Title of Project: Examining Postharvest Attributes of Fresh and Frozen Southern Highbush and Rabbiteye Blueberries in Georgia

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Objective:

The main objective of this project is to examine the postharvest fruit quality attributes of fresh and frozen southern highbush and rabbiteye cultivars commonly grown in Georgia. The goal of this project is to assess the possible variation of postharvest quality and to determine those metrics that would be best suited for analyzing elite germplasm from breeding programs. This will provide the blueberry industry with information on the potential differences between present cultivars of highbush and rabbiteye blueberries, as well as information about the potential improvements offered by new germplasm.

Description and Justification:

Blueberry Fruit Quality: Southern Highbush vs. Rabbiteye

In Georgia and in the southeastern US, two main types of blueberries are commercially grown: southern highbush (species complex between *Vaccinium corymbosum* L. and *V. darrowii* Camp) and rabbiteye (*V. virgatum* Aiton) blueberries. Within the US in 2012, the state of Georgia accounted for over 13% of US fresh fruit production ranking number four (37 million pounds), and accounted for over 12% of US processed fruit production ranking number five (33 million pounds) (USDA-ERS, 2013). In 2014, Georgia ranked number one in total harvested blueberry acreage in the US, accounting for over 20% of US harvested acreage (16,600 acres) and over 17% of total US metric tons (283,400 metric tons) (USDA-NASS, 2014). Due to harvest timing in the state and market timing within the US, highbush cultivars typically are sold on the fresh market and receive a higher price. A large portion of the rabbiteye market is sold as processed fruit. Frozen fruit is one of the main means of preparing and selling processed fruit within the state.

Often southern highbush fruit are perceived to have higher fruit quality characteristics as compared to rabbiteye fruit; however, evidence for this is inconclusive at best. Variations for firmness (compression test), soluble solid content, titratable acidity, sugar/acid ratio, pH, and the aromatic volatile concentration, were associated with cultivar differences, rather than species differences in several studies with highbush and rabbiteye cultivars (Saftner et al., 2008; Silva et al., 2005). Swift (2010) studied fresh and frozen highbush and rabbiteye fruit from different cultivars. Instrumental analyses were performed including puncture tests to examine skin toughness, and compression tests to examine berry firmness. Sensory panels were also conducted. Overall, toughness was not shown to increase with later season harvest intervals on a cultivar. Toughness was also not increased by frozen storage time (-14ºF), but did increase at the frozen storage temperature of 6ºF. The study concluded that the effect of cultivar has a larger significance than time, and that overall environmental variation has a large effect.

Numerous studies have examined the levels of beneficial health promoting compounds in blueberry fruit and berry fruits (Seeram, 2014). Most recently, Gündüz et al. (2014) examined the levels of some of the major beneficial compounds in fruit from rabbiteye and highbush cultivars. In one experiment within the overall study, there were significant differences observed between rabbiteye and southern highbush cultivars for soluble solids, total titratable acids, and total phenolic content. Differences were not observed between the two blueberry types for total antioxidant capacity, total anthocyanin content, and vitamin C levels. Although this study was very informative, it did not examine southern highbush varieties released from the UGA breeding program or advanced breeding selections.

Justification and Significance

Phenotypic variation within and among species for fruit quality characteristics is present as shown by previous research. However, no known reported studies have looked at a wide range of commercially known rabbiteye and highbush cultivars for textural quality traits, and their relationships to chemical quality traits. This project allows for the identification of possible differences within and among species for physical and chemical measurements, and for the identification of metrics most suitable for evaluating postharvest quality of elite germplasm selections. As blueberry is an important crop in Georgia and throughout the US, increased knowledge of the potential differences and similarities of fresh and frozen highbush and rabbiteye cultivar fruit quality would be beneficial for both the blueberry growers and the industry as a whole.

