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Physicochemical, carbohydrate and sensory characteristics of highbush and rabbiteye blueberry cultivars‡

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Abstract: The chemical composition, colour and texture of fresh berries from three rabbiteye ('Climax', 'Premier' and 'Tifblue') and two highbush ('Bluecrop' and 'Jersey') blueberry cultivars were measured. Shear (482 vs 290 N), compression (6.50 vs 3.96 N) and puncture forces (1.48 and 0.85 vs 0.81 and 0.43 N) were higher ($P \leq 0.05$) for rabbiteye than for highbush cultivars. Shear for 'Bluecrop' blueberries averaged 254 N, whereas for 'Climax' it was 565 N. The puncture force required to penetrate the skin was lower for 'Bluecrop' (0.78 N) and 'Jersey' (0.83 N) and higher for 'Climax' (1.71 N). However, sensory panellists found no differences ($P > 0.05$) in colour, flavour or skin toughness among the five cultivars. 'Climax' was rated lower in seediness. Rabbiteye cultivars contained more fibre and complex polysaccharides than highbush cultivars. These differences in complex carbohydrates that make up the cell wall layers may contribute to the toughness of rabbiteye cultivars and their possible longer fresh shelf-life, though taste panellists did not find this toughness objectionable.

Keywords: blueberry; highbush; rabbiteye; pectin; fibre; texture

INTRODUCTION

Rabbiteye blueberry plantings and production have been increasing in the southeastern region of the USA. Markets for the rabbiteye blueberry have expanded into the northern states where the new fruit is readily accepted. Although rabbiteye blueberries have higher yields than highbush blueberries, 9071 vs 6795 kg ha^{-1} (8000 vs 6000 lb acre^{-1}) respectively (Braswell J, personal communication), and better shelf-life, rabbiteye berries are perceived to be of inferior quality compared with highbush berries.[1]

Firmness has always been an important selection criterion, since firmer fruits withstand shipment to distant markets better than soft fruit.[2,3] Machine-harvested berries are reportedly softer and have a higher incidence of postharvest decay than hand-harvested berries.[4,5] The increasing conversion from hand to machine harvesting of blueberries by growers with large plantings or co-operatives, and the increasing shipment distances in the fresh blueberry market, could require the use of firmer fruits like the rabbiteye species to yield firmer and longer keeping quality berries.[5]

Many authors have published data on the physicochemical quality parameters of highbush[4,6,7] and rabbiteye[5,8–14] blueberries. However, none of these studies has identified the biochemical and physical differences, which appear to cause textural differences between rabbiteye and highbush berries. The objective of this study was to determine if there were any biochemical and physical differences that led to textural differences between rabbiteye and highbush blueberries.

MATERIALS AND METHODS

Three cultivars of rabbiteye (*Vaccinium ashei*) blueberries ('Climax', 'Premier' and 'Tifblue') were harvested

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in Mississippi (10–15 June) and two cultivars of highbush (*V corynbosum*) blueberries ('Bluecrop' and 'Jersey') were harvested in Michigan (1–3 July). Fresh market-grade, ripe blueberries were harvested and placed in 4 l unvented plastic buckets immediately after picking. The buckets were then placed in ice-chests with ice surrounding the buckets to the top. The blueberries were kept in the ice-chests at 5–6 °C for 48 h in a shaded and air-conditioned environment, draining and replacing the ice as needed, and the temperature of the fruits was monitored every 3 h. Highbush blueberries from Michigan were kept under the same conditions, since it took 48 h to transport them by truck to Mississippi for further analysis. After 48 h, half of the blueberries were placed in 0.067 mm polyethylene bags and quickly frozen at −55 °C for later analysis. The other half was used for analysis of fresh fruits. All cultivars were of similar plant age (6–8 years) and each cultivar was picked from three different locations (producers/replications). Since they do not ripen at the same time, picking times were different for all cultivars.

