Effect of Storage Temperatures on Fruit Quality of Various Cranberry Cultivars

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Abstract

Nine cultivars of cranberries (*Vaccinium macrocarpon* Aiton) were stored at four different temperatures (0, 5, 10, and 15°C) and were evaluated for decay, chilling injury, sugars, organic acids, fatty acids, total anthocyanins, total phenolics, antioxidant capacity, and individual flavonoids after 3 or 4 months of storage. Cranberries had high antioxidant activity (ORAC). ORAC values, anthocyanins and total phenolics content increased during storage. The highest increases occurred at 15°C storage. Peonidin 3-galactoside, cyanidin 3-galactoside, quercetin 3-galactoside and peonidin 3-arabinoside were the predominant flavonoids in cranberries. Susceptibility to chilling injury and decay varies with different cultivars. 'Ben Lear', 'Cropper', 'Early Black', and 'Stevens' showed severe symptoms of chilling injury and decay at the end of 3 or 4 months storage at 0°C. 'Crowley', 'Howes', and 'Pilgrim' were relatively resistant to chilling injury and decay, while 'Franklin' and 'Wilcox' were moderately susceptible. The susceptibility was found to be related to the fatty acid composition and ratio of unsaturated to saturated fatty acid in phospholipids and glycolipids, but was not associated with antioxidant activity, anthocyanins, phenolics, or individual flavonoids. Storage temperatures also affected content of glucose, fructose, sucrose, starch, citric acid, malic acid, and quinic acid. Storage at 5°C was found to be the optimum holding temperature with the least chilling injury symptom and decay for all cranberry cultivars evaluated.

INTRODUCTION

Refrigeration is recommended for storage of most perishable fresh produce (Gross et al., 2004). Low temperature inhibits microbial growth, retards spoilage, and suppresses undesirable metabolic changes, therefore, maintains quality and extends storage life. However, some commodities are susceptible to chilling injury and deteriorate rapidly if kept below their threshold chilling temperatures. Most berry crops including blackberries, blueberries, raspberries, and strawberries are chilling tolerant and can be stored at -0.5 to 0°C or slightly above their freezing points to maintain their quality. Unfortunately, cranberries are known to be chilling sensitive and can develop low-temperature breakdown after prolonged exposure to chilling temperatures (Prange, 2004). We initiated a study to evaluate the quality of several cultivars of cranberries after storage at various temperatures and to determine the relationship of keeping quality to fatty acid composition, antioxidant activity, anthocyanins, phenolics, and individual flavonoids.

MATERIALS AND METHODS

Cranberry fruits used in this study were grown at the Rutgers Blueberry and Cranberry Research Center in Chatsworth, NJ. Since cultural practices were all the same, cultivar differences observed at harvest were primarily due to different cultivar traits. The cranberries were hand harvested dry at commercial maturity from four replicates per cultivar and stored at 0, 5, 10, and 15°C. At harvested and after three or four months of storage, undamaged berries were selected, the seeds removed, and 30-40 berries were cut into small slices, mixed, frozen in liquid nitrogen and stored at -80°C until analyzed. To prepare the fruit extracts, five g of berries from four replicates were extracted twice with 10 ml of 80% acetone containing 0.2% formic acid using a Polytron (Brinkmann Instruments, Inc., Westbury, NY) for 2 min and then centrifuged at 20,000x*g* for 20 min. The supernatants were combined and transferred to vials, stored at -80°C, then used for analyses of ORAC, phenolics and anthocyanins.

Decay and Chilling Injury

The severity of chilling injury and decay in cranberry fruit was evaluated after storage at 0, 5, 10 and 15°C for 3 and 4 months. Symptoms of chilling injury include dull appearance and browning and eventually result in increased decay. Decay is expressed as percent of fruit showing mold growth or tissue breakdown.

Analysis of Soluble Solids (SSC), Sugars, Titratable Acids (TA), Organic Acids, Total Anthocyanin and Total Phenolic Content

The SSC of fruit was determined on a digital refractometer Palette 100 PR-100. TA was determined by diluting each 5-ml aliquot of cranberry juice to 100 ml with distilled water and adjusting the pH to 8.2 using 0.1N NaOH. Acidity was expressed as percent of citric acid equivalent. Total anthocyanin content in fruit extracts was determined using the pH differential method (Cheng and Breen, 1991). Total soluble phenolics were determined with Folin-Ciocalteu reagent by the method of Slinkard and Singleton (Slinkard, K; Singleton, 1977). The extraction, purification, and derivatization procedures for nonstructural sugars, starch and organic acids have been described previously (Wang et al., 1987). A Hewlett-Packard 5890 gas chromatograph (Hewlett-Packard, Palo Alto, CA) equipped with a flame ionization detector and a fused silica capillary (dimethylsilicone fluid, 12.5 m x 0.2 mm; Hewlett-Packard, Palo Alto, CA) was used for separation of sugars and organic acids. Sugars and organic acids were quantified by comparing peak area with those of standards (Wang et al., 1987).

