47(0.0) b	37.10(2.5) a
NHB		12.19(0.8) b	0.89(0.0) a	13.63(0.7) b

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 6 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$. *** Significant at $P \leq 0.001$, respectively.

^xValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 42 for SHB; N = 24 for RE; N = 18 for NHB

Table 4.3 Soluble solid content (SSC), total titratable acidity (TTA) and SSC : TTA mean values of the same twelve and three blueberry types harvested in 2018 and 2019.

Type	Cultivar	Soluble Solid Content (SSC) (%)		Total Titratable Acids (TTA) (%)		SSC : TTA	
		2018	2019	2018	2019	2018	2019
SHB	'Camellia'	11.83c-eB ^{zy}	14.37bcA	0.27fB	0.59cdA	45.54aA	24.49dB
	'Farthing'	15.90aA	11.70c-eB	0.49cdA	0.41fgA	33.50bcA	28.79cdA
	'Legacy' Georgia	11.07deB	15.00abA	0.45cdA	0.39fgA	25.65cB	38.88bA
	'Legacy' Michigan	11.67c-eB	13.48b-dA	0.40c-fA	0.44efA	30.13cA	30.69cdA
	'Star'	13.98a-dA	13.47b-dB	0.53cA	0.52deA	26.75cA	25.98dA
	'Suziblue'	11.67c-eA	10.85deA	0.42c-eA	0.33ghB	27.84cB	33.78deA
RE	'Alapaha'	12.42b-eB	17.83aA	0.30efA	0.29hA	41.27abB	61.96aA
	'Brightwell'	13.23a-dA	13.25b-dA	0.46cdA	0.39fgB	28.75cB	34.62bcA
	'Powderblue'	13.02b-eA	14.93abA	0.38d-fB	0.52deA	34.15bcA	28.69cdA
	'Vernon'	12.68b-eB	17.55aA	0.37d-fB	0.64bcA	34.66bcA	27.53cdB
NHB	'Aurora'	10.33eB	16.00abA	0.69bB	0.98aA	15.24dA	16.43eA
	'Elliott'	15.10abA	11.30deB	1.02aA	0.97aA	15.02dA	11.81eA
	'Liberty'	15.78aA	9.28eB	0.38d-fB	0.73bA	41.41abA	12.64eB
SHB		12.69(0.3)bA ^{xw}	13.14(0.3)bA	0.43(0.3)bA	0.45(0.6)bA	31.57(0.7)aA	30.44(0.8)bA
RE		12.84(0.0)abB	15.89(0.0)aA	0.38(0.0)cB	0.46(0.0)bA	34.71(0.1)aA	38.20(0.0)aA
NHB		13.74(1.5)aA	12.19(0.9)bA	0.70(1.4)aB	0.89(3.1)aA	23.89(3.1)bA	13.63(0.7)cB

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 6 per cultivar

^yDifferent uppercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different lowercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^xValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^wN = 36 for SHB; N = 24 for RE; N = 18 for NHB

Table 4.4 Skin color mean values of eighteen and three blueberry types harvested in 2018.

Type	Cultivar	L* ^z	a*	b*	Chroma	Hue
		***	***	***	***	***
SHB	'Camellia'	18.67 g-i ^{yx}	0.19 c-f	-3.14 bc	3.16 fg	273.00 c-e
	'Farthing'	17.46 h-j	0.48 a-c	-4.00 d-g	4.03 c-e	276.82 b-d
	'Keecrisp'	15.99 j	0.37 a-d	-3.12 bc	3.15 fg	277.10 b-d
	'Legacy' GA	19.52 e-h	0.17 c-f	-3.55 b-e	3.56 e-g	272.85 c-e
	'Legacy' MI	22.69 a-d	-0.08 ef	-3.96 d-f	3.97 de	268.60 e
	'Meadowlark'	20.08 d-g	0.30 a-e	-4.50 f-h	4.51 b-d	273.79 c-e
	'Star'	19.55 e-h	0.19 c-f	-3.76 c-e	3.77 ef	272.83 c-e
	'Suziblue'	17.27 ij	0.74 a	-3.47 b-e	3.56 e-g	281.94 ab
RE	'Alapaha'	19.64 e-g	0.14 c-f	-3.89 d-f	3.90 de	272.03 c-e
	'Austin'	18.97 f-i	0.44 a-c	-3.00 b	3.04 g	278.20 bc
	'Brightwell'	20.81 c-f	0.67 a-c	-2.10 a	2.24 h	288.09 a
	'Powderblue'	24.16 a	0.18 c-f	-4.54 f-i	4.55 b-d	272.33 c-e
	'Vernon'	21.28 b-e	0.25 b-e	-4.04 d-g	4.05 c-e	273.48 c-e
NHB	'Aurora'	18.62 g-i	-0.14 ef	-3.16 bc	3.18 fg	267.13 e
	'Bluecrop'	23.15 ab	-0.22 f	-4.88 hi	4.89 ab	267.43 e
	'Draper'	22.12 a-d	-0.14 ef	-4.67 g-i	4.67 a-c	268.29 e
	'Elliott'	20.39 d-g	0.21 c-f	-3.70 c-e	3.71 e-g	273.03 c-e
	'Liberty'	20.86 c-f	-0.03 d-f	-4.16 e-g	4.17 c-e	269.43 de
	'Nelson'	23.93 a	-0.06 d-f	-5.23 i	5.23 a	269.33 de
Type		***	***	***	***	***
SHB		18.90(0.3) b ^{wv}	0.30(0.0) a	-3.69(0.1) a	3.72(0.1) b	274.62(0.7) a
RE		20.97(0.3) a	0.34(0.0) a	-3.52(0.1) a	3.56(0.1) b	276.83(1.3) a
NHB		21.51(0.3) a	-0.06(0.0) b	-4.30(0.1) b	4.31(0.1) a	269.11(0.5) b

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zL* values range from 0 (black) to 100 (white); a* values range from negative (green) to positive (red); b* values range from negative (blue) to positive (yellow).

^yN = 9 per cultivar

^xDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$. ***Significant at $P \leq 0.001$, respectively.

^wValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^vN = 72 for SHB; N = 45 for RE; N = 54 for NHB

Table 4.5 Skin color mean values of fourteen and three blueberry types harvested in 2019.

Type Cultivar	L* ^z	a*	b*	Chroma	Hue
	***	***	***	***	***
SHB 'Camellia'	25.24 ef ^{yx}	0.45 bc	-5.09 ef	5.12 c-e	275.08 cd
'Farthing'	21.90 gh	0.62 ab	-4.01 bc	4.06 fg	278.71 ab
'Legacy' GA	22.42 gh	0.12 e	-3.53 b	3.53 g	271.91 e
'Legacy' MI	27.26 cd	0.42 b-d	-5.09 ef	5.11 c-e	274.74 de
'Patrecia'	22.22 gh	0.72 a	-4.38 cd	4.44 ef	279.35 a
'Star'	20.92 h	0.59 ab	-3.68 bc	3.73 fg	279.05 ab
'Suziblue'	15.72 i	0.18 de	-2.11 a	2.12 h	275.25 cd
RE 'Alapaha'	27.80 c	0.43 b-d	-5.70 fg	5.71 a-c	274.29 de
'Brightwell'	29.83 ab	0.63 ab	-5.88 g	5.92 ab	276.19 b-d
'Powderblue'	31.05 a	0.22 c-e	-6.02 g	6.03 ab	272.08 e
'Premier'	22.94 g	0.46 bc	-3.90 bc	3.93 fg	276.56 a-d
'Vernon'	27.01 c-e	0.63 ab	-5.39 e-g	5.43 b-d	276.64 a-d
NHB 'Aurora'	25.08 f	0.59 ab	-4.79 de	4.82 de	277.00 a-d
'Elliott'	28.57 bc	0.84 a	-6.09 g	6.15 a	277.86 a-c
'Liberty'	25.74 d-f	0.82 a	-5.39 e-g	5.45 a-d	278.68 ab
Type	***	***	***	***	***
SHB	22.24(0.14) b ^{wv}	0.44(0.0) b	-3.98(0.1) a	4.01(0.1) b	276.30(0.4) b
RE	27.73(0.5) a	0.47(0.0) b	-5.38(0.1) b	5.40(0.1) a	275.15(0.4) b
NHB	26.47(0.3) a	0.75(0.0) a	-5.42(0.1) b	5.47(0.1) a	277.85(0.3) a

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zL* values range from 0 (black) to 100 (white); a* values range from negative (green) to positive (red); b* values range from negative (blue) to positive (yellow).

^yN = 9 per cultivar

^xDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$. *** Significant at $P \leq 0.001$, respectively.

^wValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^vN = 63 for SHB; N = 45 for RE; N = 27 for NHB

Table 4.6 Skin color mean values of the same twelve and three blueberry types harvested in 2018 and 2019.

Type	Cultivar	L* ^z		a*		b*	
		2018	2019	2018	2019	2018	2019
SHB	'Camellia'	18.67deB ^y x	25.24efA	0.19cdA	0.45cdA	-3.14bA	-5.09c-eB
	'Farthing'	17.46eB	21.90gA	0.48a-cA	0.62a-cA	-4.00c-eA	-4.01bA
	'Legacy' GA	19.52cdB	22.42gA	0.17cdA	0.12fA	-3.55b-dA	-3.53bA
	'Legacy' MI	22.69abB	27.26cdA	-0.08dB	0.42c-eA	-3.96c-dA	-5.09cdB
	'Star'	19.55cdB	20.92gA	0.19cdB	0.59bcA	-3.76b-dA	-3.68bA
	'Suziblue'	17.27eA	15.72hB	0.74aA	0.18efB	-3.47cbB	-2.11aA
RE	'Alapaha'	19.64cdB	27.80cA	0.14cdB	0.43c-eA	-3.89cdA	-5.70deB
	'Brightwell'	20.81cB	29.83abA	0.67abA	0.63a-cA	-2.10aA	-5.88eB
	'Powderblue'	24.16aB	31.05aA	0.18cdA	0.22d-fA	-4.54eA	-6.02eB
	'Vernon'	21.28bcB	27.01c-eA	0.25b-dB	0.63a-cA	-4.04cedA	-5.39c-eB
NHB	'Aurora'	18.62deB	25.08fA	-0.14dB	0.59bcA	-3.16bA	-4.79cB
	'Elliott'	20.39cdB	28.57bcA	0.21b-dB	0.84aA	-3.70b-dA	-6.09eB
	'Liberty'	20.86cB	25.74d-fA	-0.03dB	0.82abA	-4.16deA	-5.39c-eB
SHB		19.19(0.3)cB ^{wv}	22.25(0.5)cA	0.28(0.1)aA	0.4(0.0)bA	-3.64(0.1)aA	-3.92(0.2)aA
RE		21.47(0.3)aB	28.92(0.4)aA	0.31(0.1)aB	0.48(0.0)bA	-3.64(0.2)aA	-5.75(0.1)cB
NHB		19.96(0.3)bB	26.47(0.3)bA	0.02(0.1)bB	0.75(0.0)aA	-3.67(0.1)aA	-5.42(0.1)bB

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zL* values range from 0 (black) to 100 (white); a* values range from negative (green) to positive (red); b* values range from negative (blue) to positive (yellow).

^yN = 9 per cultivar

^xDifferent uppercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different lowercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^wValues within parentheses indicate type Standard Error (SE). Values shown as 0.0, are $0.00 > SE < 0.049$.

^vN = 54 for SHB; N = 36 for RE; N = 27 for NHB

Table 4.7 Skin color chroma and hue mean values of the same twelve and three blueberry types harvested in 2018 and 2019.

