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Influence of Postharvest Holding on Raw and Processed Quality of Machine-harvested Blackberries[1]

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Abstract. **Under commercial conditions at harvest, mechanically harvested blackberries (*Rubus* sp.) had raw and processed quality comparable to hand-picked fruits regardless of berry temperature. However, during storage, berries machine-harvested at high temperature (36°C) deteriorated more rapidly than hand-picked berries at the same temperature. Storage of machine-harvested fruit in 20% and 40% CO_2 at 20° for up to 48 hours maintained raw and processed quality. When mold counts were not excessive, the use of flavoring ingredients in the processed product resulted in acceptable products despite unacceptable raw product quality from some treatments. Use of high CO_2 storage atmospheres with fruit held at 20° partially offset the need for refrigeration to reduce postharvest quality loss.**

Due to extremely fragile structure and high rate of fruit respiration, the postharvest-life of *Rubus* fruit (blackberry and raspberry) is relatively short. Winter et al. (11) reported that fruit held under an initial concentration of 30% CO_2 for 4 to 6 hr had better quality than untreated fruits after an unspecified period of commercial shipping. When fruit were held in a constant 25% CO_2 atmosphere or with an initial CO_2 concentration of 45% that was not maintained, they developed off-flavors after 24 hr (10). The off-flavor disappeared within about 1 hr after removal from CO_2 storage. Storage of *Rubus* fruits has received little recent attention and with the advent of their mechanical harvest (5, 7), more information is needed regarding postharvest quality and handling of machine-harvested fruit (1, 2, 3, 6). The purpose of this study was to determine the influence of machine-harvesting, berry temperature at harvest, and postharvest storage conditions on blackberry quality.

Materials and Methods

Study 1. To determine the effects of harvest method, harvest temperature and postharvest holding time on fruit quality, 'Cherokee' blackberries were obtained from a 3-year-old commercial planting located 100 km from Fayetteville, Arkansas. Fruits were either hand-picked or machine-harvested with a University of Arkansas-Blueberry Equipment, Inc. commercial cane-fruit harvester (5). To obtain 2 different berry temperatures, fruits were harvested in the early morning (prior to 8 AM) and at midday (ca. 2 PM). Berry temperature, determined by inserting thermocouples into fruit, averaged 29 and 36°C, respectively. The harvested fruit, in 10 × 30 × 61-cm wooden field crates, was immediately transported at ambient temperature (35°C) from the commercial planting to the Main Experiment Station, Fayetteville, where they were held at 29° for 0, 12, 24, and 36 hr after arrival at the laboratory. The 29° temperature was selected for holding since it was representative of non-refrigerated holding areas in local processing plants. By the 12 hr sampling all fruit had equilibrated to the 29° holding temperature. After each sampling interval, a 150 g sample was frozen for later analyses, a 250 g sample was canned (4) in a R-enamel lined 303 × 406 can uniformly filled with 20° Brix syrup for later sensory evaluations, and a 450 g sample was frozen in a polyethylene bag and later used for preparing cobblers on a commercial processing line at Good Ole Days Foods in Little Rock, Arkansas. A patented mixture of spices and ingredients was added to the cobbler samples, which were placed in the baking shells and frozen for later sensory evaluation.

Study 2. To determine the effects of CO_2 atmosphere storage on fruit quality, machine-harvested 'Cherokee' blackberries were obtained from the same source as above. Two replicates of 1 kg each were placed into air-tight chambers equipped with ventilation ports and were ventilated with ambient air or with ambient air containing added CO_2 to produce 20% or 40% concentrations at 4° and 20°C. Flow rates were maintained at 6 l per hr. Samples were taken from the 20° storage treatments after 0, 24, 36, and 48 hr and from 4° after 48 hr. At the time of sampling, a visual rating of mold growth and an evaluation of fresh product sensory quality was made after the samples were aerated for 30 min. Samples for raw product quality and processed sensory quality were prepared as previously described.