Oxygen Radical Absorbance Capacity (ORAC) Assay

The ORAC assay was carried out using a high-throughput instrument platform consisting of a robotic eight-channel liquid handling system and a microplate fluorescence reader (Huang et al., 2002). ORAC values were calculated using the regression equation between Trolox concentration and the net area under the curve (AUC) and were expressed as µmole Trolox equivalents (TE) per g fwt.

HPLC Analysis of Berry Anthocyanins and Phenolic Compounds

High-performance liquid chromatography (HPLC) was used to separate and determine individual anthocyanins and phenolic compounds in berry tissue samples (Zheng and Wang, 2003).

Extraction, Fractionation, and Analysis of Lipids

Triplicate fruit samples of 30 g fresh weight were collected from each cultivar at harvest time. Lipids were extracted, fractionated, and analyzed according to the procedures described by Wang and Faust (1992). Purified lipids were separated into neutral, glyco- and phospholipid fractions by silicic acid column chromatography on 100- to 200-mesh Bio Sil A (Bio Rad Laboratories, Richmond, CA). Total fatty acids esterified to polar lipids were derivatized to fatty acids methyl esters (FAME) for flame ionization detection-gas chromatography (FID-GC) analysis. N-heptadecanoic acid was included in all samples as an internal standard, and methyl heptadecanoate was used as an external standard. Individual FAME was identified by a comparison of peak areas with those of authentic standards (Supelco, Bellefonte, PA). This tentative identification of major polar lipid fatty acids was corroborated by further analysis of FAME by gas chromatography-mass spectrometry (GC-MS) (Wang and Faust, 1992).

Statistical Analysis

Data presented were the means ± SD of values by using NCSS Statistical Analysis System (NCSS, 2007). One-way analysis of variance (ANOVA) was used to compare the means and differences were considered significant at $p \leq 0.05$.

RESULTS AND DISCUSSION

Decay was most severe after storage at 0°C and 15°C for 3 and 4 months (Table 1). The percent fruit showing decay at 0°C was higher than those at 5, 10 and 15°C, indicating these decays were resulted from chilling injury. Fruit stored at 5°C had the least chilling injury symptoms and decay in all cultivars evaluated.

On the basis of fresh weight of fruit, 'Early Black' had significantly higher anthocyanin, phenolic content, and ORAC values than 'Ben Lear' and 'Pilgrim'. Total anthocyanin, total phenolic content and ORAC values increased with increasing storage temperatures. Compared to blueberry and lingonberry, cranberry had generally lower anthocyanin content (0.32mg of C 3-G/g fwt.), total phenolic content (3.15mg of GRE/g fwt.), and total antioxidant capacity (37.0 µmol of TE/g fwt.) (Kalt et al., 1999; Wang et al., 2005). Previous research showed that a linear relationship existed between total phenolic or anthocyanin content and ORAC in various berry crops (Wang and Lin, 2000; Kalt et al., 1999). In this study, we also found that there is a linear relationship between total phenolic or anthocyanin content and ORAC. These results suggest that the antioxidant activity of cranberries is mainly derived from the contribution of phenolic compounds.

Among anthocyanin constituents of cranberry, peonidin 3-galactoside comprised 20.8% of the total ORAC value and had a high concentration (3.82 µmol TE/g fwt.) as a main constituent in 'Ben Lear' cranberry extract (Fig. 1). Using ORAC values of all identified constituents, total antioxidant capacities were summed and calculated. Compared to their actual measured total antioxidant capacity, the calculated sum values were found to be lower (25.68 vs. 37.0 µmol TE/g fwt) and the main reasons for this may have been due to unmeasured substances in the fruit extract or synergistic interactions between the measured components.

The amount of total sugars and organic acids increased with increasing storage temperatures in all cultivars (Tables 2 and 3). Exposure to chilling temperature at 0°C does not seem to have a negative effect on the increase of sugars and organic acids during storage.