Type	Cultivar	Chroma		Hue	
		2018	2019	2018	2019
SHB	'Camellia'	3.16cB ^{zy}	5.12cdA	273.00cdA	275.08cdA
	'Farthing'	4.03abA	4.06eA	276.82bcA	278.71abA
	'Legacy' GA	3.56bcA	3.53eA	272.85cdA	271.91fA
	'Legacy' MI	3.97abB	5.11cdA	268.60cdB	274.74deA
	'Star'	3.77bcA	3.73eA	272.83cdB	279.05aA
	'Suziblue'	3.56bcA	2.12fB	281.94abA	275.25cdB
RE	'Alapaha'	3.90bB	5.71a-cA	272.03cdA	274.29d-fA
	'Brightwell'	2.24dB	5.92abA	288.09aA	276.19b-dB
	'Powderblue'	4.55aB	6.03abA	272.33cdA	272.08efA
	'Vernon'	4.05abB	5.43b-dA	273.48b-dB	276.64a-dA
NHB	'Aurora'	3.18cB	4.82dA	267.13dB	277.00a-dA
	'Elliott'	3.71bcB	6.15aA	273.03cdB	277.86a-dA
	'Liberty'	4.17abB	5.45a-dA	269.43cdB	278.68a-dA
SHB		3.68(0.1)aA ^{xw}	3.94(0.2)cA	274.34(0.9)aA	275.79(0.4)bA
RE		3.69(0.2)aB	5.77(0.1)aA	276.48(0.5)aA	274.80(0.4)cA
NHB		3.69(0.1)aB	5.47(0.1)bA	269.86(1.0)bB	277.85(0.3)aA

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 9 per cultivar

^yDifferent uppercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different lowercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 54 for SHB; N = 36 for RE; N = 27 for NHB

Table 4.8 Monomeric anthocyanin content, cyanidin-3-glucoside ($\text{mg} \cdot \text{L}^{-1}$) in eighteen cultivars and three types harvested in 2018.

Type	Cultivar	Cyanidin-3-glucoside ($\text{mg} \cdot \text{L}^{-1}$)	

SHB	'Camellia'	203.39	d-g ^{zy}
	'Farthing'	333.98	b-f
	'Keecrisp'	179.64	e-g
	'Legacy' Georgia	133.55	fg
	'Legacy' Michigan	259.39	c-g
	'Meadowlark'	286.30	c-g
	'Star'	292.92	c-g
	'Suziblue'	202.16	d-g
RE	'Alapaha'	105.95	g
	'Austin'	272.77	c-g
	'Brightwell'	199.03	d-g
	'Powderblue'	204.31	d-g
	'Vernon'	165.24	e-g

NHB	'Aurora'	399.11	b-d
	'Bluecrop'	339.55	b-d
	'Draper'	417.47	bc
	'Elliott'	923.54	a
	'Liberty'	517.98	b
	'Nelson'	290.47	c-g
Type		***	
SHB		236.42(14.2)	b ^{xw}
RE		189.46(17.9)	b
NHB		481.35(54.7)	a

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

^zN = 9 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$.

*** Significant at $P \leq 0.001$, respectively.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 24 for SHB; N = 15 for RE; N = 18 for NHB

Table 4.9 Monomeric anthocyanin content, cyanidin-3-glucoside ($\text{mg}\cdot\text{L}^{-1}$) in fourteen cultivars and three types harvested in 2019.

Type	Cultivar	Cyanidin-3-glucoside ($\text{mg}\cdot\text{L}^{-1}$)	

SHB	'Camellia'	285.94	cd ^{zy}
	'Farthing'	165.06	d-g
	'Legacy' Georgia	143.03	d-g
	'Legacy' Michigan	52.69	fg
	'Patrecia'	9.34	g
	'Star'	59.98	fg
	'Suziblue'	157.22	d-g
RE	'Alapaha'	68.18	e-g
	'Brightwell'	117.20	e-g
	'Powderblue'	222.96	de
	'Premier'	199.35	d-f
	'Vernon'	122.37	e-g
NHB	'Aurora'	728.01	a
	'Elliott'	449.81	b
	'Liberty'	394.69	bc
Type		***	
SHB		124.75(20.8)	b ^{xw}
RE		146.01(18.3)	b
NHB		524.17(55.7)	a

SHB = southern highbush; RE = rabbiteye;

NHB = northern highbush

^zN = 9 per cultivar

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$.

***Significant at $P \leq 0.001$, respectively.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 21 for SHB; N = 15 for RE; N = 9 for NHB

Table 4.10 Monomeric anthocyanin content, cyanidin-3-glucoside ($\text{mg}\cdot\text{L}^{-1}$), mean values of the same twelve and three blueberry types harvested in 2018 and 2019.

Type	Cultivar	Cyanidin-3-glucoside ($\text{mg}\cdot\text{L}^{-1}$)			
		2018		2019	
		***		***	
SHB	'Camellia'	203.39	c-eA ^{zy}	285.94	cdA
	'Farthing'	333.98	b-dA	165.06	d-fB
	'Legacy' Georgia	133.55	deA	143.03	d-fB
	'Legacy' Michigan	259.39	c-eA	52.69	fB
	'Star'	292.92	c-eA	59.98	fB
	'Suziblue'	202.16	c-eA	157.22	d-fA
RE	'Alapaha'	105.95	eA	68.18	efB
	'Brightwell'	199.03	c-eA	117.20	efA
	'Powderblue'	204.31	c-eA	222.96	deA
	'Vernon'	165.24	deA	122.37	efA
NHB	'Aurora'	399.11	bcA	728.01	aA
	'Elliott'	923.54	aA	449.81	bB
	'Liberty'	517.98	bcA	394.69	bcA
SHB		237.56(17.0)	bA ^{xw}	143.99(21.1)	bB
RE		168.63(17.6)	bA	132.68(20.6)	bA
NHB		613.54(87.8)	aA	524.17(55.7)	aA

SHB = southern highbush; RE = rabbiteye;

NHB = northern highbush

^zN = 9 per cultivar

^yDifferent uppercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different lowercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 18 for SHB; N = 12 for RE; N = 9 for NHB

Table 4.11 Consumer overall and chemical trait mean liking mean scores of eighteen cultivars and three types harvested in 2018.

Type	Cultivar	Overall Liking ***	Sweetness ***	Acidity ***	Color ***	Aroma ***	Flavor ***
SHB	'Camellia'	7.17 a ^{zy}	6.88 a-d	6.59 a-d	7.39 a-c	5.77 de	7.02 a-d
	'Farthing'	7.39 a	7.34 a	6.72 ab	7.58 ab	6.17 a-e	7.47 a
	'Keecrisp'	6.52 a-c	6.31 a-f	5.94 a-e	7.49 ab	5.41 e	6.65 a-f
	'Legacy' GA	7.30 a	7.08 ab	6.66 a-c	7.58 ab	6.72 ab	7.25 ab
	'Legacy' MI	7.08 ab	7.33 a	6.75 a	7.43 a-c	6.47 a-d	7.30 ab
	'Meadowlark'	6.58 a-c	6.48 a-f	6.20 a-e	7.75 a	5.87 c-e	6.42 b-f
	'Star'	6.46 a-c	6.54 a-f	6.01 a-e	7.41 a-c	6.51 a-d	6.82 a-e
	'Suziblue'	6.13 b-d	5.77 e-h	5.48 ef	7.48 ab	5.45 e	6.19 c-f
RE	'Alapaha'	5.12 ef	5.73 f-h	5.59 ef	7.42 a-c	6.10 b-e	5.83 fg
	'Austin'	5.93 c-e	6.52 a-f	6.23 a-e	7.31 a-c	6.63 a-c	6.60 a-f
	'Brightwell'	5.47 d-f	5.43 gh	5.43 ef	7.02 bc	6.45 a-d	5.77 fg
	'Powderblue'	6.87 a-c	7.08 ab	6.66 a-c	7.35 a-c	6.92 a	7.19 ab
	'Vernon'	5.37 d-f	5.76 e-h	5.83 b-e	7.37 a-c	6.27 a-d	5.93 e-g
NHB	'Aurora'	5.96 c-e	5.86 e-g	5.69 d-f	7.45 a-c	6.22 a-d	6.11 d-f
	'Bluecrop'	6.78 a-c	6.70 a-e	6.25 a-e	7.36 a-c	6.05 b-e	6.83 a-e
	'Draper'	5.98 c-e	5.94 d-g	5.39 ef	7.55 ab	5.75 de	6.13 c-f
	'Elliott'	4.72 f	4.82 h	4.87 f	6.84 c	6.30 a-d	5.16 g
	'Liberty'	5.89 c-e	6.07 c-g	5.80 c-e	7.17 a-c	6.16 a-e	6.07 e-g
	'Nelson'	7.02 ab	6.95 a-c	6.53 a-d	7.52 ab	6.51 a-d	7.07 a-c
Type		***	***	***	***	***	***
SHB		6.83(0.1) a ^{xw}	6.72(0.1) a	6.30(0.1) a	7.51(0.1) a	6.05(0.1) b	6.89(0.1) a
RE		5.75(0.1) c	6.11(0.1) b	5.95(0.1) b	7.30(0.1) b	6.47(0.1) a	6.27(0.1) b
NHB		6.06(0.1) b	6.06(0.1) b	5.75(0.1) b	7.32(0.1) b	6.16(0.1) b	6.23(0.1) b

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

Fruit were evaluated by consumers using a 9-point hedonic scale: 9 = extremely like 5 = neither dislike/like and 1 = extremely dislike.

^zN = 83 (83 consumers attended all four consumer panels throughout the harvest season)

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$.

*** Significant at $P \leq 0.001$, respectively.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 664 for SHB; N = 415 for RE; N = 498 for NHB

Table 4.12 Consumer mean overall and chemical trait liking scores of fourteen cultivars and three types harvested in 2019.

Type	Cultivar	Overall Liking ***	Sweetness ***	Acidity ***	Color ***	Aroma ***	Flavor ***
SHB	'Camellia'	7.28 ab ^{zy}	7.22 ab	7.00 ab	7.45 a-c	6.29 a	7.32 ab
	'Farthing'	6.44 b-d	6.03 ef	6.08 c-f	7.58 a	6.28 a	6.53 bc
	'Legacy' Georgia	6.86 a-c	6.83 a-d	6.56 a-c	7.44 a-c	6.06 ab	7.01 ab
	'Legacy' Michigan	7.51 a	7.31 a	7.08 a	7.58 a	6.14 ab	7.53 a
	'Patrecia'	7.14 ab	7.15 ab	6.64 a-c	7.67 a	6.19 ab	7.10 ab
	'Star'	5.81 d-f	6.40 b-e	6.24 b-e	7.27 a-c	6.44 a	6.51 b-d
	'Suziblue'	5.94 d-f	5.69 ef	5.67 d-f	7.13 a-c	5.54 b	6.13 cd
RE	'Alapaha'	5.36 ef	6.21 c-e	5.67 ef	6.87 c	6.28 a	5.94 cd
	'Brightwell'	6.14 c-e	6.63 a-d	6.40 a-d	7.29 a-c	6.54 a	6.68 bc
	'Powderblue'	6.67 a-d	6.92 a-c	6.60 a-c	6.94 bc	6.55 a	6.99 ab
	'Premier'	5.79 d-f	5.74 ef	5.69 d-f	7.60 a	6.55 a	6.12 cd
	'Vernon'	5.50 ef	5.73 ef	5.59 d-f	7.54 ab	6.64 a	5.87 cd
NHB	'Aurora'	5.86 d-f	5.64 ef	5.50 ef	7.33 a-c	6.01 ab	6.03 cd
	'Elliott'	5.21 f	5.28 f	5.28 f	6.85 c	6.00 ab	5.68 d
	'Liberty'	6.41 b-d	6.36 b-e	6.22 b-e	7.46 a-c	6.45 a	6.49 b-d
Type	***	***	***	***	***	***	***
SHB	6.71(0.1) a ^{xw}	6.66(0.1) a	6.47(0.1) a	7.44(0.1) a	6.14(0.1) b	6.88(0.1) a	
RE	5.89(0.1) b	6.25(0.1) b	5.99(0.1) b	7.25(0.1) b	6.51(0.1) a	6.32(0.1) b	
NHB	5.82(0.1) b	5.76(0.1) c	5.67(0.1) c	7.21(0.1) b	6.15(0.1) b	6.06(0.1) b	

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

Fruit were evaluated by consumers using a 9-point hedonic scale: 9 = extremely like 5 = neither dislike/like and 1 = extremely dislike.

^zN = 78 (78 consumers attended all four consumer panels throughout the harvest season)

^yDifferent letters within a column indicate significant differences among cultivars or types within a trait using Tukey's test, $P \leq 0.05$.

***Significant at $P \leq 0.001$, respectively.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 546 for SHB; N = 390 for RE; N = 234 for NHB

Table 4.13 Consumer mean overall, sweetness, acidity and color liking scores of the same twelve cultivars and three types harvested in 2018 and 2019.