Fruit physical characteristics

Average diameter, height (stem scar to other end) and stem scar measurements were taken using a vernier calliper (Fisher Scientific, Memphis, TN, USA) with 0.1 cm sensitivity from 10 randomly selected berries from each cultivar and location (replication). Mass per unit berry was determined from the average mass of 100 berries.

Sensory evaluation

Three fresh blueberries from each cultivar, one from each location (replication), were evaluated by 10 trained panellists using a nine-point hedonic scale approximately 48 h after harvesting. Blueberries were rated on colour, skin toughness, seediness and flavour, where 1 = dislike extremely, 5 = neither like nor dislike and 9 = like extremely.

Colour

A Labscan model 6000 0/45° spectrocolorimeter (Hunter Associates Laboratory, Fairfax, VA, USA) was used to measure colour differences among cultivars. From each cultivar and replication, duplicates of 50 g of berries each were placed in a 59 mm inner diameter ×38 mm deep glass cup. The bottom part of the glass cup was placed on a 44 mm diameter port. Hunter colour was measured as L (brightness), a (redness+, greenness−) and b (yellowness+, blueness−). Further readings were taken on the same sample after rotating the cup 180°. Hue angle ($\tan^{-1}(b/a)$) and chroma ($SI = (a^2 + b^2)^2$) (Hunter Associates Laboratory) were calculated.

Texture

Puncture test

A given berry was placed on its side on a flat steel washer (1.5 mm thick, 38 mm diameter, 10 mm hole) in the centre of the load cell and punctured with a 2 mm diameter probe at a rate of 50 mm min^{-1} and a load range of 5 N. Since the puncture test is used to measure the skin strength of fruits,[15] skin toughness was determined by measuring the peak force required for the probe to penetrate the skin (puncture-in). Skin toughness was also measured by allowing the probe to go through the berry until puncturing the skin from inside out (puncture-out).

Compression test

Compression was measured separately on 10 different berries of approximately similar size as the force required to compress the berry with a 10 mm diameter cylindrical probe at a crosshead and chart speed of 50 mm min^{-1} until the berry began releasing juice. The load range was 5 N. This is a measurement of firmness. Both puncture and compression tests were performed using an Instron model 1011 universal testing instrument (Instron Co, Canton, MA, USA).

Shear test

Fruit firmness was measured using a Kramer shear press (Food Texture Corp, Rockville, MA, USA) with a crosshead speed of 100 mm min^{-1}. A thin blade shear/compression cell (CS-2) filled with 50 g of fruit was used. The shear force (lbf) was obtained from the highest peak in the texturegram (sinusoid-like graph with crosshead speed on the abscissa and force to penetrate sample on the ordinate) and converted to N g^{-1} by multiplying by 4.4482. Total energy was calculated as the area under the texturegram and is an indicator of the internal strength of bonds within a product.[16]

Blueberry composition

Berries (100 g) from each cultivar and location (replications) were homogenised for 2 min at high speed in a glass jar (300 ml capacity) using a Waring blender (Waring Product Division, New Hartford, CT, USA). The pH of the homogenate was measured with an Accumet 925 pH meter (Fisher Scientific). The soluble solids (SS) content of juice separated from the homogenate was determined with a Bausch & Lomb Abbe 3L refractometer (Bausch & Lomb, Rochester, NY, USA) maintained at 22 °C that had previously been standardised with distilled water. Titratable acidity (TA), expressed as percentage of citric acid, was determined by AOAC method 942.15.[17] The ratio SS/TA was calculated. Moisture content was determined by weighing 25 g of the homogenate and drying it at 72 °C for 24 h to constant weight in an ISOTEMP model 318F forced air oven (Fisher Scientific).

Pectin analyses

Frozen blueberries (50 g) were thawed and blended in a Waring blender (Waring Product Division) for 3 min. Two 16 g samples of homogenate were weighed into 50 ml graduated, conical bottom centrifuge tubes.