Laboratory and sensory analyses. To determine objective quality, frozen samples were thawed in a warm water bath for 30 min and then blended with 4 drops of antifoam. Percent soluble solids was determined on a Bausch and Lomb refractometer. Acidity, expressed as % citric, was determined by titrating 5 g of puree, diluted to 125 ml with distilled water, to pH 7.0 with 0.1 N NaOH. Mold was determined by the Howard mold count technique (8). Color was measured on a Gardner Color and Color Difference Meter standardized to a dark red tile ("L"=23.1, "a"=22.0, and "b"=7.1). To determine total anthocyanin concentration, the puree was extracted with EtOH-HCl (pH 1.0) for 1 hr and filtered through facial tissue. Absorbance of the filtrate at 520 and 430 nm was determined on a Bausch and Lomb Spectronic 20 spectrophotometer which was standardized with distilled water. Total anthocyanin (TAcy) was calculated as absorbance at 520 nm × dilution factor. A degradation index (DI) was calculated by using the ratio of 520 to 430 nm absorbances (9).

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Ten trained panelists used a scale of 1 to 10 (10 = excellent, 5 = acceptable, and 1 = totally unacceptable) to rate both raw and processed fruit color intensity, lack of discoloration, wholeness, flavor, and mold (raw fruit only). Liquors from the processed products were rated for turbidity and color intensity. Gardner CDM, color, TAcy, and DI were determined on the processed fruits. About 125 g of the canned fruit was blended with 4 drops of antifoam, and color was measured on a Gardner CDM. A 5-ml aliquot of liquor was used to determine DI as previously described.

For sensory evaluations, frozen cobblers containing the experimental fruit samples were baked at 200°C for about 50 min in a conventional oven. After 25 min, samples were rotated to insure uniform baking conditions. The sensory panel rated the fruit for color acceptability, discoloration, wholeness, and flavor as previously described.

Statistical analyses. The data from Study 1 were analyzed as factorial analysis of variance with linear, quadratic and cubic effects of holding time isolated. The data from Study 2 were analyzed 2 ways. First, the 20°C holding temperature data were analyzed as factorial analysis of variance with the initial quality values excluded from the analysis. Linear and quadratic functions of storage atmosphere treatments and storage time were separated. This analysis indicated whether atmosphere, storage time or their interaction were significant. Secondly, only the 48 hr holding time data were analyzed with both 4°C and 20°C holding temperatures to determine if any atmosphere or temperature main effects or their interaction were present.

Results and Discussion

Study 1. The significant 3-way interaction among harvest method, temperature and holding time (Table 1) indicated a reduction in percent soluble solids (Table 2) of fruit machine-harvested at 36°C for a prolonged period. This loss of soluble solids was most likely the result of fermentations converting the sugars to alcohol. This response accounted for the significant main effects of harvest method and temperature.

Main effects indicated that titratable acidity was lower in machine-harvested fruit and that acidity decreased linearly with time (Tables 1 and 2). A significant 3-way interaction for titratable acidity showed that machine-harvested fruit was initially lower in acidity and that the subsequent rate of acid loss after harvest was less than that of hand-picked fruit. Fruit machine-harvested at 36°C showed a slight increase in acidity, probably due to the formation of volatile acids produced during fermentation under these conditions.

Main effects analysis on CDM "L" color (Table 1) indicated that the machine-harvested fruit averaged a slightly darker color (lower "L") (Table 2). The darker color and lower acidity of machine-harvested fruit agree with previous research (7) indicating that machine-harvested fruit is riper than hand picked fruit. Fruit picked at the cooler temperature maintained a darker color. Even though machine-harvested fruit had darker color, it lost color at a faster rate (increasing CDM "L") when picked at higher temperatures.

Discoloration was increased (lower DI) when fruit was picked at 36°C and showed a linear change with time. Main effect F-tests (Table 1) indicated that machine-harvested fruit was more discolored, but this was due primarily to the more detrimental effect of high temperatures when the fruit was machine-harvested.