Type Cultivar	Overall liking		Sweetness		Acidity		Color	
	2018	2019	2018	2019	2018	2019	2018	2019
SHB ‘Camellia’	7.26abA ^{zy}	7.11 abA	7.02abA	7.11abA	6.59abA	6.83abA	7.39aA	7.30a-cA
‘Farthing’	7.46 aA	6.63 a-cB	7.44aA	6.17b-fB	6.85aA	6.17b-fB	7.59aA	7.70aA
‘Legacy’ GA	7.35 abA	6.72 a-cB	7.11abA	6.76a-cA	6.48abA	6.46a-cA	7.61aA	7.41a-cA
‘Legacy’ MI	6.96 a-cB	7.56 aA	7.13abA	7.28aA	6.69aA	7.19aA	7.44aA	7.56abA
‘Star’	6.54 a-dA	5.78 c-eB	6.54a-cA	6.31a-eA	5.96a-cA	6.19b-eA	7.50aA	7.13a-cA
‘Suziblue’	6.30 b-eA	5.81 c-eA	5.81cdA	5.63d-fA	5.61bcA	5.69c-fA	7.46aA	7.20a-cA
RE ‘Alapaha’	5.11 fgA	5.15 eA	5.61cdA	6.04c-fA	5.57bcA	5.43efA	7.44aA	6.76cB
‘Brightwell’	5.46 d-gA	5.93 c-eA	5.26deB	6.59a-dA	5.35cdB	6.33a-eA	7.22aA	7.17a-cA
‘Powderblue’	6.83 a-cA	6.43 bcA	6.94abA	6.78a-cA	6.61abA	6.41a-dA	7.33aA	6.94bcA
‘Vernon’	5.33 e-gA	5.33 deA	5.83cdA	5.56efA	5.89a-cA	5.46d-fA	7.39aA	7.50abA
NHB ‘Aurora’	6.00 c-fA	5.74 c-eA	5.81cdA	5.59d-fA	5.61bcA	5.46d-fA	7.65aA	7.28a-cA
‘Elliott’	4.43 gB	5.13 eA	4.46eB	5.30fA	4.52dB	5.22fA	6.98aA	6.96bcA
‘Liberty’	5.89 c-fA	6.33 b-dA	6.09b-dA	6.22b-fA	5.81a-cA	6.15b-fA	7.20aA	7.35a-cA
SHB	6.98(0.1) aA ^{xw}	6.60(0.1) aB	6.84(0.1)aA	6.54(0.1)aB	6.36(0.1)aA	6.42(0.1)aA	7.50(0.1)aA	7.38(0.1)aA
RE	5.69(0.1) bA	5.71(0.1) bA	5.91(0.1)bA	6.24(0.1)aA	5.86(0.1)bA	5.91(0.1)bA	7.35(0.1)aA	7.09(0.1)bB
NHB	5.44(0.2) bA	5.73(0.2) bA	5.46(0.2)cA	5.70(0.2)bA	5.31(0.2)cA	5.61(0.2)bA	7.28(0.1)aA	7.20(0.1)abA

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

Fruit were evaluated by consumers using a 9-point hedonic scale 9 = extremely like 5 = neither dislike/like and 1 = extremely dislike.

^zN = 54 of the same panelists that attended the nine panels

^yDifferent lowercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different uppercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 324 for SHB; N = 216 for RE; N = 162 for NHB

Table 4.14 Consumer mean overall, aroma and flavor liking scores of the same twelve cultivars and three types harvested in 2018 and 2019.

Type Cultivar	Aroma		Flavor	
	2018	2019	2018	2019
SHB ‘Camellia’	5.63 cdB ^{zy}	6.26 abA	6.98 a-dA	7.28 abA
‘Farthing’	6.24 a-dA	6.04 abA	7.61 aA	6.57 a-eB
‘Legacy’ Georgia	6.72 abA	5.98 abB	7.15 abA	6.98 a-cA
‘Legacy’ Michigan	6.22 a-dA	6.09 abA	7.22 abA	7.52 aA
‘Star’	6.59 abA	6.31 abA	6.83 a-eA	6.48 b-eA
‘Suziblue’	5.54 dA	5.61 bA	6.35 b-fA	6.04 c-eA
RE ‘Alapaha’	6.20 a-dA	6.07 abA	5.83 e-gA	5.87 deA
‘Brightwell’	6.50 a-cA	6.37 abA	5.59 fgB	6.63 a-dA
‘Powderblue’	6.93 aA	6.30 abB	7.11 a-cA	6.91 a-cA
‘Vernon’	6.30 a-dA	6.46 aA	5.89 d-gA	5.70 deA
NHB ‘Aurora’	5.89 b-dA	6.02 abA	5.94 d-gA	5.89 deA
‘Elliott’	6.20 a-dA	5.96 abA	4.85 gB	5.59 eA
‘Liberty’	6.00 b-dA	6.48 aA	6.04 c-fA	6.33 b-eA
SHB	6.16(0.1) bA ^{xw}	6.05(0.1) aA	7.02(0.1) aA	6.81(0.1) aA
RE	6.48(0.1) aA	6.30(0.1) aA	6.11(0.1) bA	6.28(0.1) bA
NHB	6.03(0.1) bA	6.15(0.1) aA	5.61(0.2) cA	5.94(0.2) bA

SHB = southern highbush; RE = rabbiteye; NHB = northern highbush

Fruit were evaluated by consumers using a 9-point hedonic scale 9 = extremely like 5 = neither dislike/like and 1 = extremely dislike.

^zN = 54 of the same panelists that attended the nine panels

^yDifferent lowercase letters within a column indicate significant differences among cultivars or types within a trait and year, or different uppercase letters within a row indicate significant differences between years within a trait using Tukey's test, $P \leq 0.05$.

^xValues within parentheses indicate type Standard Error (SE).

^wN = 324 for SHB; N = 216 for RE; N = 162 for NHB



Figure 4.1 Equatorially sliced fresh blueberries during the 2019 harvest season, displaying pigmentation in the fruit skin and pulp. From left to right: ‘Aurora’, ‘Elliott’, ‘Liberty’, and ‘Camellia’.

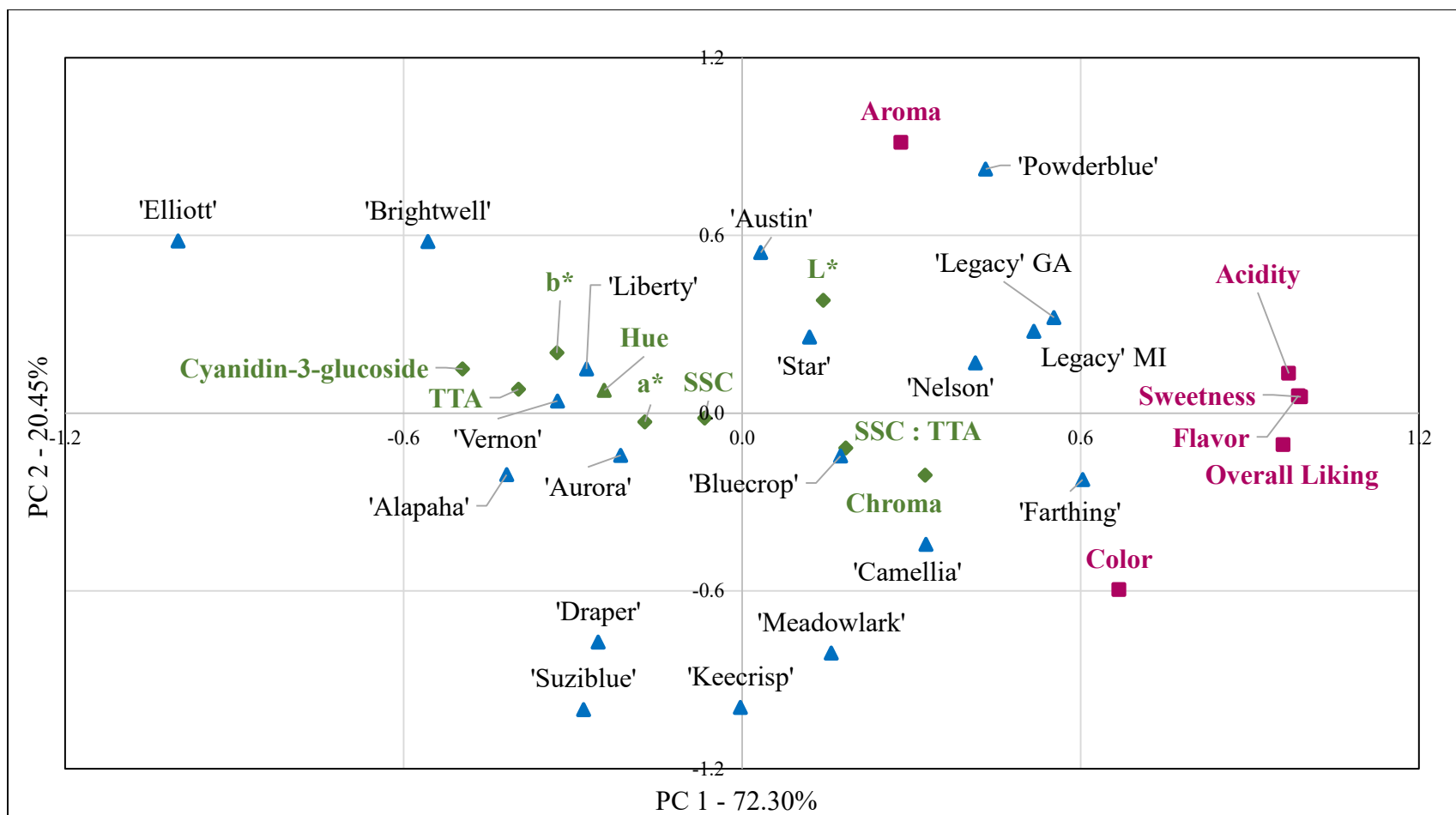


Figure 4.2 Principal component analysis (PCA) of chemical traits of eighteen cultivars (represented by triangle shapes) evaluated during the 2018 harvest season. PCA shows the correspondence of consumer mean liking scores (represented by square shapes) to instrumental analyses mean values (represented by diamond shapes).

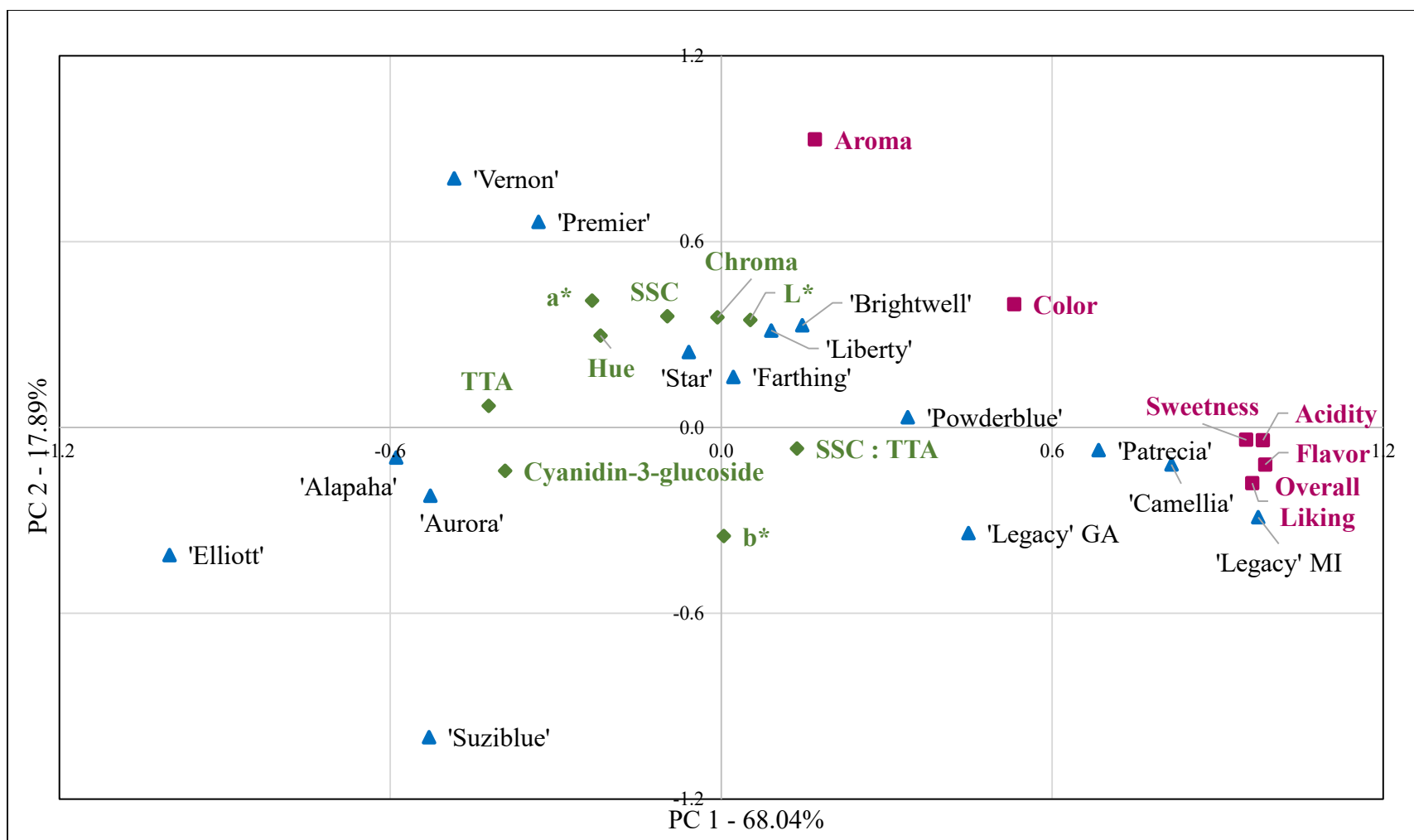


Figure 4.3 Principal component analysis (PCA) of chemical traits of fourteen cultivars (represented by triangle shapes) evaluated during the 2019 harvest season. PCA shows the correspondence of consumer mean liking scores (represented by square shapes) to instrumental analyses mean values (represented by diamond shapes).