Ethyl alcohol ($950\,g\,l^{-1}$) was heated to 75 °C and added to a volume of 45 ml. The mixture was then heated for 10 min in a water bath at 85 °C with occasional stirring. The tubes were centrifuged at $1000 \times g$ for 15 min. The supernatant was decanted and discarded and the pellet was washed again with $630\,g\,l^{-1}$ ethyl alcohol as described above. After the second washing, the pellet was dispersed with 10 ml of distilled water added to the centrifuge tube. The tubes were made up to 35 ml with distilled water and stirred vigorously at 250 rpm for 10 min using an orbital shaker (Bellco Biotechnology, Bineland, NJ, USA). The dissolved pellet was centrifuged at $1000 \times g$ for 15 min and the liquid was decanted into a 100 ml volumetric flask. To the 100 ml flask, 5 ml of 1 M NaOH and distilled water to volume were added, mixed and allowed to stand for 15 min before beginning the colorimetric procedure.

The pellet in the centrifuge tube was dispersed with 10 ml of $7.5\,g\,l^{-1}$ ammonium oxalate. The tubes were then made up to 35 ml with the oxalate solution and stirred vigorously for 10 min. The mixture was centrifuged again at $1000 \times g$ for 15 min and the liquid was decanted into a 100 ml volumetric flask. The decanted liquid was prepared for the colorimetric procedure as described below. The remaining pellet in the centrifuge tube was washed into a 100 ml volumetric flask, 5 ml of 1 M NaOH was added and the contents were made up to volume with distilled water. The solution was mixed and allowed to stand for 15 min before being filtered through Whatman No 1 paper. A colorimetric procedure for pectic substances was carried out at 540 nm in a Bausch & Lomb spectrophotometer 2000 system according to Robertson.[18] A standard curve was developed using standard solutions containing $0-160\,\mu g\,ml^{-1}$ galacturonic acid.

Fibre analyses

Neutral detergent fibre (NDF)

NDF was determined as described by Mertens.[19] Blueberries were freeze-dried in a Virtis model 10 MRTR (Virtis, Gardiner, NY, USA), ground and sieved through a 1 mm screen. Approximately 0.5 g of the sample was transferred to a 600 ml Berzelius beaker and heated. After adding 0.5 g of sodium sulfite, 50 ml of neutral solution was added and boiled for 5 min. A standardised amylase solution (2 ml) was added to the sample solution and refluxed for 60 min while boiling. After allowing the sample to settle, 30–40 ml of solution was decanted into a Gooch crucible and filtered with minimum vacuum. Hot water and 2 ml of the amylase solution were added to the crucible and allowed to react for 60 s. Boiling water was also added to the Berzelius beaker to remove and filter the residue in the beaker. Samples were rinsed twice with 30 ml of acetone, allowing 2 min soaking time between rinses. The sample was then vacuum dried. The crucible was left to dry at 100 °C overnight and weighed. Determinations were done in duplicate.

Acid detergent fibre (ADF)

ADF was determined according to AOAC method 973.18.[17] The procedure for ADF was similar to the one used for NDF; however, approximately 0.07 g of sample was used and the steps of adding the standardised amylase solution were omitted.

Acid detergent lignin

Lignin was determined according to AOAC method 973.18.[17] The final residue obtained from the ADF determination was used. The ADF residue in the crucible was covered with cooled (5 °C) $720\,g\,l^{-1}$ H_2SO_4 and stirred to a smooth paste. The acid was allowed to drain away and the crucible was refilled with $720\,g\,l^{-1}$ H_2SO_4. After 3 h the residue in the crucible was washed with hot water (85–95 °C) until free from acid, dried overnight at 100 °C and weighed.

Hemicellulose calculation

The difference between NDF and ADF was estimated as hemicellulose, although this difference may include small amounts of protein attached to cell walls (Tomlinson JE, personal communication).