After processing, the effects of the various treatments on color parameters were greater than on the raw product (Table 1). Total anthocyanin (TAcy) in the canned product was affected by harvest method and harvest temperature and showed a linear decrease with time (Tables 1 and 2). Although machine-harvested and hand-picked fruit had initially similar TAcy content, the former lost color faster and its rate of color loss was elevated by higher harvest temperatures. CDM "L" indicated that machine-harvested fruit was darker and discoloration measurements on the liquor indicated more discoloration (lower DI) due to machine harvesting, harvesting at higher temperatures, and holding for longer periods (Tables 1 and 2). Liquor from machine-harvested fruit was more discolored at the higher harvest temperature and discolored to a larger extent as the holding time increased. All of the main effects producing more discoloration appeared to be additive as indicated by the significant interaction F-tests (Table 1). These relationships were similar to TAcy determinations with regard to both treatment means and treatment significance.

Sensory evaluations of the canned blackberries (Table 3 and 4) indicated that processed quality was generally poorer when fruit

Table 1. F-test values for effects of harvest method, harvest temperature, and holding time on raw and canned quality of 'Cherokee' balckberries.

Parameter	Soluble solids (%)	Tit. acidity (%)	Color: Raw product CDM L	Raw product DI	Canned product TAcy	Canned product CDM L	Canned product DI
Main effects							
Harvest method	60.2***[z]	30.9***	7.7*	10.8**	81.6***	40.1***	210.4***
Harvest temp.	4.4*	0.2	8.2*	8.9**	49.9***	0.2	37.6***
Holding time	1.7	5.4*	1.0	4.2*	57.4***	0.9	87.3***
Linear	3.8	11.6**	2.3	8.2**	171.5***	2.1	261.2***
Quadratic	1.3	2.2	0.1	0.6	0.7	0.5	0.3
Cubic	0.0	2.2	0.7	3.8	0.1	0.0	0.4
Interactions							
Method x temp.	4.1	0.5	4.9*	8.2*	33.5***	2.1	26.7***
Temp. x time	2.3	4.1*	2.2	0.5	5.4*	0.5	5.6**
Method x time	2.4	11.1***	15.2***	0.0	17.8***	1.6	10.6***
Method x temp. x time	3.2*	4.2*	1.8	2.4	4.8*	1.3	4.9*

[z]Significance at 5% (*), 1% (**) or 0.1% (***) level.

Table 2. Effects of harvest method, harvest temperature, and holding time on raw and canned quality of 'Cherokee' blackberries.

Treatment				Color				
				Raw product[z]		Canned product[y]		
Harvest method & temp.	Holding time (hr)	Soluble solids (%)	Tit. acid (%)	CDM L	DI	TAcy	CDM L	DI
Hand								
29°	0	10.9	0.63	11.5	3.42	23.9	15.5	3.47
	12	10.9	0.63	12.1	3.54	21.1	16.3	3.21
	24	10.8	0.48	10.8	2.93	21.1	16.3	2.97
	36	10.8	0.48	10.8	3.15	20.8	15.6	2.84
36°	0	10.9	0.63	11.5	3.42	23.9	15.5	3.47
	12	10.7	0.56	11.8	3.32	20.8	15.7	3.17
	24	10.7	0.51	11.3	3.13	21.4	15.0	3.04
	36	10.9	0.48	11.0	3.12	18.5	15.0	2.63
Machine								
29°	0	10.6	0.54	10.6	3.42	23.2	12.9	3.05
	12	10.4	0.45	10.0	3.20	23.2	12.9	2.91
	24	10.2	0.42	10.8	3.30	19.6	13.2	2.62
	36	9.9	0.48	11.2	2.97	14.9	13.0	2.07
36°	0	10.2	0.47	10.3	2.81	22.9	11.8	2.99
	12	9.6	0.47	11.0	2.96	16.9	12.6	2.58
	24	9.5	0.50	11.7	2.16	10.1	14.4	1.61
	36	8.3	0.54	12.3	2.73	8.1	14.4	1.23