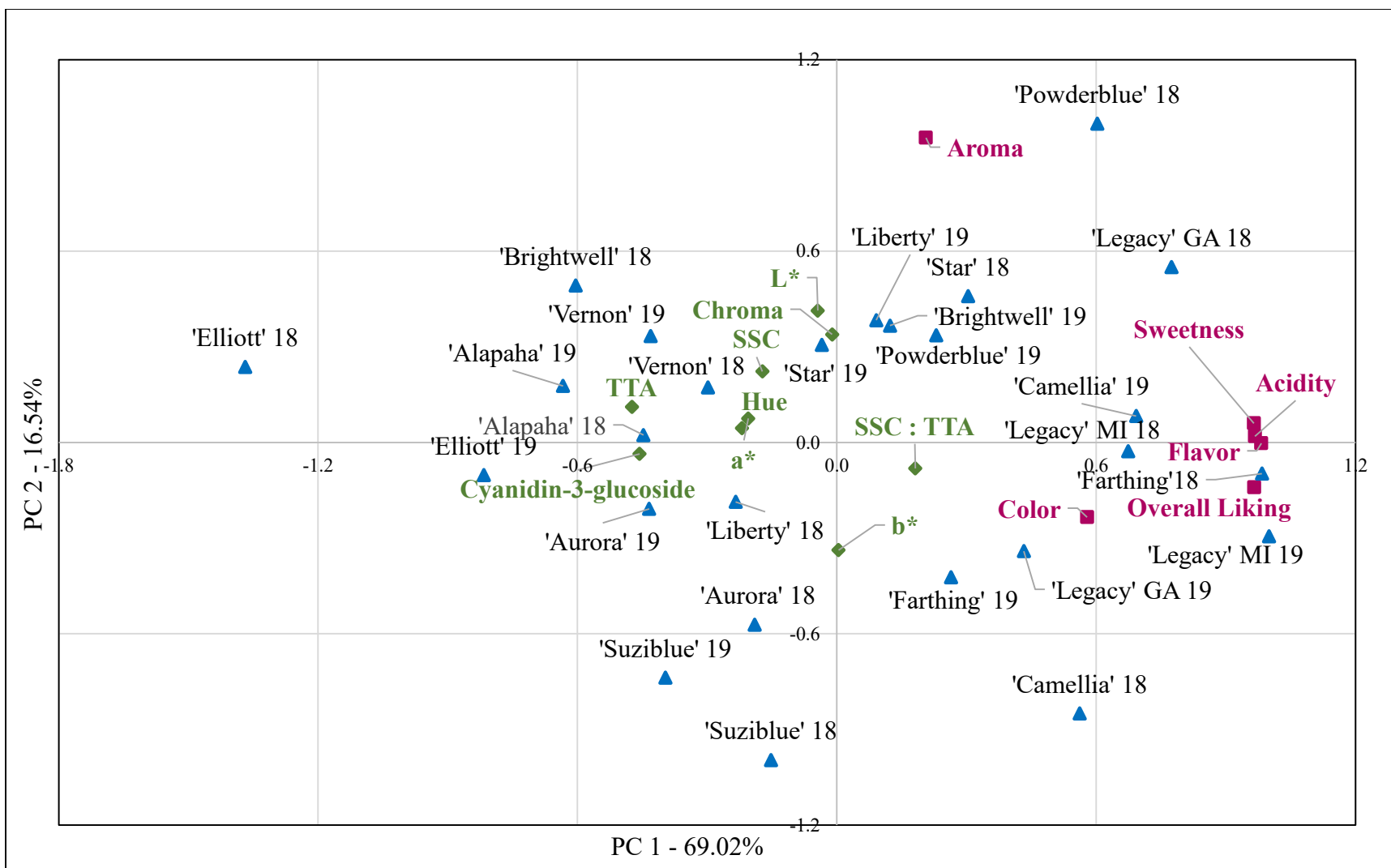


Figure 4.4 Principal component analysis (PCA) of chemical traits of same twelve cultivars (represented by triangle shapes) evaluated during the 2018 and 2019 harvest seasons. PCA shows the correspondence of consumer mean liking scores (represented by square shapes) to instrumental analyses mean values (represented by diamond shapes).

CHAPTER 5

CONCLUSIONS

Understanding the variation among cultivars and blueberry types was an important need from the Georgia blueberry industry. Physicochemical trait parameters across two harvest seasons allowed a thorough assessment of blueberry types and cultivars' fruit quality traits. This assessment coupled with consumer sensory identified relationships of traits and overall liking. For our study, it was identified that although appearance is an important trait, textural traits (including skin toughness and fruit firmness) in addition to flavor traits may affect consumer overall liking. Puncture-in, puncture-out, Kramer shear, shriveled seeds positively corresponded to consumer overall liking, whereas fiber, plump seeds, SSC, and TTA negatively corresponded to consumer overall liking.

From our research, it is unclear whether aroma and color instrumentally measured attributes associated to consumer acceptability of color, aroma and overall liking. It is important to better understand which descriptive terms coincide to instrumentally measured traits and can be interpreted by untrained panelists. Instrumental measurements cannot solely predict all acceptability scores. Overall, the blueberry industry, nurseries and breeders can target texture and flavors (sugar and acids) to increase marketability and consumer purchasing habits. Knowledge of desirable traits may help growers produce certain cultivars and increase their overall share in the blueberry market.

APPENDIX A

RECRUITMENT SCREENER FOR CONSUMER TEST OF BLUEBERRIES

Hello, we are from The University of Georgia, Sensory Evaluation and Consumer Lab (SEC Lab) at the Griffin Campus. We wanted to see if you would be interested to participate in a research study for consumer acceptability of fresh fruit. This project is being overseen by Dr. Koushik Adhikari in the Department of Food Science & Technology, UGA Griffin Campus, telephone number (770) 412-4736. The purpose of this study is to evaluate fresh fruit sample.

Do you think you might be interested in participating in this study?

{If No}: Thank you very much for your time.

{If Yes}: Please leave your name, phone number, e-mail address, and best time to call.

We need your contact information to get in touch with you if you qualify for this taste test. All information is kept strictly confidential. As a friendly reminder: please do not have any fragrance/odor (colognes, perfumes, lotions and smoke) on you when attending the taste test. Thank you.

Do you have any food allergies?

{If Yes}: Please indicate if you have any allergies to the following fresh fruit:

{If No}: What is your gender?

1. Please indicate if you have any allergies to the following fresh fruit:

- 1) Oranges
- 2) Blueberries
- 3) Mangoes
- 4) Pineapple
- 5) Strawberries
- 6) Melon
- 7) Other(s), please specify: _____

{If Blueberries are selected}: Sorry you don't qualify for this test; however, we will have more tests in the near future. Thank you. Have a nice day.

2. What is your gender?

- 1) Male
- 2) Female

3. What age ground do you belong in?

- 1) 17 and under
- 2) 18-24
- 3) 25-39
- 4) 40-54
- 5) 55-65
- 6) 66 and over

{If 17 and under is selected}: Sorry you don't qualify for this test; however, we will have more tests in the near future. Thank you. Have a nice day.

4. Please indicate, for each of these fruit, how often you consume them during the Spring/Summer?

	Daily	Once a week	2-3 times/month	Once a month	Rarely to never
Oranges					
Blueberries					
Mangoes					
Strawberries					
Pineapple					
Melon					

{If Blueberries –Rarely to never is selected}: Sorry you don't qualify for this test; however, we will have more tests in the near future. Thank you. Have a nice day.

We will be conducting a taste test on fresh fruit. There will approximately be five taste tests from May to August. This test requires you to come to ALL five taste test days. You will taste three-six samples per day. Each test will take approximately one hour to complete. To show our appreciation for your participation, we will pay you \$10.00 for each test day.

5. Are you interested in participating in this taste test?

1) Yes

2) No

{If No}: Sorry you don't qualify for this test; however, we will have more tests in the near future. Thank you. Have a nice day.

You have qualified to participate in this study. We will be conducting six sessions during Thursday's taste test day. The sessions are will be assigned on a first come first serve basis. We cannot guarantee that you will receive the time session you have selected; however, we will try out best. Please check the session(s) that may work with your schedule (You may check up to three session) that you would like to be considered for. We also cannot guarantee you that you will be chosen for this study.

1st Session			2nd Session			3rd Session			4th Session			5th Session		
May 3rd	May 4th	May 7th	May 24th	May 25th	May 28th	June 14th	June 15th	June 18th	July 26th	July 27th	July 30th	August 23th	August 24th	August 27th
9:00AM	9:00AM	9:00AM	9:00AM	9:00AM	9:00AM	9:00AM	9:00AM	9:00AM	9:00AM	9:00AM	9:00AM	9:00AM	9:00AM	9:00AM
10:30AM	10:30AM	10:30AM	10:30AM	10:30AM	10:30AM	10:30AM	10:30AM	10:30AM	10:30AM	10:30AM	10:30AM	10:30AM	10:30AM	10:30AM
12:00PM	12:00PM	12:00PM	12:00PM	12:00PM	12:00PM	12:00PM	12:00PM	12:00PM	12:00PM	12:00PM	12:00PM	12:00PM	12:00PM	12:00PM
1:30PM	1:30PM	1:30PM	1:30PM	1:30PM	1:30PM	1:30PM	1:30PM	1:30PM	1:30PM	1:30PM	1:30PM	1:30PM	1:30PM	1:30PM
3:30PM	3:30PM	3:30PM	3:30PM	3:30PM	3:30PM	3:30PM	3:30PM	3:30PM	3:30PM	3:30PM	3:30PM	3:30PM	3:30PM	3:30PM
5:00PM	5:00PM	5:00PM	5:00PM	5:00PM	5:00PM	5:00PM	5:00PM	5:00PM	5:00PM	5:00PM	5:00PM	5:00PM	5:00PM	5:00PM

APPENDIX B

CONSENT FORM FOR 2018 CONSUMER TASTE TESTS

Researcher's Statement

I am asking you to take part in a research study that is funded by the Georgia Agricultural Commodity Commission for Blueberries and the Southern Region Small Fruit Consortium. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. This form is designed to give you the information about the study so you can decide whether to be in the study or not. Please take the time to read the following information carefully. Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, you can decide if you want to be in the study or not. This process is called "informed consent." A copy of this form will be given to you. Your involvement in the study is voluntary, and you may choose not to participate or to stop at any time without penalty or loss of benefits to which you are otherwise entitled.

Principal Investigator/Researcher Information

Koushik Adhikari (770-412-4736, koushik7@uga.edu), Department of Food Science and Technology, University of Georgia, 1109 Experiment St., Griffin, GA 30223.

Purpose and Benefits of the Study

The purpose of the study is to gather sensory information on consumer opinions of fresh blueberry samples. Although there are no direct benefits for you, this information will help Georgia blueberry growers to market their produce more effectively to consumers. This will also add to the body of knowledge related to blueberry research and food product development.

Study Procedures

This research study will be conducted on three times from May to June 2018. The test will last approximately one hour per session. If you agree to participate, you will be asked to evaluate 4-6 blueberry samples. Coded samples and the score sheets (ballots) will be placed in front of you. You will evaluate samples by tasting, and indicate your evaluation/opinion on the score sheets. You will be asked some demographic questions associated with the study as well. All procedures used in the study are standard sensory analysis methods as published in books, research articles etc.

Risks and Discomforts

Although the researchers have tried to avoid risks, you may feel that some questions/procedures that are asked of you might be stressful or upsetting. You do not have to answer anything you do not want to.