Cellulose calculation

The principle of the procedure is that the ADF residue is primarily lignocellulose, of which the cellulose is dissolved by $720\,g\,l^{-1}$ H_2SO_4. The remaining residue consists of lignin and acid-insoluble ash. Thus cellulose was estimated from the difference between ADF and lignin (Tomlinson JE, personal communication).

Statistical analyses

Data were arranged in a randomised complete block (RCB) design with five cultivars as treatments and three locations (producers) of each cultivar as blocks to account for the differences between locations (producers) within the same species, and that served as replication. Averages were calculated from two subsamples from the same replication. Data were analysed by the analysis of variance (ANOVA) procedure.[20] Fisher's protected least significant differences ($P \leqslant 0.05$) were used as the method of mean separation to determine differences between the highbush and rabbiteye species and cultivars.

RESULTS AND DISCUSSION

Physical characteristics

There were no differences ($P > 0.05$) among the five cultivars in specific gravity or unit weight and diameter, but there were differences ($P \leqslant 0.05$) in height of berries (Table 1). 'Tifblue' and 'Premier' were larger in height than 'Climax', 'Jersey' and 'Bluecrop'. Stem scar width measurements were larger ($P \leqslant 0.05$) for 'Jersey', 'Climax' and 'Bluecrop' (Table 1). Scars were smaller for 'Tifblue' and 'Premier'; however,

Table 1. Unit weight, diameter, height and stem scar diameter of five blueberry cultivars[a]

	Weight (g)	Diameter (mm)	Height (mm)	Stem scar diameter (mm)
Cultivar				
Climax	1.86a	14.80a	11.59b	2.07a
Premier	1.91a	15.81a	12.89a	1.73bc
Tifblue	1.73a	15.22a	12.71a	1.43c
Bluecrop	1.90a	15.45a	11.42b	1.93ab
Jersey	1.65a	14.99a	11.40b	2.32a
Species				
Rabbiteye	1.83a	15.28a	12.40a	1.74b
Highbush	1.78a	15.22a	11.41b	2.13a

[a] Means for all cultivars or species within a column not followed by the same letter differ ($P \leqslant 0.05$).

there was no difference ($P > 0.05$) between 'Premier' and 'Bluecrop' in stem scar diameter. Makus and Morris[1] reported rabbiteye berries as being larger than highbush berries, with higher values for unit weight, diameter and height and lower values for stem scar diameter. Differences between results may be due to the earlier harvesting season for Mississippi blueberries as compared with Arkansas blueberries. However, Ballington *et al*[2] found sufficient variability in berry weight among and within species of blueberries to make definite distinctions between highbush and rabbiteye species. Again, they found rabbiteye populations collected in either Florida or Georgia different in fruit weight compared with highbush berries.

Miller and McDonald[11] indicated that rabbiteye fruits are more resistant to fungal decay than highbush fruits and generally have smaller stem scars, and 'dry' vs 'wet' scars, which tend to inhibit entry of decay-causing organisms. Furthermore, the fruit stem scar is considered to be the principal point of entry for most postharvest decay organisms; therefore a small scar is desirable.[21]

Sensory evaluation

Panellists did not find significant differences ($P > 0.05$) in colour, skin toughness and flavour, but they did find differences ($P \leqslant 0.05$) in seediness (Table 2). 'Climax' was rated lower in seediness than the other varieties, with a mean score above the average score of 5 on the nine-point hedonic scale. 'Premier' scored lower ($P \leqslant 0.05$) in seediness than 'Bluecrop', but neither of the two differed in score from 'Tifblue' and 'Jersey'. Previous sensory evaluation of thawed highbush and rabbiteye blueberries showed that rabbiteye fruit colour was preferred to highbush fruit colour, but fruits of highbush cultivars had better taste and texture and less seediness.[1] These results cannot be compared directly with results reported here, because the taste panel assessed fresh fruits rather than thawed frozen berries. Dekazos[22] reported that blueberry texture can be adversely affected by freezing. Woodiness or grittiness in frozen berries may occur when they are stored at −18 °C for as long as 6 months.

