Low-Oxygen or High-Carbon Dioxide Atmospheres to Control Postharvest Decay of Strawberries

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ABSTRACT

Decay of fresh strawberries caused by *Botrytis cinerea* and *Rhizopus stolonifer* was reduced by lowered O_2 concentration or by increased CO_2 concentration. These effects were observed after a 36-hr exposure at 15 C, and persisted for an additional 24 hr at 15 C in air. Oxygen levels which reduced decay also caused objectionable off-flavors. Off-flavors caused by CO_2 were detected only at 30% CO_2, and did not persist. Phytopathology 60: 47-49.

The use of low-oxygen atmospheres to control ripening and decay of fresh commodities during transport has gained limited commercial application due to the availability of liquid nitrogen for use as a refrigerant and as a means of reducing the level of oxygen in the atmosphere. Previous research showed that strawberries (*Fragaria chiloensis* Duchesne var. *ananassa* Bailey) developed off-flavors at oxygen concentrations that significantly reduced decay during a 5-day simulated rail shipment at 3 C (1). Since commercial equipment is now available which might permit the use of modified atmospheres for air shipment of strawberries, we have tested the effects of low-oxygen atmospheres on decay under conditions approximating those of air transport.

High-carbon dioxide (CO_2) atmospheres have been used successfully during air transit to retard ripening and the development of decay in strawberries (2, 3, 4). To obtain data under more controlled conditions, we included a series of high-CO_2 atmospheres in these tests.

Materials and Methods.—Strawberries of Fresno, Tioga, Solano, and Z5A cultivars were obtained from various growing areas in California, and were placed under experimental conditions on the day of harvest. Experimental methods and data-handling procedures used in this study were identical to those described in a previous report (1), except that the berries were exposed to the modified atmospheres under simulated transit conditions of 34-36 hr at 15 C. The flow rate of gases through the controlled-atmosphere chamber was equivalent to one air change per hr for the first 18 hr, after which it was reduced to about one air change every 2 hr.

Taste panel scores were based on paired samples. The preferred sample was given a value of 1 and the other 0. When ties occurred, each sample was given a score of 0.5. These data were analyzed by calculation of Kendall's coefficient of concordance (6).

Results and Discussion.—Grey mold rot (*Botrytis cinerea* Pers. ex Fr.) and, to a lesser extent, Rhizopus rot (*Rhizopus stolonifer* [Ehr. ex Fr.] Lind) was reduced significantly by lowered oxygen concentrations or by raised CO_2 levels (Table 1). Treatment effects on decay were apparent at the first examination, and also after the berries were held for 24 additional hr in air.

The individual preferences of the tasters indicate not only the differences among treatments, but also the differences among tasters. It would be valid to consider the individual preferences in evaluating the treatments, but it seemed easier to group together those tasters with similar preferences, and to discuss them in this way. Combining of unlike preferences tended to obscure the differences that were evident when the preferences of individuals were considered. With one exception, the tasters who disliked the berries from low-oxygen treatments also disliked the berries from the high CO_2 treatments.

When tasting berries from high-CO_2 treatments, Group I tasters consistently objected at the first examination to berries that had been treated with 30% CO_2, but at the second examination there were no significant preferences (Table 2). This finding would suggest the disappearance of off-flavors induced by the 30% CO_2 treatment, or that there was a flavor loss among all treatments by the time of the second examination. Disappearance of off-flavors induced by high CO_2 has been observed with cauliflower (5). Group II tasters failed to show strong preferences at the first examination, but preferred the high-CO_2 treatments to the checks at the second examination.

Immediately after berries were removed from low-oxygen atmospheres, Group I tasters preferred the nontreated berries to any with low-oxygen treatment, while Group II tasters preferred the berries held in 1% oxygen (Table 3). At the second examination, the Group I tasters preferred the nontreated berries and the 1%-oxygen treatment, while Group II showed no statistically significant preference. Unlike berries exposed to high CO_2, not all the berries subjected to reduced oxygen lost off-flavors after 24 hr in air. Judging from the response of the Group I tasters, treatments of 0.5% oxygen or lower resulted in persisting off-flavors.

Although low-oxygen atmospheres retard decay during simulated air transit, the method cannot be recommended for strawberries because of the unpleasant off-flavors that develop. Carbon dioxide atmospheres of 10-20% retard decay without causing off-flavors. Off-flavors produced at 30% CO_2 tend to disappear, and would probably not be important commercially.