Galactolipids and phospholipids are essential constituents of all biomembranes. The lipid composition of various membranes in plant cells greatly affects the fluidity of their lipid matrix. Changes occurring in the lipid composition of these membranes will certainly modify their permeability, energy transduction capacity, and the activities of membrane-bound enzymes (Lynch and Thompson, 1982). The identification of fatty acid esters in cranberries was established by GC-MS. The full electron impact (EI) mass spectra of fatty acid ester in GC-MS were similar to the authentic standards as previously reported (Heller and Milne, 1978). The EI mass spectra of palmitate, stearate, oleate, linoleate, and linolenate derived from extracted galacto- and phospholipids had weak molecular ions M^+, but the isobutane chemical ionization (CI) had very intense quasimolecular ions $(M + 1)^+$. The molecular ions M^+ in EI of palmitate, stearate, oleate, linoleate, and linolenate were 270, 298, 296, 294, and 292, respectively. The quasimolecular ions $(M + 1)^+$ in CI of palmitate, stearate, oleate, linoleate, and linolenate were 271, 299, 297, 295, and 293, respectively. The GC-MS relative retention times of palmitate (5.93 min), stearate (9.52 min), oleate (9.80 min), linoleate (10.53 min), and linolenate (11.63 min) were identical to the relative retention times of authentic samples.

Palmitic (C16:0), stearic (C18:0), oleic (C18:1), linoleic (C18:2), and α-linolenic (C18:3) acids occurred in galacto- and phospholipids in cranberries (Table 4). Palmitic, linoleic, and α-linolenic were the predominant fatty acids in cranberries. Storage temperatures significantly affect the fatty acids composition. There was a corresponding increase in the percentage of saturated lipids in warmer storage temperatures in cranberries except for the fruit stored in 0°C for four months where chilling injury and decay occurred. The ratios of unsaturated (18:1 + 18:2 + 18:3) to saturated (16:0 + 18:0) fatty acid and 18:3 to 18:2 of galactolipids and phospholipids were lower in 0, 10 and 15°C storage fruit than in 5°C. Higher ratios were correspondent with lower susceptibility to chilling injury at 5°C. 'Pilgrim' had higher ratio of unsaturated to saturated and 18:3 to 18:2 fatty acid of galactolipids and phospholipids than Early Black (Table 4). Fatty acid unsaturation is one of the key factors regulating membrane function (Dickens and Thompson, 1982). The decrease of this ratio may contribute to the decrease in membrane fluidity in cranberries. Therefore, alteration in the composition of membrane lipids can be achieved by changing storage temperatures.

In conclusion, storage temperature greatly affected quality of cranberry fruit. Chilling injury occurred at 0°C, but 5°C was found to be an optimum storage temperature. The susceptibility to chilling injury and decay was related to the fatty acid composition and ratio of unsaturated to saturated fatty acid in phospholipids and glycolipids, but was not associated with antioxidant activity, anthocyanins, phenolics, or individual flavonoids.

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Tables

Table 1 Percent of fruit of various cranberry cultivars showing decay after storage at different temperatures for 3 and 4 months.

Cultivar	after 3 months storage				after 4 months storage			
	Storage temperature (°C)				Storage temperature (°C)			
	0	5	10	15	0	5	10	15
Ben Lear	53.9	3.0	16.7	38.7	55.2	4.8	26.7	42.9
Cropper	33.3	2.2	5.7	11.7	44.4	10.0	13.1	35.9
Crowley	8.5	0	0.5	11.5	12.1	3.2	6.3	30.8
Early Black	30.1	0.7	8.2	18.7	36.8	7.3	11.4	29.3
Franklin	19.4	0.5	10.2	30.2	25.8	4.8	13.5	36.8
Howes	8.5	2.7	4.8	19.3	12.9	4.3	6.8	50.3
Pilgrim	10.3	0	4.0	9.1	17.9	0.5	5.1	17.3
Stevens	28.9	0	4.8	21.7	38.3	7.0	12.1	29.8
Wilcox	14.8	0	3.4	21.8	19.6	3.1	6.7	49.1

Table 2. Soluble solids (SSC) and sugar (fructose, glucose, sucrose, starch and total sugars) content of fruit of cranberry cultivars stored for four months at different storage temperatures.