Table 2. Sensory panel responses to fresh fruits of five blueberry cultivars[a]

	Sensory rating[b]			
	Colour	Skin toughness	Seediness	Flavour
Cultivar				
Climax	7.7a	5.7a	5.3c	6.5a
Premier	8.3a	7.2a	7.2b	7.4a
Tifblue	8.2a	6.1a	7.6ab	7.6a
Bluecrop	8.5a	7.5a	8.6a	7.3a
Jersey	8.2a	6.6a	7.3ab	7.4a
Species				
Rabbiteye	8.1a	6.3a	6.7a	7.2a
Highbush	8.4a	7.1a	8.0b	7.4a

[a] Means for all cultivars or species within a column not followed by the same letter differ ($P \leqslant 0.05$).
[b] On a nine-point hedonic scale, where 1 = dislike extremely, 5 = neither like nor dislike and 9 = like extremely.

Colour

Hunter L values did not differ ($P > 0.05$) among cultivars, except for 'Climax' which had lower ($P \leqslant 0.05$) L and higher hue value (Table 3). Sapers *et al*[13] stated that Hunter L measurements showed a relationship with visual assessments of waxy bloom on fresh highbush blueberries. Higher L values correlated with samples that scored high for bloom. Consequently, lower L values would indicate that 'Climax' has less waxy bloom than the other cultivars. 'Jersey' and 'Bluecrop' had higher Hunter b value (Table 3) and were more intense (SI) in colour (Table 3) than 'Climax' and 'Tifblue' blueberries. Colour is an important quality factor influencing fresh market value and the suitability of the berries for processing. However, blueberry colour is a highly complex attribute affected by the total anthocyanin content[23] and the quantity and structure of surface wax.[24]

Table 3. Hunter colour values of five blueberry cultivars[a]

	L	a	b	Hue angle[b]	Chroma (SI)[c]
Cultivar					
Climax	14.9b	0.12a	−2.36a	274a	2.37b
Premier	20.0a	−0.12b	−3.00ab	268b	3.00ab
Tifblue	19.6a	−0.18b	−2.41a	266b	2.41b
Bluecrop	20.9a	−0.26b	−3.56b	266b	3.57a
Jersey	19.9a	−0.21b	−3.84b	267b	3.84a
Species					
Rabbiteye	18.2a	0.06a	2.59a	269a	2.60b
Highbush	20.4a	0.24b	3.70b	267a	3.71a

[a] Means for all cultivars or species within a column not followed by the same letter differ ($P \leqslant 0.05$).
[b] Hue angle = $\tan^{-1}(b/a)$.
[c] SI = $(a^2 + b^2)^2$.

Table 4. Skin toughness and firmness of five blueberry cultivars[a]

	Skin toughness			Firmness	
	Puncture-in (N)	Puncture-out (N)	Compression force (N)	Shear force (N)	Total energy (J)
Cultivar					
Climax	1.71a	1.03a	7.28a	565a	8.29a
Premier	1.22c	0.69c	5.18b	406c	7.14b
Tifblue	1.50b	0.82b	7.04a	475b	8.72a
Bluecrop	0.78d	0.36e	4.33c	254e	5.86c
Jersey	0.83d	0.49d	3.58d	326d	6.31c
Species					
Rabbiteye	1.48a	0.85a	6.50a	482a	8.05a
Highbush	0.81b	0.43b	3.96b	290b	6.08b

[a] Means for all cultivars or species within a column not followed by the same letter differ ($P \leqslant 0.05$).

Skin toughness and fruit firmness

Skin toughness determined by the puncture tests showed significant differences among cultivars (Table 4). 'Climax' skins were the toughest ($P \leqslant 0.05$) to penetrate, followed by 'Tifblue' then by 'Premier'. Among rabbiteye cultivars, 'Premier' were softer than 'Tifblue' and 'Climax' (Table 4). These results were consistent on both tests, penetration of the skins from outside and inside the berry, ie puncture-in and puncture-out respectively. Similarly, both tests showed that 'Jersey' and 'Bluecrop' had softer ($P \leqslant 0.05$) skins than the three rabbiteye varieties ('Climax', 'Premier' and 'Tifblue'). However, the puncture-out test showed that 'Jersey' skins were tougher than 'Bluecrop', while the puncture-in test showed no differences between the two highbush varieties.