[z]Gardner CDM standardized to a dark red tile ("L"=23.1, "a"=22.0, "b"=7.1). TAcy=Absorbance units of acidified ethanol extract (pH 1.0) at 520 nm/g of fruit. DI=Abs. $_{520}$ nm/Abs. $_{430}$ nm.
[y]TAcy and CDM "L" determined on pureed fruit. DI determined using liquor. A lower DI indicates greater discoloration.

was machine-harvested or harvested at the higher temperature. Although these main effects were significant, interactions indicated little difference between the 2 methods of harvesting or the 2 harvest temperatures. Most quality attributes of fruit machine-harvested at 29°C were very similar to those of the fruit hand-picked at either temperature. However, fruit machine-harvested at 36° declined in sensory quality at a much faster rate than did machine-harvested fruit at 29° or any of the hand picked treatments.

Blackberries from both harvest methods and harvest temperatures had acceptable raw and processed quality prior to postharvest holding. After 24 hr holding, fruit machine harvested at 36°C was always rated unacceptable in quality. Fruit machine-harvested at 29° retained marginally acceptable quality after 36 hr, whereas, hand-picked fruit at both temperatures was always rated within the acceptable range after 36 hr holding. The more rapid quality loss of machine-harvested compared to hand-picked fruit at high temperatures supports possible benefits of night harvesting during hot seasons to help preserve fruit quality during transit.

Study 2. At 20°C, increasing the CO_2 concentration in the storage atmosphere linearly reduced mold content determined by the Howard mold count technique and improved visual ratings of

Table 3. F-test values for effects of harvest method, harvest temperature, and holding time on sensory evaluations of canned 'Cherokee' blackberries.

	Fruit				Liquor	
Parameter	Color intensity	Lack of discoloration	Wholeness	Flavor	Color intensity	Turbidity
Main effects						
Harvest method	66.9***[z]	116.9***	32.5***	69.1***	187.3***	23.4***
Harvest temp.	63.3***	38.0***	27.2***	28.7***	66.3***	26.9***
Holding time	31.3***	49.1***	38.6***	29.5***	75.5***	42.1***
Linear	85.9***	144.5***	107.5***	85.1***	217.3***	117.0***
Quadratic	7.9**	2.4	8.3**	2.4	3.0	9.1**
Cubic	0.1	0.4	0.1	0.9	6.4*	0.1
Interactions						
Method x temp.	76.5***	27.5***	27.9***	31.9***	45.7***	22.8***
Temp. x time	8.2**	10.6***	5.2*	8.5**	13.3***	7.8**
Method x time	22.2***	10.2***	2.1	3.4*	41.5***	2.1
Method x temp. x time	9.3***	8.7**	7.5**	9.7***	15.5***	4.9*

[z]Significance at 5% (*), 1% (**) or 0.1% (***) level.

Table 4. Effects of harvest method, harvest temperature, and holding time on sensory evaluations of canned 'Cherokee' blackberries.[z]

Treatment		Fruit				Liquor	
Harvest method & temp.	Holding time (hr)	Color intensity	Lack of discoloration	Wholeness	Flavor	Color intensity	Turbidity
Hand							
29°	0	7.3	8.2	8.5	8.2	8.0	8.7
	12	7.6	7.9	8.5	8.0	8.0	8.4
	24	7.4	7.3	7.8	7.0	7.5	7.6
	36	7.2	6.8	6.0	6.6	7.5	6.7
36°	0	7.3	8.2	8.5	8.2	8.0	8.7
	12	7.7	7.7	8.1	7.9	7.6	8.5
	24	7.6	7.3	8.0	7.5	7.6	7.8
	36	7.2	6.4	6.2	6.4	7.0	6.0
Machine							
29°	0	7.8	7.3	7.8	7.1	7.9	8.4
	12	7.7	6.8	8.2	7.0	7.4	8.0
	24	7.6	6.9	7.7	7.3	7.1	8.1
	36	6.6	5.3	6.8	6.1	4.6	6.8
36°	0	7.4	7.3	8.0	7.2	7.5	8.0
	12	6.5	6.5	7.0	6.6	7.1	7.7
	24	4.3	3.0	5.2	2.9	2.3	4.8
	36	3.4	1.3	2.6	1.4	1.6	2.3

