Changes in Sensory Quality of Sterile Cantaloupe Dice Stored in Controlled Atmospheres

R.E. O'CONNOR-SHAW, R. ROBERTS, A.L. FORD, and S.M. NOTTINGHAM

ABSTRACT

Diced cantaloupe flesh that was microbiologically sterile was prepared to study the physiological deterioration of fruit when stored under a range of controlled atmospheres at 4.5°C. Sterile fruit pieces were prepared by boiling whole melons for 3 min, then dicing aseptically. Storage atmospheres were in continuous flow and contained from 0 to 26% CO_2 and 3.5 to 17% O_2. Sensory assessments were carried out by a highly trained panel at 14 day intervals. Acceptable product up to 28 days was obtained for three treatments: 6% CO_2 and 6% O_2, 9.5% CO_2 and 3.5% O_2, and 15% CO_2 and 6% O_2. Overall treatment with 0, 19.5 or 26% CO_2 (irrespective of O_2 concentration) caused significant deterioration in sensory characteristics.

Key Words: aseptic packaging, cantaloupe, fruit pieces, sensory quality

INTRODUCTION

SHELF-LIFE OF WHOLE and minimally processed fruit and vegetables can be greatly extended by altering the proportions of atmospheric gases in controlled atmosphere (CA) storage or modified atmosphere packaging (MAP). Shelf-life is generally extended through inhibition of respiration and ethylene production, which slows deteriorative changes of senescence (Huxsoll and Bolin, 1989; O'Connor et al., 1992; Shewfelt, 1986; Watada et al., 1990). A variety of disorders, including development of off-flavors, can result if product is exposed to O_2 concentrations below, or CO_2 concentrations above, certain threshholds (Brecht, 1980; Kader et al., 1989; Rolle and Chism, 1987). The additional shelf-life gained through use of controlled atmospheres depends upon factors including cultivar, physiological age, quality, degree of processing, storage conditions and microflora (Brecht, 1980; Harvey, 1978, Kader et al., 1989; Wills et al., 1989).

One to 20% CO_2 and 2 to 5% O_2 are used for CA storage of whole fruit. Little information is available on ideal atmospheric storage conditions for minimally processed fruit. In a patent application, Powrie et al. (1988) have claimed a shelf-life of 12 wk at 1°C for sliced melon, using MAP and gas impermeable containers. However, no details were given about melon cultivar or initial atmospheres. O'Connor-Shaw et al. (1995) reported that a significant reduction occurred in "typical" flavor of cantaloupe pieces stored in air at 4°C during 4 days storage.

In our unpublished preliminary experiments, cantaloupe dice were prepared using good manufacturing practices and stored in CA under 0 to 27% CO_2 and 3 to 16% O_2 at 5°C. Results indicated that despite low initial total microorganism and yeast counts, 1.2×10^3 and 1.3×10^2 CFU/g respectively, colonies were visible on fruit after 17 day storage. High CO_2 levels inhibited for 14 days the growth on standard methods agar of an inoculum of 10^3 CFU/g obtained by washing cantaloupe flesh with sterile diluent. This inhibition lost its effect after 21 days.

The effect of these levels of CO_2 and O_2 on microbial growth rates is not clear from published results. Lund (1982) reported that a reduction of O_2 concentrations to ≤5% was generally required before growth of aerobic bacteria was affected. Anaerobes range widely in sensitivity to O_2 from strict anaerobes incapable of growth at O_2 concentrations of <0.5% to moderate anaerobes capable of growth at 8% (Loesche, 1969; Morris, 1976). However, it is unclear whether molecular O_2 or adverse redox potential inhibits anaerobic growth (Hentges and Maier, 1972; Lund et al., 1984). Carbon dioxide concentrations of 5% are optimal for growth of microorganisms (Meynell and Meynell, 1975), but concentrations of 25% decrease growth rates (Farber, 1991, Labuza and Breene, 1989). General mechanisms for CO_2 inhibition have not been reported (Jones, 1989; Leeson, 1987; Silliker and Wolfe, 1980). These results have suggested that atmospheres used for CA storage of fruit were not low enough in O_2 or high enough in CO_2 to inhibit growth of spoilage microorganisms. Thus microbial spoilage appears to be a limiting factor for shelf-life of fruit pieces stored in CA conditions.

Deterioration of minimally processed fruit occurs by inherent enzymic and microbiological mechanisms which operate simultaneously. In order to separate these two processes, we have used sterile fruit flesh. Our objective was to place sterile cantaloupe dice under CA storage in atmospheres consisting of 0 to 26% CO_2 and 3.5 to 17% O_2 at 4.5°C for 28 days to establish conditions which would give a 28 day shelf-life.

MATERIALS & METHODS

Experimental design

Cantaloupe pieces were prepared, stored and presented for sensory analysis according to an alpha design. This form of incomplete block design consisted of 40 treatments (36 atmospheric conditions different from air and four air treatments) with a block size of five (i.e. melons were processed and tested five at a time) and replicated three times. The design of the experiment was chosen to adjust for the effects of a range of variables including age of fruit and period of laboratory storage before testing. Past experience had shown it was possible to store melons for 14 days at temperatures between 2 and 5°C with only slight losses in sensory quality.