No other risks except for *food allergies* are anticipated from participating in this research study. However, because the food to be tested is known beforehand, the situation can normally be avoided. Please do not participate in the tests if you have any allergies towards peanuts and products containing peanuts. It is your responsibility to inform the researchers about your food allergies.

Please list any known food allergies that you have:

Blueberry Allergy Symptoms

<http://www.inflammation-repair.manchester.ac.uk/informall/allergenic-food/?FoodId=37>

An allergic response to blueberries usually occurs 5-15 minutes after consumption and can range from mild to severe.

Mild blueberry allergy signs and symptoms can include:

- Redness and swelling of the lips
- Itching or tingling in or around the mouth and throat
- Inflammation in the mouth and/or throat
- Relapse can occur 15 to 60 minutes after initial symptoms

More severe blueberry allergy symptoms include:

- Rash of itchy round, red welts on the skin (urticaria), may have swelling
- Abdominal pain or burning, cramps
- Vomiting and/or diarrhea

Anaphylaxis: A life-threatening reaction

Anaphylaxis is a life-threatening medical emergency that requires treatment with an epinephrine (adrenaline) injector (EpiPen, Twinject) and a trip to the emergency room.

Although a rare reaction in response to blueberry consumption,

Anaphylaxis signs and symptoms can include all of the above, plus:

- Constriction of airways
- Swelling of your throat that makes it difficult to breathe
- A decrease in blood pressure (shock)
- Rapid pulse
- Dizziness, lightheadedness or loss of consciousness

Other life threatening reactions such as severe asthma attack or glottis oedema are rarely observed.

Seek immediate medical attention if you display symptoms of blueberry allergy

Incentives for participation

On completion of each session (45 minutes; 3 weeks apart, 3 sessions total), you will be paid a monetary incentive of **\$10**. You will have to provide your name and mailing address on a separate payment sheet for audit purposes before receiving the money.

If you are injured by this research

The researchers will exercise all reasonable care to protect you from harm as a result of your participation. In the event that any research-related activities result in an injury, the sole responsibility of the researchers will be to arrange for your transportation to an appropriate health care facility. If you think that you have suffered a research-related injury, you should seek immediate medical attention and then contact Koushik Adhikari right away at 770-412-4736. In the event that you suffer a research-related injury, your medical expenses will be your responsibility or that of your third-party payer, although you are not precluded from seeking to collect compensation for injury related to malpractice, fault, or blame on the part of those involved in the research.

Privacy/Confidentiality

The results of this participation will be confidential and will not be released in any individually identifiable form without my prior consent unless required by law. Your confidentiality will be maintained in that a participant’s name will not appear on the ballot or in the published study itself, and the researcher will not know who said what and cannot connect comments back to the participant. The data will be reported in aggregate form. Score sheets and the signed informed consents will be stored with principal investigator for period of three years and then destroyed. Researchers will not release identifiable results of the study to anyone other than individuals working on the project without your written consent unless required by law.

Research Subject’s Consent to Participate in Research

If you have any questions about this research project, please feel free to call Paula Scott at 770-412-4747 ext 230, or email sensory@uga.edu, to voluntarily agree to take part in this study, you must sign on the line below. Your signature below indicates that you have read or had read to you this entire consent form, and have had all of your questions answered.

Koushik Adhikari		
Name of Researcher	Signature	Date
Name of Participant	Signature	Date

Please sign both copies, keep one and return one to the researcher.

Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 629 Boyd GSRC, Athens, Georgia 30602; telephone (706) 542-3199; email address irb@uga.edu.

APPENDIX C

BALLOTS OF 2018 CONSUMER TESTS

Blueberry Consumer Acceptability Test

Consumer#:	Date:	Session Time:
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INSTRUCTIONS

- You will taste # fresh blueberry samples in this session. You will receive the samples one by one.
- Make sure that the 3-digit sample number on the sample cup matches the 3-digit sample number on your ballot.
- For each sample, please taste the sample and answer the questions.
- Please take a bite of the cracker and drink some water in between samples to rinse your mouth.
- There is a set of demographic questions after the last sample. Please make sure you complete them before you leave.

Sample _____

INSTRUCTIONS: PLEASE CLEAN YOUR PALATE WITH CRACKERS AND RINSE YOUR MOUTH WITH WATER BEFORE STARTING.

Please look at this sample, and then answer the following questions:

Please rate how much you like/dislike the **color** of this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dislike	Dislike	Dislike	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

Please rate how much you like/dislike the **fruit size** of this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dislike	Dislike	Dislike	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

Please sniff this sample at least 3 times, and then answer the following question:

Mark the box that best describes how much you like/dislike the **aroma** of this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dislike	Dislike	Dislike	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

Please taste 3 or more pieces of the sample and answer the following questions:

Overall, please rate how much you like/dislike the **flavor** of this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please rate how much you like/dislike the **sweetness** for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please rate how much you like/dislike the **acidity** for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Overall, please rate how much you like/dislike the **texture** of this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please rate how much you like/dislike the **fruit firmness** for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please rate how much you like/dislike the **blueberry skin toughness** for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please rate how much you like/dislike the **grittiness/graininess** for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please rate how much you like/dislike the **seediness** for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please rate your **overall liking** of this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please select the words that best describe the attributes you **LIKE** in this blueberry sample.

Fruity flavor	<input type="checkbox"/>	Sweet/tart balance	<input type="checkbox"/>	Juiciness	<input type="checkbox"/>	Chewiness	<input type="checkbox"/>
Crispy/pops in mouth	<input type="checkbox"/>	Mealiness	<input type="checkbox"/>	Smooth texture	<input type="checkbox"/>	Very sweet, no sugar needed	<input type="checkbox"/>

Please select the words that best describe the attributes that you **DISLIKE** in this blueberry sample.

Fruity flavor	<input type="checkbox"/>	Sweet/tart balance	<input type="checkbox"/>	Juiciness	<input type="checkbox"/>	Chewiness	<input type="checkbox"/>
Crispy/pops in mouth	<input type="checkbox"/>	Mealiness	<input type="checkbox"/>	Smooth texture	<input type="checkbox"/>	Very sweet, no sugar needed	<input type="checkbox"/>

How likely are you to consume this sample a second time?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9
Extremely Unlikely				Moderate				Extremely Likely

If you knew that this sample was higher in nutritional compounds than other blueberries (anthocyanins, antioxidants, vitamin C, dietary fiber etc.), how likely would you be to consume this sample a second time?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9
Extremely Unlikely				Moderate				Extremely Likely

APPENDIX D

Blueberry Consumer Acceptability Test

DEMOGRAPHIC QUESTIONNAIRE

Date: **June 3, 2018**

Consumer #: _____

Please answer all questions. All your answers will be kept confidential

1	Which of the following describes your age group? 18-24 years old _____ 25-34 years old _____ 35-44 years old _____ 45-54 years old _____ 55-65 years old _____ 66+ years old _____
2	What is your gender? Male _____ Female _____
3	Please mark the category that best represents your race/ethnicity. White/Caucasian _____ Black/African American _____ Hispanic/Latino _____ Asian _____ Pacific Islander _____ Other(s), please specify: _____

4	<p>How many adults and children are in your household (put 0 if not applicable)</p> <p>Self _____</p> <p>Two adults _____</p> <p>Two or more adults _____</p> <p>Children under 18 _____</p> <p>Children under 10 _____</p> <p>Children under 2 _____</p>
5	<p>Please mark the category that best represents your household income before taxes in 2017.</p> <p>Less than \$25,999 _____</p> <p>\$25,000 to \$49,999 _____</p> <p>\$50,000 to \$75,999 _____</p> <p>\$76,000 to \$99,999 _____</p> <p>\$100,000 to \$149,999 _____</p> <p>\$150,000 and greater _____</p>
6	<p>What is your education level?</p> <p>Some high school _____</p> <p>High school degree _____</p> <p>Some college _____</p> <p>College degree _____</p> <p>Some graduate study _____</p> <p>Graduate degree _____</p>
<p>Questions 7 - 9 are related to your general fresh fruit consumption.</p>	
7	<p>How often do you purchase fresh fruit?</p> <p>Once a week _____</p> <p>Twice a month _____</p> <p>Monthly or less _____</p>
8	<p>On average, how much do you typically spend per grocery purchase on fresh fruit for your household?</p> <p>_____</p>

9	<p>At your last grocery store visit, which of the following fresh fruit did you purchase? (Check all that apply)</p> <table border="0"> <tr> <td>Apples</td> <td>_____</td> <td>Mangoes</td> <td>_____</td> </tr> <tr> <td>Oranges/Mandarins</td> <td>_____</td> <td>Strawberries</td> <td>_____</td> </tr> <tr> <td>Bananas</td> <td>_____</td> <td>Raspberries</td> <td>_____</td> </tr> <tr> <td>Grapes</td> <td>_____</td> <td>Pineapple</td> <td>_____</td> </tr> <tr> <td>Peaches</td> <td>_____</td> <td>Pears</td> <td>_____</td> </tr> <tr> <td>Blueberries</td> <td>_____</td> <td>Pomegranates</td> <td>_____</td> </tr> <tr> <td>Melons</td> <td>_____</td> <td>Cherries</td> <td>_____</td> </tr> <tr> <td>Blackberries</td> <td>_____</td> <td>Other(s), please specify: _____</td> <td></td> </tr> </table>	Apples	_____	Mangoes	_____	Oranges/Mandarins	_____	Strawberries	_____	Bananas	_____	Raspberries	_____	Grapes	_____	Pineapple	_____	Peaches	_____	Pears	_____	Blueberries	_____	Pomegranates	_____	Melons	_____	Cherries	_____	Blackberries	_____	Other(s), please specify: _____	
Apples	_____	Mangoes	_____																														
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Blackberries	_____	Other(s), please specify: _____																															
<p>Questions 10 - 14 are related to your fresh blueberry consumption.</p>																																	
10	<p>Which of the following aspects do you care about (mostly) when buying fresh blueberries? (Check all that apply)</p> <table border="0"> <tr> <td>Aroma</td> <td>_____</td> <td>Cost</td> <td>_____</td> </tr> <tr> <td>Shape/Size</td> <td>_____</td> <td>Damage/defect free</td> <td>_____</td> </tr> <tr> <td>Color</td> <td>_____</td> <td>Organic</td> <td>_____</td> </tr> <tr> <td>Firmness</td> <td>_____</td> <td>Locally grown</td> <td>_____</td> </tr> <tr> <td>Damage/defect</td> <td>_____</td> <td>Nutritional value</td> <td>_____</td> </tr> <tr> <td>Flavor</td> <td>_____</td> <td></td> <td></td> </tr> </table>	Aroma	_____	Cost	_____	Shape/Size	_____	Damage/defect free	_____	Color	_____	Organic	_____	Firmness	_____	Locally grown	_____	Damage/defect	_____	Nutritional value	_____	Flavor	_____										
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Flavor	_____																																

11

When purchasing fresh blueberries at one time:

What size do you usually purchase?

How many do you usually purchase?

(Check all that apply)



4 – 6oz clamshell



11oz clamshell (1 pint)



16 – 18oz clamshell



24oz – 2lb clamshell

12	<p>When are you most likely to purchase fresh blueberries? (Check all that apply)</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">January _____</td> <td style="width: 50%;">July _____</td> </tr> <tr> <td>February _____</td> <td>August _____</td> </tr> <tr> <td>March _____</td> <td>September _____</td> </tr> <tr> <td>April _____</td> <td>October _____</td> </tr> <tr> <td>May _____</td> <td>November _____</td> </tr> <tr> <td>June _____</td> <td>December _____</td> </tr> </table>	January _____	July _____	February _____	August _____	March _____	September _____	April _____	October _____	May _____	November _____	June _____	December _____
January _____	July _____												
February _____	August _____												
March _____	September _____												
April _____	October _____												
May _____	November _____												
June _____	December _____												
13	<p>Are you generally satisfied with the fresh blueberries that are available at your local supermarket?</p> <table style="width: 100%; border: none; text-align: center;"> <tr> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>Not at all Satisfied</td> <td>Somewhat Dissatisfied</td> <td>Neither Satisfied or Dissatisfied</td> <td>Somewhat Satisfied</td> <td>Very Satisfied</td> </tr> </table> <p>Please specify the reasons</p> <hr/> <hr/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Not at all Satisfied	Somewhat Dissatisfied	Neither Satisfied or Dissatisfied	Somewhat Satisfied	Very Satisfied		
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>									
Not at all Satisfied	Somewhat Dissatisfied	Neither Satisfied or Dissatisfied	Somewhat Satisfied	Very Satisfied									
14	<p>Which of the following terms have you come across in regards to blueberries? (Check all that apply)</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 80%;">Highbush</td> <td>_____</td> </tr> <tr> <td>Rabbiteye</td> <td>_____</td> </tr> <tr> <td>Wild</td> <td>_____</td> </tr> <tr> <td>Lowbush</td> <td>_____</td> </tr> <tr> <td>None of the above</td> <td>_____</td> </tr> </table>	Highbush	_____	Rabbiteye	_____	Wild	_____	Lowbush	_____	None of the above	_____		
Highbush	_____												
Rabbiteye	_____												
Wild	_____												
Lowbush	_____												
None of the above	_____												

THANK YOU FOR YOUR PARTICIPATION!