[z]All attributes were rated on a scale of 1 to 10 with 10=excellent, 5=minimum acceptability, and 1=totally unacceptable.

mold control (Tables 5 and 6). A slight but significant decline in TAcy occurred at the 40% CO_2 concentration. Storage atmosphere had no effect on % soluble solids or titratable acidity. Discoloration (DI) and the sensory evaluations or color intensity, wholeness, flavor and general appearance showed quadratic relationships (Table 5) with atmospheric CO_2 content. The 40% concentration was most beneficial in maintaining sensory ratings and 20% CO_2 was of little benefit compared to the ambient atmosphere (Table 6).

Most quality attributes that changed during storage exhibited a linear relationship with time (Tables 5 and 6). However, the rate of fruit discoloration and loss of visual color intensity were not totally linear. Discoloration did not change dramatically until 48 hr holding and loss of color intensity was most rapid between 24 and 36 hr. The 2-way interaction of storage atmosphere and time indicated that the 40% CO_2 concentration was most effective in maintaining visual mold control and preventing discoloration and loss of color intensity at the longer storage time.

Storage atmosphere had no effect on objective color measurements of the blackberry fruit after processing (Tables 7 and 8). However, sensory evaluations of both the fruit and liquor indicated that CO_2 in the storage atmosphere maintained better quality. This maintenance of sensory quality during storage showed a linear relationship with CO_2 concentration in the storage atmosphere. As expected, most objective and sensory quality parameters of the canned product showed linear deterioration with time. However, rate of discoloration, both objective and sensory, and loss of fruit wholeness and liquor color intensity showed quadratic relationships with time and changes were most rapid after 36 hr holding. The significant storage atmosphere and storage time interactions on discoloration, wholeness, flavor, and li-

Table 5. F-test values of the effects of storage atmosphere and holding time on raw product quality of machine harvested 'Cherokee' blackberries held at 20°C.

Parameter	Mold (%)	Visual control of mold	Soluble solids (%)	Tit. acidity (%)	Color			Sensory evaluation			
					CDM L	TAcy	DI	Color intensity	Wholeness	Flavor	General appearance
Main effects											
Atmosphere	2.7	48.0***[z]	0.1	1.1	2.1	3.0	3.3	15.1**	32.9***	14.7**	17.4**
Linear	5.4*	9.7**	0.0	0.8	4.2	5.9*	1.9	22.6***	61.3***	22.1***	28.3***
Quadratic	0.0	0.6	0.1	1.4	0.0	0.0	4.6*	7.5*	4.6*	7.4*	6.5*
Time	9.7**	74.8***	2.9	0.5	1.8	2.5	22.3***	16.0**	16.6**	21.3***	13.1**
Linear	19.4***	149.6***	5.6*	0.4	1.7	3.0	30.5***	16.6***	32.9***	39.2***	25.9***
Quadratic	0.0	0.0	0.2	0.7	1.9	1.9	14.2**	15.4**	0.1	3.3	0.3
Interaction											
Atm. x time	1.1	9.2**	2.8	0.5	1.2	1.6	4.9*	6.8*	3.5	3.3	2.2

[z]Significance at 5% (*), 1% (**) or 0.1% (***) level.

Table 6. Effects of storage atmosphere and holding time on raw product quality of machine harvested 'Cherokee' blackberries held at 20°C.