Cultivar	Temp (°C)	SSC (%)	Fructose	Glucose	Sucrose	Starch	Total
			mg/g fresh weight				
Ben Lear	Initial	8.3±0.1	2.56±0.04	34.7±1.34	2.16±0.06	1.32±0.00	40.9±1.33
	0	8.5±0.1	3.85±0.11	35.0±1.10	1.05±0.02	1.06±0.05	41.1±1.28
	5	8.2±0.1	3.22±0.03	36.0±0.22	1.12±0.03	1.05±0.01	41.6±0.15
	10	8.6±0.1	4.12±0.06	39.4±0.38	1.15±0.01	1.06±0.07	46.1±0.43
	15	9.0±0.1	6.16±0.10	46.4±1.17	1.16±0.02	0.93±0.03	54.8±1.07
Cropper	Initial	8.8±0.1	6.09±0.16	24.2±0.81	0.84±0.05	1.19±0.00	32.5±1.01
	0	9.0±0.1	8.07±0.06	31.0±1.99	0.09±0.04	0.97±0.01	40.5±2.21
	5	8.9±0.0	8.51±0.08	29.1±0.49	0.62±0.02	1.02±0.01	39.6±0.72
	10	9.0±0.1	9.42±0.05	34.0±0.83	0.66±0.04	0.90±0.00	45.3±0.59
	15	10.1±0.1	12.9±0.20	41.4±0.62	0.61±0.02	0.78±0.01	55.6±0.76
Crowley	Initial	8.4±0.1	2.72±0.04	29.6±0.69	1.76±0.09	1.17±0.03	35.5±0.88
	0	8.4±0.0	3.41±0.04.	29.2±0.01	1.34±0.02	1.03±0.01	35.1±0.08
	5	8.5±0.1	3.40±0.15	33.4±1.56	1.08±0.06	0.95±0.04	39.9±1.80
	10	8.5±0.1	3.86±0.05	37.7±0.62	0.81±0.07	0.96±0.02	43.5±0.54
	15	9.0±0.1	4.62±0.08	39.0±0.12	0.72±0.03	0.90±0.02	45.4±0.13
Early Black	Initial	8.3±0.0	2.98±0.06	23.7±0.81	0.68±0.04	1.19±0.01	28.7±0.90
	0	8.4±0.1	3.35±0.14	28.6±3.34	0.37±0.04	1.09±0.01	33.6±3.46
	5	8.5±0.0	3.30±0.10	26.2±0.83	0.56±0.05	1.09±0.01	29.6±3.25
	10	8.8±0.0	5.18±0.16	35.4±1.79	0.57±0.01	1.06±0.04	42.3±1.68
	15	9.0±0.0	7.86±0.12	40.5±0.34	0.48±0.02	0.90±0.01	49.9±0.01
Franklin	Initial	7.8±0.1	2.32±0.05	25.0±1.44	0.68±0.04	1.18±0.04	29.3±1.50
	0	7.9±0.1	2.44±0.06	26.9±0.86	0.67±0.01	1.16±0.03	31.4±0.95
	5	8.0±0.1	3.54±0.20	26.6±0.76	0.56±0.00	1.12±0.12	32.3±0.78
	10	8.2±0.1	5.09±0.06	30.0±1.24	0.38±0.00	1.04±0.08	36.7±1.35
	15	8.6±0.1	6.58±0.37	35.3±1.17	0.35±0.05	0.95±0.01	43.3±1.41
Howes	Initial	8.7±0.1	3.30±0.17	28.6±0.67	2.20±0.08	1.17±0.01	35.5±0.59
	0	8.8±0.1	3.73±0.04	29.8±0.60	1.42±0.05	1.00±0.01	36.1±0.68
	5	8.5±0.0	4.30±0.06	31.9±0.36	1.68±0.04	0.98±0.01	39.1±0.26
	10	9.3±0.1	5.32±1.20	34.4±2.86	1.19±0.10	0.94±0.02	42.0±3.92
	15	10.0±0.1	6.84±0.13	42.2±1.34	0.91±0.04	0.78±0.02	53.9±5.71
Pilgrim	Initial	8.4±0.0	3.52±0.33	26.3±0.93	1.04±0.01	1.18±0.01	31.2±1.31
	0	8.4±0.1	4.66±0.06	30.1±1.06	0.49±0.00	1.09±0.00	36.5±1.12
	5	8.5±0.1	4.96±0.08	30.5±0.48	0.70±0.19	1.07±0.01	37.2±0.37
	10	8.8±0.1	5.18±0.21	36.5±1.94	0.64±0.01	1.02±0.01	43.5±2.10
	15	9.3±0.1	7.36±0.08	40.7±0.37	0.50±0.02	0.90±0.01	49.6±0.27
Stevens	Initial	8.4±0.1	3.12±0.04	29.4±1.54	1.21±0.03	1.16±0.02	35.1±1.61
	0	8.8±0.1	3.53±0.04	31.3±0.23	0.60±0.02	1.10±0.01	36.2±0.83
	5	9.0±0.1	4.25±0.11	35.8±0.88	1.02±0.06	1.14±0.05	42.4±0.13
	10	9.1±0.1	4.43±0.06	38.7±1.62	0.65±0.01	1.10±0.02	45.0±1.48
	15	9.4±0.1	5.86±0.13	45.8±1.35	0.72±0.04	0.86±0.05	53.4±1.36
Wilcox	Initial	9.1±0.1	3.59±0.54	27.7±1.76	1.14±0.06	1.20±0.01	33.8±2.34
	0	9.0±0.1	5.30±0.29	29.6±0.34	0.98±0.05	1.08±0.01	37.0±0.01
	5	9.2±0.1	5.22±0.23	32.9±0.17	0.96±0.02	1.02±0.02	40.2±0.03
	10	9.2±0.1	6.36±0.11	36.8±0.02	0.90±0.01	0.91±0.01	45.0±0.70
	15	10.8±0.2	7.14±0.40	44.2±0.04	0.62±0.01	0.82±0.03	48.1±1.41