Methodologies:

During 2014, preliminary work looking at various postharvest attributes of fresh and frozen fruit of several southern highbush and rabbiteye cultivars was initiated in Georgia. The 2014 initial work continued into 2015, and this current 2015 project is continuing the initial work with a more complete data collection and analyses and includes a larger array of cultivars and some elite selections. For the 2015 season, genotypes are being evaluated using physical and chemical analyses performed in the 2014 season. The tests are being repeated to examine the presence or absence of year to year variability for the traits being tested. Studying the differences within and between years will strengthen overall conclusions drawn, and help in the elucidation of species and cultivar fruit quality rankings for fresh and frozen fruit. Multiple years tested will examine the repeatability of these rankings over different environments (as represented by years) for tests performed.

During the 2015 harvest season fruit was collected from several southern highbush cultivars: ‘Rebel’, ‘Star’, ‘Emerald’, ‘Farthing’, ‘Meadowlark’, ‘Legacy’, and ‘Camellia’; and additional advanced highbush selections: TH-1111, TH-1125, TH-917, TH-921, TH-944, and TH-948. Also fruit from several rabbiteye cultivars was collected as well: ‘Vernon’, ‘Alapaha’, ‘Brightwell’, ‘Krewer’, ‘Powderblue’, ‘Tifblue’, ‘Titan’, and ‘Ochlockonee’, ‘Premier’. Genotypes represent an array of fruit ripening times throughout the season (early, middle and late season ripening). Fruit from both southern highbush and rabbiteye were harvested when plants were approximately 50% ripe at the University of Georgia Blueberry Research Farm near Alapaha, GA from April to July. Fruit were harvested from multiple plants for each genotype and were placed in clamshells (200 to 250g per clamshell). Clamshells were packed in open plastic bags in coolers on ice and transported back to the Griffin campus, Griffin, GA.

Fresh fruit were held at approximately 4ºC overnight and until all initial tests are completed. Some of the fruit were frozen and held at -15ºC and are being tested again at one month, six months, and at approximately 12 months after freezing. An Instron universal testing machine (Model 1122, Instron Corp., Canton, MA) will be used to estimated puncture in (skin strength), and Kramer shear press (fruit firmness) as outlined in Silva et al., 2005. Berries were brought to room temperature of approximately 20ºC for one hour for the fresh samples. Frozen fruit are thawed at room temperature for two hours. For fresh samples, punctures were be run one to two days after harvest, and Kramer shear presses three to four days after harvest. These timelines are kept similar to the 2014 tests for consistency when comparing years. For frozen samples, each test is run for recently thawed berries. Tests are arranged in order of most to least sensitive. Twelve berries of similar size per plant per cultivar are used for puncture analyses, and two samples of 50.0+/-1.0g of berries are used for the Kramer Shear tests.

Additional southern highbush rabbiteye fruit were collected from commercial packers (Alma Pak in Alma, GA; and Naturipe in Alma, GA) in May through July to compare freezing methods. From Alma Pak, fruit for several rabbiteye cultivars were collected for fresh (F), individual quick frozen (IQF), and bulk frozen (B): ‘Brightwell’ (F,IQF,B), ‘Austin’ (F,IQF,B), ‘Premier’(F,IQF,B), ‘Alapaha’ (F,IQF,B), ‘Ochlockonee’(IQF,B), ‘Powderblue’(F,IQF,B), ‘Tifblue’(IQF,B), and ‘Vernon’ (F, IQF,B). Fruit were also collected for southern highbush cultivars for fresh (F), individual quick frozen (IQF), and bulk frozen (B): ‘Emerald’ (F,IQF,B), ‘Star’ (F), and ‘Farthing’ (F,IQF,B). From Naturipe, fruit for rabbiteye cultivars were collected for fresh (F), individual quick frozen (IQF), and bulk frozen (B): ‘Brightwell’ (F,IQF,B), ‘Premier’ (F,IQF,B), and ‘Alapaha’ (F,IQF,B). Fruit were also collected for southern highbush cultivars for individual quick frozen (IQF) and bulk frozen (B): ‘Emerald’ (IQF,B), and ‘Star’ (IQF,B). Fruit from commercial packers were packed in freezer bags and corrugated cardboard boxes, and were transported frozen packed on ice in coolers to the Griffin campus. Fresh, IQF and bulk frozen fruit are divided into three representative replicates per box at time of testing. Remaining frozen samples were analyzed with IQF and bulk frozen at one month, and will be again tested at six and approximately 12 month after freezing.