The shear force curve (not shown) had two peaks as discussed by Dekazos and Smith.[9] The first peak occurred at the breaking of the skins, then there was a dip in the curve until the resistance offered by the flesh increased. Means from the first peak (Table 4) showed comparable results to those from the puncture tests. In ascending order, from least to most resistant, the varieties responded to shearing as follows: 'Bluecrop' > 'Jersey' > 'Premier' > 'Tifblue' > 'Climax'. When measuring total energy (Table 4) from shearing the berries, 'Climax' and 'Tifblue' blueberries were firmer than 'Premier', the latter being firmer than 'Jersey' and 'Bluecrop'. There was no difference between the two highbush cultivars. On average, the force required to puncture the skin of, compress or shear rabbiteye berries was double that needed for highbush berries, whereas total energy was 25% higher for rabbiteye berries. This indicates that these species may differ in skin thickness and/or cell wall components. These results are comparable to those reported by Makus and Morris.[1]

Blueberry composition

Mean values of pH, titratable acidity (TA), soluble solids (SS), SS/TA ratio and moisture content showed no differences ($P > 0.05$) among the five cultivars or between the two species (data not presented). These findings differ from those of Makus and Morris,[1] who determined that pH, soluble solids and titratable acidity were higher in rabbiteye than in highbush fruits.

The selection of blueberry fruit of good keeping quality has been shown to involve soluble solids, pH, total acidity levels and SS/TA ratios.[6,7,25] However, Ballington *et al*[2] found that soluble solids tend to vary from year to year among and within blueberry species and that highbush population from the Deep South had the highest soluble solids. Sapers *et al*[13] found that the first harvest of four highbush cultivars studied was higher in acidity than the second harvest. Ballington *et al*[2] also found that there were differences between rabbiteye populations originating in Georgia and Florida, with Georgia populations having consistently higher acidity. They concluded that, within a single location and year, genetic components are undoubtedly more important than environmental (temperature, moisture, soil) differences within the field, but not between locations and years.

The above findings may help to explain the differences between the present and Makus and Morris's[1] results. Their results were based on blueberry plantings from a single location, whereas this study was based on plantings from different locations and two regions. The present results, having been determined from different locations and regions, would be closer to those of a true population.

Pectin analyses

'Bluecrop' berries had higher ($P \leqslant 0.05$) water-soluble pectin (WSP) than all three rabbiteye cultivars (Table 5). 'Jersey' was only higher ($P \leqslant 0.05$) in WSP than 'Climax'. 'Premier' had higher ($P \leqslant 0.05$) total pectin (Table 5) than the other four cultivars.

Changes in the composition of the cell wall and middle lamella of fruits have been linked to textural alterations. Pectin substances are the major components of the middle lamella and primary cell walls, and their solubilisation is often correlated with a loss of firmness.[26–28] According to Whistler and

Table 5. Pectin components (g galacturonic acid per 100 g fruit) of five blueberry cultivars[a]

	Pectin soluble in			Total pectin
	Water[b]	Oxalate[c]	Hydroxide[d]	
Cultivar				
Climax	0.015c	0.128c	0.362bc	0.505b
Premier	0.016bc	0.176b	0.484a	0.676a
Tifblue	0.019bc	0.145c	0.374b	0.539b
Bluecrop	0.029ab	0.219a	0.265c	0.514b
Jersey	0.026ab	0.174b	0.309bc	0.508b
Species				
Rabbiteye	0.017a	0.150a	0.407a	0.537a
Highbush	0.028b	0.197a	0.287b	0.511a

[a] Means for all cultivars or species within a column not followed by the same letter differ ($P \leqslant 0.05$).
[b] Also known as pectic acid.
[c] Also known as pectinic acid.
[d] Also known as protopectin.