Table 3. pH, titratable acid (TA) and organic acid content (malic, citric, quinic, and total organic acids) of fruit of cranberry cultivars stored for four months at different storage.

Cultivar	Temp (^oC)	pH	TA (%)	Malic	Citric	Quinic	Total
				mg/g fresh weight			
Ben Lear	Initial	2.22±0.03	2.96±0.01	0.16±0.01	3.99±0.14	0.46±0.03	4.61±0.13
	0	2.39±0.01	2.92±0.02	0.51±0.03	7.68±0.04	0.98±0.06	9.16±0.12
	5	2.42±0.03	0.92±0.04	0.24±0.02	5.72±0.13	0.80±0.05	6.76±0.02
	10	2.60±0.01	2.67±0.04	0.46±0.02	8.99±0.01	1.30±0.06	10.78±0.09
	15	2.68±0.01	2.12±0.01	0.64±0.06	10.69±0.06	1.24±0.04	12.58±0.04
Cropper	Initial	2.18±0.01	2.75±0.01	0.18±0.04	3.99±0.06	0.50±0.05	4.68±0.07
	0	2.18±0.02	2.70±0.02	0.47±0.03	6.42±0.04	1.06±0.08	7.96±0.07
	5	2.23±0.00	2.67±0.02	1.10±0.16	5.66±0.06	0.90±0.02	7.65±0.24
	10	2.56±0.02	2.55±0.02	0.55±0.03	8.97±0.08	0.95±0.06	10.47±0.00
	15	2.70±0.00	2.20±0.00	0.58±0.01	7.61±0.03	1.32±0.02	9.52±0.06
Crowley	Initial	2.24±0.01	2.68±0.01	0.07±0.01	4.23±0.03	0.42±0.03	4.72±0.07
	0	2.34±0.04	2.62±0.02	0.30±0.04	8.00±0.01	1.01±0.03	9.31±0.06
	5	2.36±0.02	2.62±0.02	0.17±0.03	8.32±0.08	0.80±0.04	9.30±0.01
	10	2.48±0.02	2.47±0.03	0.54±0.03	9.04±0.04	1.64±0.01	11.21±0.06
	15	2.68±0.02	2.48±0.02	1.08±0.03	8.82±0.05	1.45±0.03	11.24±0.01
Early Black	Initial	2.20±0.01	3.10±0.01	0.14±0.04	6.08±0.15	0.44±0.04	6.67±0.16
	0	2.32±0.04	2.92±0.02	0.40±0.06	7.30±0.01	0.93±0.01	8.63±0.07
	5	2.38±0.02	2.90±0.04	0.97±0.03	6.39±0.01	1.23±0.04	8.59±0.00
	10	2.52±0.01	2.84±0.01	1.07±0.13	11.89±0.04	1.26±0.06	14.22±0.14
	15	2.69±0.01	2.74±0.06	1.34±0.04	11.74±0.06	1.34±0.02	14.43±0.04
Franklin	Initial	2.20±0.01	2.82±0.04	0.10±0.02	5.45±0.06	0.52±0.04	6.08±0.11
	0	2.41±0.01	2.79±0.01	0.41±0.08	7.34±0.05	1.01±0.13	8.76±0.26
	5	2.54±0.01	2.71±0.01	0.50±0.01	8.15±0.04	0.72±0.06	9.37±0.11
	10	2.60±0.01	2.66±0.04	0.76±0.09	12.72±0.03	1.54±0.08	14.52±0.14