Six months frozen textural data are currently being collected for all samples. Twelve month frozen textural data will be collected spring/summer 2016. In addition to the above planned textural analyses, juice extracted from fruit will be measured for total soluble solids (ºBrix), pH, titratable acidity (TTA), anthocyanin content (cyanidin-3-glucoside equivalents in mg/L), sugar acid ratio, sugar profile, organic acid profile, and antioxidant profile. These tests will be run at the University of Georgia Agricultural and Environmental Services Lab in winter 2016. Frozen fruit will also be analyzed in winter 2016 for fiber traits (NDF and ADF) at the University of Georgia Agricultural and Environmental Services Lab. Lastly, frozen fruit will be examined for seed traits including number of plump and shriveled seed, total number of seed, seed weight (g), and percent seed weight/berry weight (g) spring/summer 2016.

Data are analyzed using the GLM procedure in SAS (v.9.4) to examine year, location, genotype, replicate, and type differences and interactions. Genotype differences within a location and test were examined using the Tukey HSD ($P \leq 0.05$) within the GLM procedure. PROC CORR is used to examine relationships of data across years.

Current Results:

Fresh fruit harvested in 2014 and 2015 from the UGA Blueberry Research Farm were examined for textural analyses examining max load (N) for skin strength (puncture in) and for fruit firmness (Kramer shear press). For both puncture and Kramer Shear tests, years were significantly different ($P \leq 0.05$) and there were significant interactions between genotype and year for both puncture and Kramer tests ($P<0.0001$) (Table 1). Data were then examined separately for year (Table 2).

For both puncture and Kramer Shear tests within each year, genotypes were significantly different ($P<0.0001$). For skin strength, there was no significant difference between SHB and REs in 2014 (1.005N vs. 1.002N, $P=0.86$), and SHB were significantly higher than REs in 2015 (1.020N vs. 0.855N, $P<0.0001$). For fruit firmness, REs were significantly higher than SHB in both 2014 (578.34N vs. 350.31N, $P<0.0001$) and 2015 (493.55N vs. 370.44N, $P<0.0001$) (Tables 2 and 3).

To examine if a similar trend existed between 2014 and 2015 data for puncture and Kramer shear tests, Pearson correlations were examined. For the puncture test, a similar trend existed across years within SHB genotypes (r=0.17, $P=0.003$), and across SHB and RE genotypes (r=0.14, $P=0.0008$). However, both correlations were weak. Within REs in 2014, no significant correlation existed between the 2014 and 2015 data (*P*=0.06). For the Kramer shear test, a similar trend existed across years within SHB genotypes (r=0.65, *P*<0.0001) and across SHB and RE genotypes (r=0.64, *P*<0.0001). A weak correlation also existed across years within RE genotypes (r=0.32 and *P*=0.04) for the Kramer shear test (Table 4).

Data for frozen texture, chemical quality components, fiber traits, and seed traits will be compared within 2015 fruit, and between 2014 and 2015 fruit, in a similar manner when 2015 data collection is completed.

Current Conclusions:

1. The fresh fruit results suggest that the puncture test (skin strength) and the Kramer shear test (fruit firmness) for the genotypes examined vary across years (Table 1).
2. There is a range for both skin strength and fruit firmness for fresh fruit across the genotypes examined in both 2014 and 2015 (Tables 2 and 3).
3. The results suggest that across all the genotypes examined, SHB and REs are not different for skin strength in 2014, but SHB are higher than REs for skin strength in 2015 (Tables 2 and 3).
4. The results suggest that across all the genotypes examined, the REs have firmer fresh fruit than do the SHB for both years (Tables 2 and 3).
5. Fresh fruit skin strength between genotypes across years was weakly correlated within the SHB genotypes, and within the SHB and RE combined genotypes. No correlation was observed within the RE genotypes across years for skin strength (Table 4).
6. Fresh fruit firmness between genotypes across years was moderately correlated within the SHB genotypes, and within the SHB and RE genotypes combined. A weak correlation existed for fruit firmness within RE genotypes across years (Table 4).