TABLE 1. Per cent of strawberries decayed after 34-36 hr at 15 C in low-oxygen or high carbon dioxide atmospheres (Examination 1), and after an additional 24 hr in normal air atmospheres (Examination 2)

	Decay at indicated atmospheres										
	Oxygen concn.					Geometric mean	Carbon dioxide concentration				Geometric mean
Type of decay	21	1.00	0.50	0.25	0.00		0	10	20	30	
	%	%	%	%	%	%	%	%	%	%	%
Rhizopus rot											
Exam. 1	10.0[a]	6.5	8.0	8.1	4.8	7.4 a	5.3[b]	3.9	4.5	3.8	4.4 a
Exam. 2	14.1	6.6	9.9	10.1	8.2	9.4 b	12.4	7.4	7.1	5.5	7.8 b
Geometric mean	12.2[c] a	6.5 b	8.9 ab	9.0 ab	6.3 b		8.4 a	5.4 b	5.7 ab	4.5 b	
Gray mold rot											
Exam. 1	2.5	1.5	1.4	0.6	0.9	1.3 a	2.3	1.5	0.7	0.7	1.2 a
Exam. 2	7.9	2.6	2.7	3.5	1.3	3.1 b	5.0	3.6	2.3	1.4	2.8 b
Geometric mean	4.5 a	2.0 b	2.0 b	1.7 b	1.1 b		3.5 a	2.4 a	1.4 b	1.0 b	
Total decay	16.7	8.5	10.9	10.7	7.4		11.9	7.8	7.1	5.5	

[a] Values represent adjusted geometric means of four repetitions of an incomplete block design having four replications.
[b] Values represent adjusted geometric means of four repetitions of an incomplete block design having three replications.
[c] Means not followed by the same letter are significantly different at the 5% level.

TABLE 2. Taste preferences for strawberries held at different concentrations of carbon dioxide for 34-36 hr at 15 C (Examination 1) and for an additional 24 hr in air (Examination 2)

		Taste preferences at indicated carbon dioxide concentration				Statistical significance[b]	
Taster[a] group	Exam.	0%	10%	20%	30%	W[b]	F
		no.	*no.*	*no.*	*no.*		
I	1	24.0[c]	22.0	23.0	3.0	0.419	13.64**
	2	10.5	13.0	13.0	11.5	0.014	0.17
II	1	21.0	27.0	26.5	21.5	0.024	0.63
	2	11.0	23.0	19.0	31.0	0.212	5.98**
Total I		34.5	35.0	36.0	14.5	0.161	6.40**
Total II		32.0	50.0	45.5	52.5	0.056	2.89*
	Total 1	45.0	49.0	49.5	24.5	0.107	8.40**
	Total 2	21.5	36.0	32.0	42.5	0.096	3.79*
Total of all groups and examinations		66.5	85.0	81.5	67.0	0.020	1.64

[a] Group I contained four tasters; Group II, five tasters.
[b] W is Kendall's coefficient of concordance.
[c] Values represent total preferences when compared to each of the other treatments individually. * = Significant at the 5% level. ** = Significant at the 1% level.

TABLE 3. Taste preferences for strawberries held at different concentrations of oxygen for 34-36 hr at 15 C (Examination 1) and for an additional 24 hr in air (Examination 2)

		Taste preferences at indicated oxygen concentration					Statistical significance[b]	
Taster[a] group	Exam.	0%	0.25%	0.50%	1%	21%	W[b]	F
		no.	*no.*	*no.*	*no.*	*no.*		
I	1	15.0[c]	22.0	25.0	38.0	50.0	0.346	15.32**
	2	5.5	13.5	24.5	33.5	33.0	0.499	20.92**
II	1	24.5	30.0	37.5	43.5	34.5	0.072	2.55*
	2	18.0	13.5	27.5	21.0	20.0	0.104	2.19
Total I		20.5	35.5	49.5	71.5	83.0	0.386	32.10**
Total II		42.5	43.5	65.0	64.5	54.5	0.065	3.68
	Total 1	39.5	52.0	62.5	81.5	84.5	0.133	10.48**
	Total 2	23.5	27.0	52.0	54.5	53.0	0.214	11.18**
Total of all groups and examinations		63.0	79.0	114.5	136.0	137.5	0.162	20.26**

[a] Each group contained six tasters.
[b] W is Kendall's coefficient of concordance.
[c] Values represent total preferences when compared to each of the other treatments individually. * = Significant at the 5% level. ** = Significant at the 1% level.

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