	15	2.66±0.01	2.60±0.01	1.04±0.04	12.32±0.01	1.04±0.02	14.4±0.08
Howes	Initial	2.20±0.01	2.68±0.03	0.14±0.02	1.88±0.13	0.56±0.04	2.58±0.12
	0	2.34±0.05	2.59±0.01	0.64±0.13	4.91±0.06	1.50±0.04	7.05±0.11
	5	2.38±0.01	2.61±0.03	0.37±0.17	5.88±0.11	1.14±0.09	7.40±0.37
	10	2.48±0.01	2.49±0.01	0.38±0.15	5.92±0.04	1.35±0.04	7.64±0.23
	15	2.78±0.07	2.42±0.01	0.41±0.03	9.76±0.05	2.18±0.03	13.36±0.01
Pilgrim	Initial	2.14±0.02	2.77±0.00	0.08±0.01	5.56±0.03	0.59±0.04	6.24±0.06
	0	2.31±0.01	2.66±0.03	0.58±0.02	8.28±0.04	1.38±0.05	10.23±0.07
	5	2.34±0.05	2.66±0.01	0.52±0.12	8.58±0.01	0.94±0.08	10.02±0.19
	10	2.48±0.04	2.51±0.03	1.10±0.12	7.69±0.30	1.40±0.08	10.16±0.49
	15	2.72±0.04	2.28±0.04	0.52±0.05	10.22±0.06	1.48±0.06	12.23±0.04
Stevens	Initial	2.24±0.04	2.91±0.01	0.12±0.01	6.03±0.06	0.49±0.04	6.64±0.12
	0	2.34±0.04	2.87±0.03	0.70±0.02	9.87±0.06	1.26±0.06	11.82±0.13
	5	2.44±0.04	2.85±0.01	0.39±0.04	8.20±0.01	0.91±0.08	9.50±0.14
	10	2.56±0.02	2.72±0.01	1.56±0.08	8.61±0.01	1.33±0.08	11.50±0.01
	15	2.68±0.01	2.39±0.01	0.76±0.05	10.72±0.03	1.13±0.07	12.60±0.09
Wilcox	Initial	2.16±0.08	3.03±0.01	0.20±0.03	3.18±0.09	0.44±0.05	3.81±0.17
	0	2.38±0.01	2.94±0.01	0.56±0.11	4.90±0.10	1.06±0.11	6.53±0.11
	5	2.48±0.01	2.77±0.01	2.82±0.16	4.32±0.05	1.12±0.03	6.26±0.08
	10	2.56±0.02	2.48±0.03	0.42±0.05	5.06±0.10	1.07±0.04	6.54±0.11
	15	3.08±0.02	2.12±0.04	1.51±0.03	8.72±0.04	1.71±0.01	11.94±0.05

Table 4. Composition of fatty acids, palmitic (16:0), stearic (18:0), oleic (18:1), linoleic (18:2), and linolenic (18:3) acid content (weight percent of total) of galactolipids and phospholipids and ratios of (A) unsaturated (18:1 + 18:2 + 18:3) to saturated (16:0 + 18:0) and (B)18:3 to 18:2 in fruit of 'Early Black' and 'Pilgrim') stored for four months at different storage temperatures. Means within same column of ratio A or ratio B followed by different letters were significantly different at the $P \leq 0.05$.