Daniel,[29] protopectin is related to the hard texture of unripe fruits and vegetables.

Results from this study show that the highbush species appear to have more enzymatic activity than the rabbiteye species, since highbush berries had more solubilisation of protopectin, indicated by significantly higher values of water-soluble pectin (pectic acid), even though the total amount of pectin was lower.[26,28] Thus higher values for total pectin for rabbiteye blueberries, with significantly lower values for soluble pectin responsible for fruit softening, and significantly higher values for protopectin, indicate that rabbiteye blueberries would tend to be tougher than highbush blueberries. These findings confirm the firmness and skin toughness results discussed previously.

Fibre analyses

'Climax' and 'Premier' had higher ($P \leqslant 0.05$) NDF and lignin than 'Bluecrop' and 'Jersey' blueberries (Table 6). 'Tifblue' was lower ($P \leqslant 0.05$) in fibre and lignin than the other two rabbiteye berries.

The texture of plant foods is highly influenced by the type and amount of material making up the cell wall structure.[30] Cellulose, hemicellulose, pectin and lignin are primary components of fruit cell walls. The present results show that differences in texture between rabbiteye, primarily 'Climax' and 'Premier', and highbush blueberries would in part be due to differences in their cell wall structure.

Lignin makes up most of the secondary walls of stone cells. These cells, depending on the size and number, give many fruits a gritty or woody texture, since they impart considerable rigidity and toughness to the cell wall.[31] According to these results, it seems that the amount of lignin present in the fruit is a characteristic of the cultivar rather than the species. According to Dekazos[22] and Gough,[32] stone cells are found throughout most of the flesh of rabbiteye blueberries. Although there are no studies to quantify stone cells between cultivars, lignin determination may be a tool to do so.

Although the nutritional aspect is not within the scope of the present study, a comment on dietary fibre should be made. According to the AACC,[33] NDF determination is considered the method of choice for assessing the insoluble dietary fibre content of cereals. Thus these results indicate that 'Climax' and 'Premier' are a better source of insoluble and soluble dietary fibre than the other three cultivars, since they had higher ($P \leqslant 0.05$) NDF and ADF values (Table 6).

CONCLUSIONS

Rabbiteye blueberries are firmer and have a tougher skin than highbush blueberries. Pectin and lignin analyses indicate that these textural differences between types may be attributed to the variations in cell wall components. Based on these results, rabbiteye berries may be able to withstand storage, harvesting, shipping and handling better than highbush berries, thus yielding a longer keeping quality berry. The differences between the rabbiteye cultivars may be partly due to

Table 6. Neutral detergent fibre (NDF), acid detergent fibre (ADF), lignin, hemicellulose, cellulose on a dry matter basis and moisture of five freeze-dried blueberry cultivars[a]

	NDF (%)	ADF (%)	Lignin (%)	Hemicellulose (%)	Cellulose (%)	Moisture (%)
Cultivar						
Climax	20.00a	14.74a	8.13a	5.26a	6.61a	83.4a
Premier	20.24a	14.90a	7.57a	5.34a	7.33a	83.6a
Tifblue	13.58b	8.69b	3.98c	4.89a	4.72b	82.6a
Bluecrop	9.24c	7.04b	3.80c	2.19b	3.42b	85.3a
Jersey	10.08c	9.06b	5.65b	1.02b	3.24b	84.2a
Species						
Rabbiteye	17.94a	12.78a	6.56a	5.16a	6.22a	83.2a
Highbush	9.66b	8.05a	4.73b	1.61b	3.33b	84.8a

[a] Means for all cultivars or species within a column not followed by the same letter differ ($P \leqslant 0.05$).

their time to maturity. 'Climax' is an earlier cultivar, followed by 'Premier' and finally 'Tifblue'.

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