Please answer all questions. All your answers will be kept confidential

1	<p>In what way do you “MOST OFTEN” consume fresh blueberries? (Check one.)</p> <p>Fresh fruit by itself _____</p> <p>Fresh fruit as a food topping _____ (ex: on yogurt, cereal, fruit salad, dessert topping, in a smoothie, etc.)</p> <p>As ingredient in recipes &/or to bake with _____</p> <p>To can in jars, jams, for later use _____</p> <p>To freeze for later use _____</p> <p>Other, please specify below _____ _____ _____</p>
2	<p>Without repeating your answer from question #1 above, what <u>other ways</u> do you consume fresh blueberries? (Check-all-that-apply)</p> <p>Fresh fruit by itself _____</p> <p>Fresh fruit as a food topping _____ (ex: on yogurt, cereal, fruit salad, dessert topping, in a smoothie, etc.)</p> <p>As ingredient in recipes &/or to bake with _____</p> <p>To can in jars, jams, for later use _____</p> <p>To freeze for later use _____</p> <p>Other, please specify below _____ _____ _____</p>

3	<p>You purchase/consume fresh blueberries: (Check-all-that-apply)</p> <p>As a grocery staple _____</p> <p>For special occasions _____</p> <p>As a special treat _____</p> <p>Other, please specify below _____</p> <p>_____</p>
4	<p>How often do you purchase fresh blueberries?</p> <p>1-2 times per week _____</p> <p>1 time every two weeks _____</p> <p>Monthly or less _____</p> <p>Other, please specify below _____</p> <p>_____</p> <p>_____</p>
5	<p>How often do you consume fresh blueberries?</p> <p>Less than 1 time per week _____</p> <p>1-2 times per week _____</p> <p>3-4 times per week _____</p> <p>5-7 times per week _____</p>
6	<p>I like to consume fresh blueberries because they: (Select <u>ONLY TWO MOST IMPORTANT REASONS TO YOU</u>)</p> <p>Taste good _____</p> <p>Are full of flavor _____</p> <p>Have health benefits _____</p> <p>(ex: contains fiber, vitamin C, antioxidants, anthocyanins)</p> <p>Are easy to eat and/or prepare _____</p> <p>Help with weight control _____</p> <p>Other, please specify below _____</p> <p>_____</p> <p>_____</p>

7	<p>Please mark the following as it pertains to your fresh blueberry consumption.</p> <p>Able to eat 'all' blueberries purchased before they are no longer desirable or 'go bad' ___ Agree ___ Disagree</p> <p>Able to eat 'most' blueberries purchased before they are no longer desirable or 'go bad' ___ Agree ___ Disagree</p> <p>Often have issues or problems with storing fresh blueberries before consumption ___ Agree ___ Disagree</p>
8	<p>Are you satisfied with your present consumption of fresh blueberries?</p> <p>Yes _____</p> <p>No _____</p> <p>Please explain your choice:</p> <p>_____</p> <p>_____</p>

THANK YOU FOR YOUR PARTICIPATION!

Date: June 14, 2018

Consumer #: _____

Please answer all questions. All your answers will be kept confidential

1	<p>If you knew that the fresh blueberries you are purchasing are higher in <u>anthocyanins</u>:</p> <p>a. Would you be willing to pay more?</p> <p>Yes _____</p> <p>No _____</p> <p>If yes, by how much more average retail price (approximately \$4.50/pound)?</p> <p>_____</p> <p>b. Would you buy more fruit than you normally would?</p> <p>Yes _____</p> <p>No _____</p> <p>If yes, by how much more than you usually purchase? (Check one)</p> <table><tr><td>10% more</td><td>_____</td><td>2 times more</td><td>_____</td></tr><tr><td>25% more</td><td>_____</td><td>2.5 times more</td><td>_____</td></tr><tr><td>50% more</td><td>_____</td><td>3 times more</td><td>_____</td></tr><tr><td>75% more</td><td>_____</td><td>Other, please specify</td><td>_____</td></tr></table>	10% more	_____	2 times more	_____	25% more	_____	2.5 times more	_____	50% more	_____	3 times more	_____	75% more	_____	Other, please specify	_____
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50% more	_____	3 times more	_____														
75% more	_____	Other, please specify	_____														

2	<p>If you knew that the fresh blueberries you are purchasing are higher in <u>antioxidants</u>:</p> <p>a. Would you be willing to pay more?</p> <p>Yes _____</p> <p>No _____</p> <p>If yes, by how much more average retail price (approximately \$4.50/pound)?</p> <p>_____</p> <p>b. Would you buy more fruit than you normally would?</p> <p>Yes _____</p> <p>No _____</p> <p>If yes, by how much more than you usually purchase? (Check one)</p> <table border="0"> <tr> <td>10% more</td> <td>_____</td> <td>2 times more</td> <td>_____</td> </tr> <tr> <td>25% more</td> <td>_____</td> <td>2.5 times more</td> <td>_____</td> </tr> <tr> <td>50% more</td> <td>_____</td> <td>3 times more</td> <td>_____</td> </tr> <tr> <td>75% more</td> <td>_____</td> <td>Other, please specify</td> <td>_____</td> </tr> </table>	10% more	_____	2 times more	_____	25% more	_____	2.5 times more	_____	50% more	_____	3 times more	_____	75% more	_____	Other, please specify	_____
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25% more	_____	2.5 times more	_____														
50% more	_____	3 times more	_____														
75% more	_____	Other, please specify	_____														
3	<p>If you knew that the fresh blueberries you are purchasing are higher in <u>dietary fiber</u>:</p> <p>a. Would you be willing to pay more?</p> <p>Yes _____</p> <p>No _____</p> <p>If yes, by how much more average retail price (approximately \$4.50/pound)?</p> <p>_____</p> <p>b. Would you buy more fruit than you normally would?</p> <p>Yes _____</p> <p>No _____</p> <p>If yes, by how much more than you usually purchase? (Check one)</p> <table border="0"> <tr> <td>10% more</td> <td>_____</td> <td>2 times more</td> <td>_____</td> </tr> <tr> <td>25% more</td> <td>_____</td> <td>2.5 times more</td> <td>_____</td> </tr> <tr> <td>50% more</td> <td>_____</td> <td>3 times more</td> <td>_____</td> </tr> <tr> <td>75% more</td> <td>_____</td> <td>Other, please specify</td> <td>_____</td> </tr> </table>	10% more	_____	2 times more	_____	25% more	_____	2.5 times more	_____	50% more	_____	3 times more	_____	75% more	_____	Other, please specify	_____
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50% more	_____	3 times more	_____														
75% more	_____	Other, please specify	_____														

4	<p>If you knew that the fresh blueberries you are purchasing are higher in <u>vitamin C</u>:</p> <p>a. Would you be willing to pay more?</p> <p style="padding-left: 40px;">Yes _____</p> <p style="padding-left: 40px;">No _____</p> <p style="padding-left: 40px;">If yes, by how much more average retail price (approximately \$4.50/pound)?</p> <p style="padding-left: 40px;">_____</p> <hr/> <p>b. Would you buy more fruit than you normally would?</p> <p style="padding-left: 40px;">Yes _____</p> <p style="padding-left: 40px;">No _____</p> <p style="padding-left: 40px;">If yes, by how much more than you usually purchase? (Check one)</p> <table style="width: 100%; border: none;"> <tr> <td style="padding-left: 40px;">10% more _____</td> <td style="padding-left: 40px;">2 times more _____</td> </tr> <tr> <td style="padding-left: 40px;">25% more _____</td> <td style="padding-left: 40px;">2.5 times more _____</td> </tr> <tr> <td style="padding-left: 40px;">50% more _____</td> <td style="padding-left: 40px;">3 times more _____</td> </tr> <tr> <td style="padding-left: 40px;">75% more _____</td> <td style="padding-left: 40px;">Other, please specify _____</td> </tr> </table>	10% more _____	2 times more _____	25% more _____	2.5 times more _____	50% more _____	3 times more _____	75% more _____	Other, please specify _____
10% more _____	2 times more _____								
25% more _____	2.5 times more _____								
50% more _____	3 times more _____								
75% more _____	Other, please specify _____								

THANK YOU FOR YOUR PARTICIPATION!

Date: August 23, 2018

Consumer #: _____

Below are some questions about your blueberry eating habits.

1	<p>Do you eat other fruits while eating blueberries?</p> <p style="padding-left: 40px;">Yes _____</p> <p style="padding-left: 40px;">No _____</p>
---	--

2	<p>If <u>YES</u> to Question 1, which other fruits do you eat with blueberries? (Check-all-that-apply)</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">Apples _____</td> <td style="width: 50%;">Mangoes _____</td> </tr> <tr> <td>Oranges/Mandarins _____</td> <td>Strawberries _____</td> </tr> <tr> <td>Bananas _____</td> <td>Raspberries _____</td> </tr> <tr> <td>Grapes _____</td> <td>Pineapple _____</td> </tr> <tr> <td>Peaches _____</td> <td>Citrus _____</td> </tr> <tr> <td>Blueberries _____</td> <td>Pomegranates _____</td> </tr> <tr> <td>Melons _____</td> <td>Cherries _____</td> </tr> <tr> <td>Blackberries _____</td> <td><i>Other</i> _____</td> </tr> </table>	Apples _____	Mangoes _____	Oranges/Mandarins _____	Strawberries _____	Bananas _____	Raspberries _____	Grapes _____	Pineapple _____	Peaches _____	Citrus _____	Blueberries _____	Pomegranates _____	Melons _____	Cherries _____	Blackberries _____	<i>Other</i> _____
Apples _____	Mangoes _____																
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Bananas _____	Raspberries _____																
Grapes _____	Pineapple _____																
Peaches _____	Citrus _____																
Blueberries _____	Pomegranates _____																
Melons _____	Cherries _____																
Blackberries _____	<i>Other</i> _____																
3	<p>Do you prefer to eat blueberries by pairing them with another food item?</p> <p>Yes _____</p> <p>No _____</p>																
4	<p>If <u>YES</u> to Question 3, which other food products do you pair with blueberries or that contain blueberries? (Check-all-that-apply)</p> <p>Cereals, oatmeal, granola _____</p> <p>Baked goods (cobbler, muffins, scones, pies, etc.) _____</p> <p>Dairy products (milk, yogurt, cream, ice cream, etc.) _____</p> <p>Salads _____</p> <p>Nuts _____</p> <p>Other, please specify: _____</p>																
5	<p>Do you prefer to eat blueberries by pairing them with a protein source?</p> <p>Yes _____</p> <p>No _____</p>																

6	<p>If <u>YES to Question 5</u>, with which protein sources do you pair blueberries? (Check-all-that-apply)</p> <p>Beef _____</p> <p>Chicken _____</p> <p>Pork, ham _____</p> <p>Fish _____</p> <p>Shellfish _____</p> <p>Tofu _____</p> <p>Other, please specify: _____</p> <p>Please describe how you prepare the blueberries that you use with a protein source:</p> <p>_____</p>
7	<p>Do you drink beverages that contain blueberries or that have blueberry flavor?</p> <p>Yes _____</p> <p>No _____</p>
8	<p>If <u>YES to Question 7</u>, which beverages have you consumed before that are made with or that have blueberries or blueberry flavor (Check-all-that-apply)</p> <p>Tea _____</p> <p>Flavored Milk _____</p> <p>Kombucha _____</p> <p>Smoothie _____</p> <p>Wine _____</p> <p>Alcoholic beverages (rum, vodka, liqueurs) _____</p> <p>Other, please specify: _____</p>

9	When eating blueberries, do you prefer the appearance of the fruit to have a: Deep blue, almost black color _____ Shade of light blue _____ Soft, cloudy white coating _____ Dark blue outside and inside _____ Dark blue outside and pale inside _____		
10	Which blueberry flavors do you see as <u>POSITIVE</u>? (Check-all-that-apply)		
	Fruity flavor <input type="checkbox"/>	Bold and intense blueberry flavor <input type="checkbox"/>	Complex flavor with a hint of bitter <input type="checkbox"/>
	So sweet, no sugar needed <input type="checkbox"/>	Tart berry that wakes the taste buds <input type="checkbox"/>	Mild Flavor, but compliments well <input type="checkbox"/>
11	Which blueberry flavors do you see as <u>NEGATIVE</u>? (Check-all-that-apply)		
	Fruity flavor <input type="checkbox"/>	Bold and intense blueberry flavor <input type="checkbox"/>	Complex flavor with a hint of bitter <input type="checkbox"/>
	So sweet, no sugar needed <input type="checkbox"/>	Tart berry that wakes the taste buds <input type="checkbox"/>	Mild flavor, but compliments well <input type="checkbox"/>

THANK YOU FOR YOUR PARTICIPATION!