Impact Statement:

Georgia is a major player in the blueberry industry, and the varieties grown in the state are also grown throughout the Southeast. With large portions of the Southeastern blueberry market growing both southern highbush and rabbiteye varieties, perceived differences that may pit the varieties of one type against the other have the potential to negatively impact the production, marketing and sale of a major portion of the state's and region's commercial blueberry market. The current research results presented here, and data being collected, will enable the blueberry stakeholders (growers, producers, and marketers) to make informed decisions regarding variety selection for production and marketing. The results from this study will also help to protect against subjectively-based fruit quality opinions thereby helping to reduce the potential financial risk of producing varieties that may be perceived as lesser quality.

Citation(s) for any publications arising from this project:

Table 1. ANOVA of max load (N) for puncture and Kramer shear test for blueberry fruit harvested[a] from southern highbush (SHB) and rabbiteye (RE) genotypes[b] over the two harvest seasons, 2014 and 2015.

		Max Load N	
	df	Puncture, *P*-value	Kramer Shear, *P*-value
year	1	<.0001	0.0454
geno[c]	15	<.0001	<.0001
rep(geno)	32	0.2304	0.0001
geno*year	15	<.0001	<.0001
type[d]	1	<.0001	<.0001

[a] Fruit was harvested from UGA Blueberry Research Farm near Alapaha, GA.
[b] Seven RE genotypes: 'Vernon', 'Alapaha', 'Brightwell', 'Powderblue', 'Tifblue', 'Ochlockonee', 'Premier'; Nine SHB genotypes: 'Rebel', 'Star', 'Emerald', 'Farthing', 'Meadowlark', 'Legacy', 'Camellia', TH-1111, TH-1125.
[c] Three replicates per genotype were tested. Each replicate was composed of: 12 berries for puncture, and 2 subsamples of 50.0+/-1.0g berries for Kramer shear tests.
[d] Type compares SHB and RE genotypes.

Table 2. ANOVA of max load (N) for puncture and Kramer shear test for blueberry fruit harvested[a] from southern highbush (SHB) and rabbiteye (RE) genotypes[b] during the 2014 and 2015 seasons.

	2014 Max Load N			2015 Max Load N		
	df	Puncture, *P*-value	Kramer Shear, *P*-value	df	Puncture, *P*-value	Kramer Shear, *P*-value
geno[c]	15	<.0001	<.0001	22	<.0001	<.0001
rep(geno)	32	0.1702	<.0001	46	0.1327	0.0354
type[d]	1	0.8614	<.0001	1	<.0001	<.0001

[a] Fruit was harvested from UGA Blueberry Research Farm near Alapaha, GA.
[b] Seven RE genotypes: 'Vernon', 'Alapaha', 'Brightwell', 'Powderblue', 'Tifblue', 'Ochlockonee', 'Premier'; Nine SHB genotypes: 'Rebel', 'Star', 'Emerald', 'Farthing', 'Meadowlark', 'Legacy', 'Camellia', TH-1111, TH-1125.
[c] Three replicates per genotype were tested. Each replicate was composed of: 12 berries for puncture, and 2 subsamples of 50.0+/-1.0g berries for Kramer shear tests.
[d] Type compares SHB and RE genotypes.

Table 3. Skin strength (puncture) and fruit firmness (Kramer shear) of southern highbush (SHB) and rabbiteye (RE) genotypes harvested [a] during the 2014 and 2015 seasons.