cultivar	Temperature (°C)	% Fatty acid composition 16:0	18:0	18:1	18:2	18:3	ratio A unsat/sat	ratio b 18:3/18:2
Early Black				*galactolipid*				*galactolipid*
	initial	24.8	4.53	1.89	51.44	17.34	2.41b	0.34a
	0	26.39	4.39	3.62	55.12	13.47	2.28b	0.24c
	5	22.76	4.67	2.33	54.39	15.85	2.65a	0.29bc
	10	25.95	4.39	1.32	53.94	14.40	2.30b	0.27bc
	15	27.36	5.10	6.55	55.89	5.10	2.08c	0.09d
				galactolipid				*galactolipid*
Pilgrim	initial	21.31	5.10	2.55	50.17	20.87	2.79a	0.41a
	0	24.88	5.95	1.98	52.04	15.15	2.24b	0.29bc
	5	21.55	4.48	1.79	54.65	17.53	2.84a	0.32bc
	10	25.20	4.71	1.88	54.12	14.08	2.34b	0.26bc
	15	27.33	5.19	1.60	55.86	10.03	2.08c	0.20c
Early Black				*phospholipid*				*phospholipid*
	initial	28.33	2.85	1.90	55.91	11.01	2.20b	0.20a
	0	28.20	3.31	1.10	56.75	10.64	2.17b	0.19a
	5	25.46	3.29	2.46	56.09	12.70	2.48a	0.23a
	10	26.10	2.88	0.96	58.21	11.85	2.45a	0.20a
	15	26.28	2.83	1.42	62.62	6.86	2.44a	0.11b
Pilgrim				*phospholipid*				*phospholipid*
	initial	23.38	3.61	1.80	59.43	11.79	2.71b	0.20ab
	0	24.50	3.14	1.31	58.04	13.01	2.62bc	0.22ab
	5	23.01	2.36	1.01	58.97	14.65	2.94a	0.25a
	10	23.43	2.44	0.81	59.39	13.93	2.87a	0.23ab
	15	25.30	3.60	1.50	58.71	10.89	2.46c	0.19b

Figures

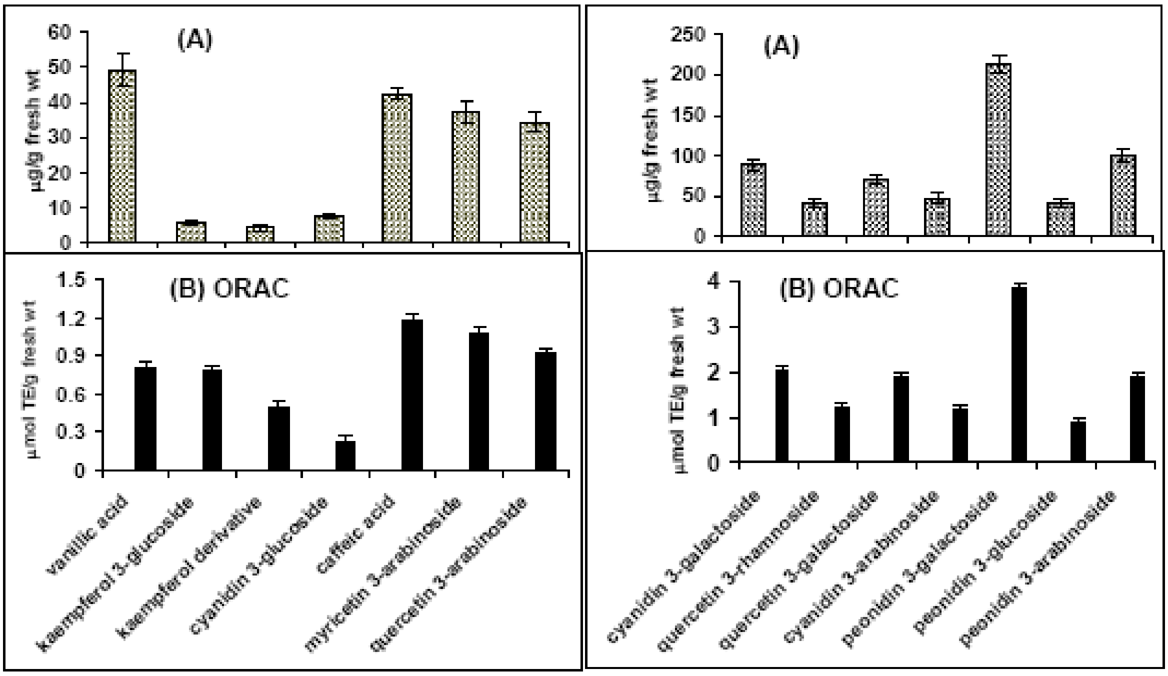

Fig. 1. Concentration of individual phenolic compound (A) and calculated contribution of each phenolic compound to the total antioxidant activity (ORAC) (B) in 'Ben Lear' cranberries.