Storage atm. & time (hr)	Mold (%)	Visual control of mold[z]	Soluble solids (%)	Tit. acidity (%)	Color[y] CDM L	Color[y] TAcy	Color[y] DI	Sensory evaluation[z] Color intensity	Sensory evaluation[z] Wholeness	Sensory evaluation[z] Flavor	Sensory evaluation[z] General appearance
Initial	8	10	10.4	.71	10.0	33.0	3.68	----	----	----	----
Ambient											
24	30	8	10.4	.63	9.8	27.8	3.75	6.0	5.0	5.0	5.5
36	42	4	10.1	.59	10.7	28.5	3.70	5.0	4.0	4.0	4.5
48	60	1	8.3	.62	10.1	28.5	3.28	5.0	3.0	3.0	3.0
20% CO_2											
24	22	10	9.5	.66	10.2	28.5	3.74	7.0	6.0	6.0	6.0
36	44	6	9.2	.66	10.7	28.5	3.68	4.0	5.0	3.0	4.0
48	48	1	9.7	.66	10.4	28.5	3.08	5.0	3.0	3.0	3.5
40% CO_2											
24	28	10	9.8	.62	10.6	27.0	3.59	6.5	7.0	6.0	6.5
36	28	9	9.6	.62	10.5	27.8	3.79	6.5	6.0	5.5	5.3
48	40	8	9.4	.69	10.9	25.5	3.62	6.5	6.5	5.0	6.0

[z]Rated on a scale of 1 to 10 with 10=excellent, 5=minimum acceptability, 1=totally unacceptable.
[y]Gardner CDM standardized to a dark red tile ("L"=23.1, "a"=22.0, and "b"=7.1). TAcy = Absorbance units of acidified ethanol extract (pH 1.0) at 520 nm/g of fruit. DI = Abs. $_{520}$ nm/Abs. $_{430}$ nm.

quor turbidity demonstrated the beneficial effects of CO_2 during extended holding periods.

Sensory evaluation of commercially processed cobblers using the experimental fruit samples indicated a linear relationship between CO_2 concentration in the storage atmosphere and maintenance of processed quality, except for flavor, during postharvest holding (Tables 9 and 10). However, attributes were rated acceptable for all treatments even after 48 hr holding. The use of flavoring ingredients in these processed cobblers resulted in acceptable flavor ratings despite unacceptable raw product quality from some treatments. Wholeness and flavor ratings declined as a linear function of time, but decline in color intensity and increased discoloration with time were not linear, showing rapid changes only after 36 hr holding.

Comparing the effects of 2 storage temperatures (4° and 20°C) after 48 hr holding under the different CO_2 atmospheres (Tables 11 and 12) showed that the lower temperature reduced mold counts, improved visual ratings of mold control, and resulted in higher soluble solids and sensory evaluation ratings. The interaction of temperature and atmosphere was significant, indicating that high CO_2 concentration in the storage atmosphere at 20°C could partially substitute for refrigeration during postharvest holding in ambient atmosphere. Many raw product quality values of samples stored in 4° ambient atmosphere and ones stored at 20°C under high CO_2 atmospheres were similar. These effects were present in the canned product as well as cobblers (data not shown).

Conclusions

Blackberries hand-picked at 29 and 36°C and ones machine-harvested at 29° had minimal changes in raw product quality during storage at 29° for up to 36 hr. Blackberries that were machine-harvested at 36° deteriorated at a more rapid rate. Machine-harvesting at the lowest possible temperature would be advantageous for maintaining fruit quality during handling and storage. In southern production areas, this may require night or early morning harvesting after the field heat has dissipated from the berries. The removal of the field heat from the berries immediately after har-

Table 7. F-test values of the effects of storage atmosphere and holding time on objective color and sensory evaluations of canned machine harvested 'Cherokee' blackberries held at 20°C.