		2014						2015					
		Puncture			Kramer			Puncture			Kramer		
Type	Geno	N[b]	Maxload N		N[c]	Maxload N		N[b]	Maxload N		N[c]	Maxload N	
SHB	Camellia	36	0.929	FDE[d]	6	312.93	GIH	36	0.934	FGIEH	6	270.07	KJ
	Emerald	36	0.915	FDE	6	353.20	GFH	36	0.826	IKHJ	6	320.02	HGJI
	Farthing	36	1.213	A	6	357.47	GF	35	1.253	A	6	440.02	C
	Legacy	35	1.139	BA	6	414.39	ED	36	1.014	FDEC	6	434.74	DC
	Meadowlark	36	0.966	FDEC	6	425.98	D	36	1.060	BDEC	6	467.14	C
	Rebel	36	0.795	F	6	285.36	I	36	0.873	FGIHJ	6	306.05	JI
	Star	36	0.939	FDE	6	303.53	IH	35	1.029	FDEC	6	317.82	HJI
	Suziblue	---	---	---	---	---	---	36	1.164	BAC	6	332.56	HGFI
	TH-1111	36	1.242	A	6	334.89	GIFH	35	1.200	BA	6	432.40	DC
	TH-1125	36	0.903	FE	6	365.04	EF	36	1.105	BDAC	6	424.64	DCE
	TH-917	---	---	---	---	---	---	36	1.229	A	6	418.04	DCE
	TH-921	---	---	---	---	---	---	35	0.986	FGDEH	6	474.76	C
	TH-944	---	---	---	---	---	---	34	0.692	K	6	226.61	K
	TH-948	---	---	---	---	---	---	36	0.910	FGIEHJ	6	321.25	HGJI
RE	Alapaha	36	1.118	BAC	6	576.26	C	33	0.822	IKHJ	6	380.52	DFE
	Brightwell	36	1.079	BDAC	6	567.74	C	33	0.922	FGIEH	6	576.21	B
	Krewer	---	---	---	---	---	---	36	1.005	FGDEC	6	458.27	C
	Ochlockonee	36	0.954	FDEC	6	542.03	C	35	0.749	KJ	6	622.98	B
	Powderblue	36	1.140	BA	6	722.18	A	35	0.801	IKJ	6	708.04	A
	Premier	36	0.821	FE	6	417.49	D	35	0.690	K	6	377.37	DGFE
	Tifblue	36	0.929	FDE	6	555.09	C	34	0.839	GIKHJ	6	597.40	B
	Titan	---	---	---	---	---	---	35	1.039	FBDEC	6	353.56	HGFI
	Vernon	35	0.970	BDEC	6	667.58	B	34	0.823	IKHJ	6	367.61	HGFE
SHB		323	1.005	A	54	350.31	B	498	1.020	A	84	370.44	B
RE		251	1.002	A	42	578.34	A	310	0.855	B	54	493.55	A

[a] Fruit was harvested from UGA Blueberry Research Farm near Alapaha, GA.

[b] Three replicates per genotype were tested, each replicate was composed of 12 berries.

[c] Three replicates per genotype were tested, each replicate was composed of 2 subsamples of 50.0+/-1.0g berries.

[d] Differences examined using the Tukey HSD ($P \leq 0.05$).

Table 4. Pearson correlation coefficients (r) for skin strength (puncture) and fruit firmness (Kramer shear) in southern highbush (SHB) and rabbiteye (RE) genotypes[a] harvested[b] over the two seasons, 2014 and 2015.

	Puncture Max Load N			Kramer Max Load N		
	SHB	RE	SHB and RE	SHB	RE	SHB and RE
r	0.17	0.12	0.14	0.65	0.32	0.64
P-value	0.0029	0.0624	0.0008	<.0001	0.042	<.0001
n[c]	321	239	560	54	42	96

[a] Seven RE genotypes: 'Vernon', 'Alapaha', 'Brightwell', 'Powderblue', 'Tifblue', 'Ochlockonee', 'Premier'; Nine SHB genotypes: 'Rebel', 'Star', 'Emerald', 'Farthing', 'Meadowlark', 'Legacy', 'Camellia', TH-1111, TH-1125.
[b] Fruit was harvested from UGA Blueberry Research Farm near Alapaha, GA.
[c] Three replicates per genotype were tested. Each replicate was composed of: 12 berries for puncture, and 2 subsamples of 50.0+/-1.0g berries for Kramer shear tests.

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