APPENDIX E

CONSENT FORM OF 2019 CONSUMER TESTS

Researcher's Statement

I am asking you to take part in a research study that is funded by the Georgia Agricultural Commodity Commission for Blueberries and the Southern Region Small Fruit Consortium. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. This form is designed to give you the information about the study so you can decide whether to be in the study or not. Please take the time to read the following information carefully. Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, you can decide if you want to be in the study or not. This process is called "informed consent." A copy of this form will be given to you. Your involvement in the study is voluntary, and you may choose not to participate or to stop at any time without penalty or loss of benefits to which you are otherwise entitled.

Principal Investigator/Researcher Information

Koushik Adhikari (770-412-4736, koushik7@uga.edu), Department of Food Science and Technology, University of Georgia, 1109 Experiment St., Griffin, GA 30223.

Purpose and Benefits of the Study

The purpose of the study is to gather sensory information on consumer opinions of fresh blueberry samples. Although there are no direct benefits for you, this information will help Georgia blueberry growers to market their produce more effectively to consumers. This will also add to the body of knowledge related to blueberry research and food product development.

Study Procedures

This research study will be conducted on three times from May to August 2019. The test will last approximately one hour per session. If you agree to participate, you will be asked to evaluate 4-6 blueberry samples. Coded samples and the score sheets (ballots) will be placed in front of you. You will evaluate samples by tasting, and indicate your evaluation/opinion on the score sheets. You will be asked some demographic questions associated with the study as well. All procedures used in the study are standard sensory analysis methods as published in books, research articles etc.

Risks and Discomforts

Although the researchers have tried to avoid risks, you may feel that some questions/procedures that are asked of you might be stressful or upsetting. You do not have to answer anything you do not want to.

No other risks except for *food allergies* are anticipated from participating in this research study. However, because the food to be tested is known beforehand, the situation can normally be avoided. Please do not participate in the tests if you have any allergies towards peanuts and products containing peanuts. It is your responsibility to inform the researchers about your food allergies.

Please list any known food allergies that you have:

Blueberry Allergy Symptoms

<http://www.inflammation-repair.manchester.ac.uk/informall/allergenic-food/?FoodId=37>

An allergic response to blueberries usually occurs 5-15 minutes after consumption and can range from mild to severe.

Mild blueberry allergy signs and symptoms can include:

- Redness and swelling of the lips
- Itching or tingling in or around the mouth and throat
- Inflammation in the mouth and/or throat
- Relapse can occur 15 to 60 minutes after initial symptoms

More severe blueberry allergy symptoms include:

- Rash of itchy round, red welts on the skin (urticaria), may have swelling
- Abdominal pain or burning, cramps
- Vomiting and/or diarrhea

Anaphylaxis: A life-threatening reaction

Anaphylaxis is a life-threatening medical emergency that requires treatment with an epinephrine (adrenaline) injector (EpiPen, Twinject) and a trip to the emergency room.

Although a rare reaction in response to blueberry consumption,

Anaphylaxis signs and symptoms can include all of the above, plus:

- Constriction of airways
- Swelling of your throat that makes it difficult to breathe
- A decrease in blood pressure (shock)
- Rapid pulse
- Dizziness, lightheadedness or loss of consciousness

Other life threatening reactions such as severe asthma attack or glottis oedema are rarely observed.

Seek immediate medical attention if you display symptoms of blueberry allergy

Incentives for participation

On completion of each session (45 minutes; 3 weeks apart, 5 sessions total), you will be paid a monetary incentive of **\$10**. You will have to provide your name and mailing address on a separate payment sheet for audit purposes before receiving the money.

If you are injured by this research

The researchers will exercise all reasonable care to protect you from harm as a result of your participation. In the event that any research-related activities result in an injury, the sole responsibility of the researchers will be to arrange for your transportation to an appropriate health care facility. If you think that you have suffered a research-related injury, you should seek immediate medical attention and then contact Koushik Adhikari right away at 770-412-4736. In the event that you suffer a research-related injury, your medical expenses will be your responsibility or that of your third-party payer, although you are not precluded from seeking to collect compensation for injury related to malpractice, fault, or blame on the part of those involved in the research.

APPENDIX F

BALLOTS OF 2019 CONSUMER TESTS

Session Time:	Date:	Consumer Number:
---------------	-------	------------------

INSTRUCTIONS

- You will taste # fresh blueberry samples in this session. You will receive the samples one by one.
- Make sure that the 3-digit sample number on the sample cup matches the 3-digit sample number on your ballot.
- For each sample, please taste the sample and answer the questions.
- Please drink some water in between samples to rinse your mouth.
- There is a set of demographic questions after the last sample. Please make sure you complete them before you leave.
- If you have any question at any time, push **'HELP'** button on the booth and someone will come to help you.

You received an Index Card at the Check-in.
Please write down the number from the Index Card.

Index card No.:

###

Blueberry Questionnaire

LOOKING at the sample in front of you, please answer the following questions:

1. Please rate how much you like/dislike the **COLOR** of this sample.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like it extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. Please rate how much you like/dislike the **FRUIT SIZE** of this sample.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like it extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Please **SMELL** this sample **at least 3 times**, and then answer the following question:

3. Mark the box that best describes how much you like/dislike the **AROMA** of this sample.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like it extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Please **TASTE** 3 or more sample berries and answer the following questions:

4. Please rate how much you like/dislike the **OVERALL FLAVOR** of this sample.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like it extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5. Please rate how much you like/dislike the **SWEETNESS** for this sample.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like it extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

6. Please rate how much you like/dislike the **ACIDITY** for this sample.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like it extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

7. Please rate how much you like/dislike the **OVERALL TEXTURE** of this sample.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like it extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

8. Please rate how much you like/dislike the **FRUIT FIRMNESS** for this sample.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like it extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

9. Please rate how much you like/dislike the **BLUEBERRY SKIN TOUGHNESS** for this sample.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like it extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

10. Please rate how much you like/dislike the **GRITTINESS/GRAININESS** for this sample.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like it extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

11. Please rate how much you like/dislike the **SEEDINESS** for this sample.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like it extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

12. Please rate your **OVERALL LIKING** of this sample.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like it extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

13. Please select the words that best describe the attributes you **LIKE** in this blueberry sample. (You can check as many as you would like)

<input type="checkbox"/> Fruity flavor	<input type="checkbox"/> Sweet/tart balance	<input type="checkbox"/> Juiciness	<input type="checkbox"/> Chewiness
<input type="checkbox"/> Crispy/pops in mouth	<input type="checkbox"/> Mealiness	<input type="checkbox"/> Smooth texture	<input type="checkbox"/> Very sweet, no sugar needed

14. Please select the words that best describe the attributes that you **DISLIKE** in this blueberry sample. (You can check as many as you would like)

<input type="checkbox"/> Fruity flavor	<input type="checkbox"/> Sweet/tart balance	<input type="checkbox"/> Juiciness	<input type="checkbox"/> Chewiness
<input type="checkbox"/> Crispy/pops in mouth	<input type="checkbox"/> Mealiness	<input type="checkbox"/> Smooth texture	<input type="checkbox"/> Very sweet, no sugar needed

15. How likely are you to consume this sample a second time?

Extremely Unlikely				Moderate				Extremely Likely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

16. If you knew that this sample was higher in nutritional compounds than other blueberries (anthocyanins, antioxidants, vitamin C, dietary fiber etc.), how likely would you be to consume this sample a second time?

Extremely
Unlikely

Moderate

Extremely Likely

A horizontal Likert scale consisting of nine empty rectangular boxes for rating the likelihood of consuming the sample a second time.

APPENDIX G

DEMOGRAPHIC QUESTIONNAIRE OF 2019 CONSUMER TESTS

Demographic Questions

1. Which of the following describes your age group?

18-24 years old

25-34 years old

35-44 years old

45-54 years old

55-65 years old

66+ years old

2. What is your gender?

Male

Female

3. Please mark the category that best represents your race/ethnicity.

White/Caucasian

Black/African American

Hispanic/Latino

Asian

Pacific Islander

Other

4. How many adults and children are in your household?

Please check the choice first, and put the number related with your choice in the box.

Self

Two adults

Two or more adults

Children under 18

Children under 10

Children under 2

5. Please mark the category that best represents your household income before taxes in 2018?

less than \$25,000

\$25,000 to \$49,999

\$50,000 to \$75,999

\$76,000 to \$99,999

\$100,000 to \$149,999

\$150,000 and greater

6. What is your education level?

- Some high school
- High school degree
- Some college
- College degree
- Some graduate study
- Graduate degree

Date: May 9, 2019

Consumer #: _____

Blueberry purchasing questionnaire

1. How often do you purchase fresh fruit?

- Once a week
- Twice a month
- Once a month or less

2. On average, how much do you typically spend per grocery purchase on fresh fruit for your household?

- \$0 - \$5
- \$6 - 10
- \$11 - 15
- \$16 - 20
- \$21 and above

3. How often do you eat fresh fruit?

- Two or more times daily
- At least once daily
- At least three times or more per week
- At least twice per week
- Rarely

4. When are you most likely to purchase fresh blueberries? (Check all that apply)





- | | | | |
|------------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| <input type="checkbox"/> January | <input type="checkbox"/> February | <input type="checkbox"/> March | <input type="checkbox"/> April |
| <input type="checkbox"/> May | <input type="checkbox"/> June | <input type="checkbox"/> July | <input type="checkbox"/> August |
| <input type="checkbox"/> September | <input type="checkbox"/> October | <input type="checkbox"/> November | <input type="checkbox"/> December |

5. What do you look for, when purchasing fresh blueberries? (Check all that apply)

- | | | | |
|--|--|---|--------------------------------------|
| <input type="checkbox"/> Cost | <input type="checkbox"/> Shape/size | <input type="checkbox"/> Color | <input type="checkbox"/> Firmness |
| <input type="checkbox"/> Organic | <input type="checkbox"/> Locally grown | <input type="checkbox"/> Damage/defect free | <input type="checkbox"/> Storability |
| <input type="checkbox"/> Nutritional value | <input type="checkbox"/> Aroma | <input type="checkbox"/> Flavor | |

6. When purchasing fresh blueberries, what size container do they come in and how many do you purchase at once? (Check all that apply)

Please select the size container(s), and then type how many you usually purchase, at once, in the comments.

- | | | | |
|--|--|---|---|
| <input type="checkbox"/>

4-6oz clamshell
<input type="text"/> | <input type="checkbox"/>

11oz clamshell (1 pint)
<input type="text"/> | <input type="checkbox"/>

16-18oz clamshell
<input type="text"/> | <input type="checkbox"/>

24oz - 2lb clamshell
<input type="text"/> |
|--|--|---|---|

7. Which of the following terms have you come across in regards to blueberries? (Check all that apply)

- Highbush
- Rabbiteye
- Wild
- Lowbush
- High-low bush
- None of the above

Thank you for completing this test!
Please Click on ‘Finish’ Button at the bottom of the computer screen to upload your answers.
Then, press the ‘Done’ button to notify the server.
Do not leave, until the server returns your index card.
Please remember to take your index card and spit cup!