Parameter	Objective color CDM L	Objective color TAcy	Objective color DI	Fruit Color intensity	Fruit Lack of discoloration	Fruit Wholeness	Fruit Flavor	Liquor Color intensity	Liquor Turbidity
Main effects									
Atmosphere	1.9	1.5	2.6	4.3	8.3*[z]	8.5*	8.1*	4.1	6.2*
Linear	3.4	3.0	4.5	7.6*	15.4**	14.5**	14.7**	7.4*	11.8**
Quadratic	0.5	0.0	0.8	1.1	1.2	2.5	1.4	0.8	0.7
Time	12.5**	26.5***	24.4***	13.3**	42.9***	30.0***	28.9***	24.1***	44.5***
Linear	23.3***	51.0***	43.2***	26.6***	71.5***	55.2***	55.8***	42.4***	86.4***
Quadratic	1.6	2.0	6.4*	0.0	14.3**	4.7*	2.0	5.7*	2.5
Interaction									
Atm. x time	3.9	1.0	2.3	2.2	4.3*	4.0*	4.1*	0.7	4.1*

[z]Significance at 5% (*), 1% (**) or 0.1% (***) level.

Table 8. Effects of storage atmosphere and holding time on objective color and sensory evaluations of canned machine harvested 'Cherokee' blackberries held at 20°C.[z]

Storage atm. & time (hr)	Objective color[y] CDM L	TAcy	DI	Fruit Color intensity	Lack of discoloration	Wholeness	Flavor	Liquor Color intensity	Turbidity
Initial	6.3	9.6	2.28	7.5	7.2	7.5	7.6	8.6	8.1
Ambient									
24	6.2	8.2	2.03	7.3	7.4	7.5	7.6	7.5	7.5
36	6.5	6.5	1.61	6.6	6.1	6.1	6.2	6.6	6.2
48	7.3	5.1	1.39	4.9	4.5	3.0	4.5	3.9	4.2
20% CO_2									
24	6.9	8.8	2.09	7.6	7.2	7.2	7.0	8.3	7.3
36	6.6	7.3	2.09	6.7	7.0	7.0	6.9	7.4	6.4
48	6.5	5.2	1.35	6.6	5.3	5.7	6.3	5.5	5.9
40% CO_2									
24	6.4	7.9	1.97	7.6	7.0	7.5	7.5	7.8	7.4
36	6.3	8.1	2.09	6.9	7.6	7.3	7.4	7.8	7.3
48	6.7	5.9	1.55	6.6	6.1	5.9	6.2	5.8	5.6

[z]Fruits were processed in 20° Brix syrup. All sensory attributes were rated on a scale of 1-10 with 10=excellent, 5=minimum acceptability, and 1=totally unacceptable.
[y]TAcy and CDM "L" were determined on puree of the fruits. DI was determined on the liquor.

Table 9. F-test values of the effects of storage atmosphere and holding time on sensory evaluations of cobblers made from machine harvested 'Cherokee' blackberries held at 20°C.

Parameter	Color intensity	Lack of discoloration	Wholeness	Flavor	Average of all scores
Main effects					
Atmosphere	3.0	6.1*[z]	6.5*	0.4	5.6*
Linear	4.8*	12.2**	12.9**	0.8	10.9**
Quadratic	1.1	0.0	0.2	0.0	0.3
Time	27.8***	63.8***	13.4**	6.9*	38.9***
Linear	46.4***	105.0***	23.5***	10.7**	64.6***
Quadratic	9.4**	22.9***	3.3	3.0	13.4**
Interaction					
Atm. x time	1.4	1.9	2.0	0.4	1.7

[z]Significance at 5% (*), 1% (**) or 0.1% (***) level.

Table 10. Effects of storage atmosphere and holding time on sensory evaluations of cobblers made from machine harvested 'Cherokee' blackberries held at 20°C.[z]

Storage atm. & time (hr)	Color intensity	Lack of discoloration	Wholeness	Flavor	Average of all scores
Initial	7.4	8.0	7.9	7.2	7.6
Ambient					
24	7.7	7.8	7.6	7.2	7.6
36	7.4	7.4	5.7	7.0	6.9
48	5.4	5.0	5.1	5.6	5.3
20% CO_2					
24	7.6	7.7	7.4	7.1	7.5
36	7.7	7.6	7.3	7.5	7.5
48	6.6	6.1	6.6	6.8	6.5
40% CO_2					
24	8.0	8.1	7.7	7.4	7.8
36	7.7	8.0	8.0	7.1	7.7
48	6.8	6.3	6.8	6.4	6.6

[z]All sensory attributes were rated on a scale of 1-10 with 10=excellent, 5=minimum acceptability, and 1=totally unacceptable.

Table 11. F-test values on the effects of storage temperature and atmosphere on raw product quality of machine harvested 'Cherokee' blackberries held for 48 hr.

Parameter	Mold (%)	Visual control of mold	Soluble solids (%)	Tit. acidity (%)	Color CDM L	Color TAcy	Color DI	Sensory evaluation Color intensity	Sensory evaluation Whole-ness	Sensory evaluation Flavor	Sensory evaluation General appearance
Main effects											
Temperature	125.0***[z]	400.0***	7.6*	0.5	3.8	2.7	0.2	9.0*	169.0***	49.0***	36.0**
Atmosphere	31.8**	49.0***	2.6	2.4	3.3	8.9*	9.2*	9.0*	93.0***	4.0	12.3*
Linear	602.1***	73.6***	3.4	4.5	36.0***	0.2	177.4***	44.3***	79.0***	6.0*	24.0***
Quadratic	34.0***	24.5***	1.7	0.2	5.4*	7.6*	799.5***	14.8**	1.9	2.0	0.5
Interaction											
Temp. x atm.	1.3	49.0***	7.1	0.1	1.3	11.3*	1.5	9.0*	37.0***	4.0*	5.3*

[z]Significance at 5% (*), 1% (**) or 0.1% (***) level.

Table 12. Effects of storage temperature and atmosphere on raw product quality of machine harvested 'Cherokee' blackberries held for 48 hr.

Storage temp. & atm.	Mold (%)	Visual control of mold[z]	Soluble solids (%)	Tit. acidity (%)	Color[y] CDM L	Color[y] TAcy	Color[y] DI	Sensory evaluation[z] Color intensity	Sensory evaluation[z] Whole-ness	Sensory evaluation[z] Flavor	Sensory evaluation[z] General appearance
Initial	8	10	10.4	.71	10.0	33.0	3.68	----	----	----	----
4°C											
Ambient	38	10	9.8	.59	9.7	27.0	3.45	6.0	5.0	6.0	5.5
20% CO_2	26	10	9.6	.66	10.4	25.5	3.17	6.0	7.0	6.0	6.5
40% CO_2	24	10	9.4	.66	10.1	29.9	3.46	6.0	7.0	6.0	6.5
20°											
Ambient	60	1	8.3	.62	10.1	28.5	3.28	5.0	3.0	3.0	3.0
20% CO_2	48	1	9.7	.66	10.4	28.5	3.08	5.0	3.0	3.0	3.5
40% CO_2	40	8	9.6	.69	10.9	25.5	3.62	6.5	6.5	5.0	6.0

[z]Rated on a scale of 1 to 10 with 10=excellent, 5=minimum acceptability, 1=totally unacceptable.
[y]Gardner CDM standardized to a dark red tile ("L"=23.1, "a"=22.0, and "b"=7.1). TAcy=Absorbance units of acidified ethanol extract (pH 1.0) at 520 nm/g of fruit. DI=Abs. $_{520}$ nm/Abs. $_{430}$ nm.

vest by refrigerated storage or the maintenance of continuous flow, high CO_2 atmospheres (20 to 40%) can be used to prolong postharvest quality of machine-harvested blackberries under southern conditions.

Processing the berries using sugar or making cobblers using sugar and flavoring ingredients resulted in product acceptability of fruit from harvest and holding treatments which produced unacceptable raw product quality. However, other quality parameters such as excessive mold counts in the raw product could prevent utilization of these berries.

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