Date: May 23, 2019

Consumer #: _____

Blueberry marketing questionnaire

1. Where do you typically buy your fresh fruit from?

- Supercenter chain store
- Local commercial grocery store
- Farmers market
- Roadside stand
- Pick-your-own
- Mom and pop grocery store
- I grow my own

2. What features do you like about the place where you buy your fruit from? (Check all that apply)

Convenient location

Quality of its fruit

Variety of fruit available

Helpfulness of grocery store staff

Low prices

3. Which of the following attribute(s) do you look for when buying fresh fruit? (Check all that apply)

Locally grown "Georgia grown" sticker Organic Sustainable

Free of pesticides Hand-harvested Mechanically-harvested None

4. When buying fruit, how often do you read the stickers and/or labels to find out where the fruit were grown?

Always

Frequently

Sometimes

Seldom

Never

5. What do you define as locally grown fruit? Fruit grown in...

State of Georgia Southeast region of the US East coast United States

6. If you had more access to locally grown fruit at the grocery store, would you be more willing to buy them?

<input type="radio"/> Yes <input type="text"/>	<input type="radio"/> No <input type="text"/>
---	--

7. During the blueberry harvest season, how interested are you in buying locally grown blueberries?

<input type="radio"/> Very interested
<input type="radio"/> Somewhat interested
<input type="radio"/> Not very interested
<input type="radio"/> Not at all interested

8. How important is the place where blueberries are grown?

<input type="radio"/> Very important
<input type="radio"/> Somewhat important
<input type="radio"/> Not very important
<input type="radio"/> Not at all important

9. Would you be willing to buy more blueberries if you knew you were buying locally grown blueberries?

<input type="radio"/> Yes
<input type="radio"/> No

If you answered YES to question 9, please answer question 10. If you answered NO to question 9, please skip question 10.

10. How much more blueberries would you be willing to buy?

10% more

25% more

50% more

75% more

100% more

Thank you for completing this test!
Please Click on ‘Finish’ Button at the bottom of the computer screen to upload your answers.
Then, press the ‘Done’ button to notify the server.
Do not leave, until the server returns your index card.
Please remember to take your index card and spit cup!

Date: June 13, 2019

Consumer #: _____

Blueberry pairing questionnaire

1. Do you eat OTHER fruit while eating blueberries?

Yes

No

If you answered YES to question 1, please move on to question 2. If you answered NO skip question 2 and move to question 3.

2. Which OTHER fruit do you eat with blueberries (Check-all-that-apply)

<input type="checkbox"/> Apples	<input type="checkbox"/> Raspberries
<input type="checkbox"/> Oranges/Mandarins	<input type="checkbox"/> Blackberries
<input type="checkbox"/> Citrus	<input type="checkbox"/> Mangoes
<input type="checkbox"/> Bananas	<input type="checkbox"/> Pineapples
<input type="checkbox"/> Peaches	<input type="checkbox"/> Pomegranates
<input type="checkbox"/> Cherries	<input type="checkbox"/> Melons
<input type="checkbox"/> Grapes	<input type="checkbox"/> Others, please specify <input type="text"/>
<input type="checkbox"/> Strawberries	

3. Do you eat OTHER food products (breakfast cereal, cobbler, jams, yogurt), with blueberries and/or contain blueberries (fresh, frozen, dried)?

<input type="radio"/> Yes
<input type="radio"/> No

If you answered YES to question 3, please move on to question 4. If you answered NO skip question 4 and move to question 5.

4. Which other food product(s) do you eat with and/or contain blueberries? (Check-all-that-apply)

<input type="checkbox"/>	Breakfast cereals, oatmeal, granola
<input type="checkbox"/>	Baked goods (cobbler, cakes, muffins, scones, pies, pancakes, waffles)
<input type="checkbox"/>	Dairy products (yogurt, cream cheese, pudding, ice cream)
<input type="checkbox"/>	Preserves (jam, jelly, marmalade)
<input type="checkbox"/>	Salads
<input type="checkbox"/>	Trail mix and nuts (walnuts, almonds, pecan, pistachios, cashews)
<input type="checkbox"/>	Others, please specify: <input type="text"/>

5. Do you drink beverages that contain blueberries or have blueberry flavor?

<input type="radio"/>	Yes
<input type="radio"/>	No

If you answered **YES** to question 5, please move on to question 6. If you answered **NO** skip question 6 and move to question 7

6. Which beverage(s) do you drink that are made with blueberries and/or have blueberry flavor? (Check-all-that-apply)

<input type="checkbox"/>	Tea	<input type="checkbox"/>	Kombucha	<input type="checkbox"/>	Flavored milk	<input type="checkbox"/>	Smoothie
<input type="checkbox"/>	Kefir	<input type="checkbox"/>	Yogurt drinks	<input type="checkbox"/>	Wine	<input type="checkbox"/>	Hard lemonade, cider, liqueur
<input type="checkbox"/>	Flavored distilled spirits (rum, gin, vodka)	<input type="checkbox"/>	Others, please specify <input type="text"/>				

7. **Blueberry sauces and preserves have been incorporated in savory dishes that include protein sources (meats, shellfish, tofu). Would you be interested in trying blueberry sauces/preserves with a protein source?**

Yes

No

If you answered **YES** to question 7, please move on to question 8. If you answered **NO** skip question 8 and move to question 9.

8. **Which protein source(s) do you think you would be interested in eating with a blueberry food product? (Check-all-that-apply)**

Beef

Chicken

Pork

Fish

Shellfish (crab, crayfish, lobster, shrimp)

Tofu

Others, please specify:

9. **When looking at blueberries, do you prefer them to be:**

Deep blue, almost black

A shade of light blue

White, waxy skin

Dark blue outside and inside

Dark blue outside and pale inside

10. Which blueberry flavors do you see as POSITIVE? (Check-all-that-apply)

Fruity flavor

Bold and intense blueberry flavor

Complex flavor with a hint of bitter

So sweet, no sugar needed

Tart berry that wakes the taste buds

Mild flavor, but compliments well

11. Which blueberry flavors do you see as NEGATIVE? (Check-all-that-apply)

Fruity flavor

Bold and intense blueberry flavor

Complex flavor with a hint of bitter

So sweet, no sugar needed

Tart berry that wakes the taste buds

Mild flavor, but compliments well

Thank you for completing this test!
Please Click on 'Finish' Button at the bottom of the computer screen to upload your answers.
Then, press the 'Done' button to notify the server.
Do not leave, until the server returns your index card.
Please remember to take your index card and spit cup!

Date: August 22, 2019

Consumer #: _____

Blueberry nutrition questionnaire

1. I eat fresh fruit because they: (Check-all-that-apply)

Promote a healthy lifestyle

Provide a balanced diet

Are a good source of vitamins

Are tasty

Other(s), please specify:

2. How often do you look for information about health benefits of fruits?

Never

Rarely

Every once in a while

Sometimes

Almost always

3. **How interested are you in health benefits of blueberries?**

Not at all interested

Slightly interested

Somewhat interested

Very interested

Extremely interested

4. **What ways of communication would help you become more interested in blueberry health benefits? (Check-all-that-apply)**

<input type="checkbox"/> Paper ads (magazine and newspapers)	<input type="checkbox"/> Grocery stores giving away samples and personnel telling you about blueberry health benefits
<input type="checkbox"/> Social media ads (Facebook, Instagram, Twitter, Pinterest)	<input type="checkbox"/> Farmer markets and blueberry stands
<input type="checkbox"/> Music station ads (Pandora, Youtube, Spotify, radio)	<input type="checkbox"/> I'm not interested in blueberry health benefits
<input type="checkbox"/> Blueberry packaging labeled with health benefits	<input type="checkbox"/> Other(s), please specify: <input type="text"/>
<input type="checkbox"/> Overview cards in supermarkets with health benefits	

Please carefully read the statement below and answer the following questions.



A superfood is rich in antioxidants, fiber or fatty acids and is considered beneficial to a person's health.

Reasons why blueberries have been recognized as a superfood:

- Low in calories (80 calories per cup)
- High amount of fiber, vitamins, minerals and antioxidants
- May help protect against aging, certain cancers, cholesterol and heart disease
- May lower blood pressure, accelerate muscle recovery and help improve memory and brain functionality

5. After reading this information, how interested are you in health benefits of blueberries?

Not at all interested

Slightly interested

Somewhat interested

Very interested

Extremely interested

6. Which blueberry nutrients and their health benefits would you be interested in? (Check-all-that-apply)

Fiber (may reduce type 2 diabetes and improve weight loss)

Vitamins (may improve bone health and metabolism)

Minerals (may reduce inflammation and improve blood sugar regulation)

Antioxidants (may lower blood pressure and reduce skin aging)

Others, please specify

7. After reading this information, would you be willing to buy more blueberries than you normally would?

Yes

No

If you answered YES to question 7, please move on to question 8. If you answered NO skip question 8. You have now completed the taste test.

8. How much more blueberries would you be willing to buy?

25% more

50% more

75% more

100% more

Anthocyanins give fruit their blue, purple, and red color.

Their health benefits include:

- May reduce the risk of **obesity and type 2 diabetes**
- May promote general **eye health**
- May reduce the risk of **heart diseases**

9. If you knew that the fresh blueberries were higher in **anthocyanins**, would you be willing to pay **more**?

Yes

No

If you answered 'YES', continue with question 10. If you answered 'NO' please move to question 11.

10. How much **more** would you be willing to pay (approximately \$4.50/pound for current fresh blueberries)?

25% more

50% more

75% more

100% more

11. If you knew that the fresh blueberries were higher in ***anthocyanins***, would you be willing to buy **more**?

Yes

No

If you answered ‘YES’, continue to question 12. If you answered ‘NO’ please move to question 13.

12. How much **more** would you be willing to buy that you usually do?

25% more

50% more

75% more

100% more

Antioxidants are found naturally in fruit.

Their health benefits include:

- May promote brain health
- May lower blood pressure levels
- May lower cholesterol levels
- May reduce skin aging

13. If you knew that the fresh blueberries were higher in antioxidants, would you be willing to pay more?

Yes

No

If you answered 'YES', continue to question 14. If you answered 'NO' please move to question 15.

14. How much more would you be willing to pay (approximately \$4.50/pound for current fresh blueberries)?

25% more

50% more

75% more

100% more

15. If you knew that the fresh blueberries were higher in antioxidants, would you be willing to buy more?

Yes

No

If you answered 'YES', continue with question 16. If you answered 'NO' please move to question 17.

16. How much **more** would you be willing to buy that you usually do?

25% more

50% more

75% more

100% more

Dietary fiber are parts of fruit that are not digested or absorbed by the body. Recommended human **daily dietary fiber** intake is about **25-30** grams a day. One cup of **blueberries** is about **16%** of your daily dietary fiber!

Their health benefits include:

- May help with **weight loss** and healthy **weight maintenance**
- May promote a better **digestive health**
- May lower **cholesterol**
- May reduce the risk of **type 2 diabetes**

17. If you knew that the fresh blueberries were higher in **dietary fiber**, would you be willing to pay **more**?

Yes

No

If you answered 'YES', continue to question 18. If you answered 'NO' please move to question 19.

18. How much **more** would you be willing to pay (approximately \$4.50/pound for current fresh blueberries)?

25% more

50% more

75% more

100% more

19. If you knew that the fresh blueberries were higher in ***dietary fiber***, would you be willing to buy **more**?

Yes

No

If you answered 'YES', continue to question 20. If you answered 'NO' please move to question 21.

20. How much **more** would you be willing to buy that you usually do?

25% more

50% more

75% more

100% more

Vitamin C is found in numerous fruit.

Their health benefits include:

- **May promote bone health**
- **May assist with collagen production**
- **May assist with certain cancer protection**

21. If you knew that the fresh blueberries were higher in **vitamin C**, would you be willing to pay **more**?

Yes

No

If you answered ‘YES’, continue with question 22. If you answered ‘NO’ please move to question 23.

22. How much **more** would you be willing to pay (approximately \$4.50/pound for current fresh blueberries)?

25% more

50% more

75% more

100% more

23. If you knew that the fresh blueberries were higher in **vitamin C**, would you be willing to buy **more**?

Yes

No

If you answered 'YES', continue with question 24. If you answered 'NO' you are finished with demographic questions.

24. How much **more** would you be willing to buy that you usually do?

25% more

50% more

75% more

100% more

Thank you for completing this test!

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APPENDIX H

EXAMPLE OF SERVING SEQUENCE FOR CONSUMER TESTS

‘Legacy’ GA: 742, ‘Vernon’: 239, ‘Premier’: 854, ‘Camellia’: 676.

Design title: Williams Design (1 Latin Square)

Design type: Quantitative Descriptive

Samples: 4

Presented: 4

Orders in Base Block: 4

Multiplier: 28

Total orders in design: 112

Number of sample sets in test: 110

Number of Session: 1

Consumer	1st	2nd	3rd	4th
dawg001	742	676	854	239
dawg002	854	742	239	676
dawg003	239	854	676	742
dawg004	676	239	742	854
dawg005	742	676	854	239
dawg006	854	742	239	676