Fruit preparation

At the start of each trial, 40 Eastern Star cultivar cantaloupes were purchased at a local market from a single grower. Melons were stored at 4.5°C before dicing. Each melon was processed individually and at no stage was dice from one fruit mixed with that from another. Cantaloupes were immersed separately in boiling water for 3 min. From that point, all equipment was autoclaved, or sanitized by immersion in 200 ppm chlorine solution for 18 hr, operators wore gloves which were changed as necessary, and procedures were carried out in a laminar flow cabinet. Each melon was removed from boiling water and placed in a bag. The bag was sealed and immersed in iced water for 8 to 10 min. Each melon was removed from the bag and placed in a sterile cup in laminar air flow for 30 min to dry the skin.

A small piece of skin (about 35 mm diam) was removed to form a "window" through which a knife could be inserted into the flesh. Using a fresh knife, each melon was cut in half along the longitudinal axis. After removing seeds with a spoon, each half was cut longitudinally into six slices. Each slice was cut into triangular end pieces and seven or eight equally sized dice (≈8.5g) by first making a series of cuts perpendicular to the skin but not contacting it, and then by cutting parallel to the skin. A fresh knife was used if the skin was touched during cutting.

The authors are affiliated with the Centre for Food Technology, Queensland Department of Primary Industries, 19 Hercules Street, Hamilton, Brisbane, QLD 4007, Australia. Address inquiries to Mr. S.M. Nottingham.

Table 1—Attributes and descriptors used to describe the sensory characteristics of diced cantaloupe

Attribute	Scale end points 0	100	Descriptors
Appearance quality	extremely poor	extremely good	bruised, damaged, dark, dry, discolored, fragmented, moldy, mushy, pale, slimy, squashed, tired, translucent, uneven color, other, normal
Odor intensity	none	very strong	bland, earthy, fermented, fresh, moldy, musty, perfumy, solvent, sour, stale, typical, vegetable, yeasty, other
Flavor quality	extremely poor	extremely good	bitter, characteristic, chemical, earthy, fermented, fresh, lacking, musty, perfumy, sickly, solvent, sour, stale, other
sweetness	none	extremely sweet	
Texture quality	extremely poor	extremely good	broken down, coarse, crisp, fibrous, fizzy, floury, gritty, hard, mushy, pithy, rubbery, slimy, soft, soggy, wet, other, normal
juciness	extremely dry	extremely juicy	
firm/soft	extremely firm	extremely soft	
Overall quality	extremely poor	extremely good	

Triangular end pieces were put aside as they were cut for inclusion in time zero sensory analysis. Other dice were collected in a 750 mL polypropylene Chanrol C30 container (AMGM, Port Klang, Malaysia). Eighteen dice were immediately removed for time zero testing: six pieces constituted the sample for microbiological tests; the remaining 12 pieces, together with end pieces, formed the sample for sensory analysis. A double layer of muslin was secured over the opening of the container holding the remaining dice (≈70 pieces) and the container placed in a CA storage element which was immediately connected to the CA system.

Ten fruit were processed per day, in two sessions, over a consecutive 4 day period. Each fruit was assigned to one of the 40 storage atmospheres, or treatments, according to the experimental design.

Controlled atmosphere storage

Cantaloupe pieces (≈600g) were stored under a continuous flow, 6 × 6 matrix of atmospheres at 4.5°C. Gas compositions entering the CA storage elements were analyzed once per trial. Mean CO_2 concentrations (± SD) were 0%, 5.8 ± 0.4%, 9.4 ± 0.2%, 14.9 ± 0.5%, 19.5 ± 0.3%, and 26.2 ± 0.5%. Mean O_2 concentrations (± SD) were 3.3 ± 0.2%, 6.2 ± 0.5%, 10.6 ± 0.7%, 13.0 ± 0.7%, 15.4 ± 0.8% and 17.2 ± 0.8%. Nitrogen provided the balance. Flow rates of gas mixtures were 54 ± 3 mL/min. Static respiration rates for cantaloupe dice in air at 5°C were 10.0 mL CO_2/kg/hr and 8.4 mL O_2/kg/hr. At 54 mL/min, we calculated that respiration caused a 0.2% increase in nominal CO_2 concentrations and a 0.1% reduction in nominal O_2 concentrations. The effects of respiration on storage atmospheres were probably smaller than this since fruit respires more rapidly in air than in modified atmospheres we used. Consequently the effects of respiration on storage atmospheres were not taken into account. Relative humidities of gas mixtures ranged from 90 to 95%. The CA storage elements were 4L square containers (Modular mates square 3, Tupperware Australia, Hawthorne, VIC, Australia) with inlet and outlet tubes attached to the lid.

Gas compositions were analyzed using a Shimadzu Series 8A gas chromatograph (Tokyo, Japan) fitted with an Alltech CTR1 column (Deerfield, IL, USA). The chromatograph was equipped with a 90 mA thermal conductivity detector and operated isothermally at 40°C with a gas flow of 35 mL/min. Helium was used as carrier gas with an injection volume of 1 mL. A standard gas mixture, 9.73% CO_2, 1.17% O_2 and 89.1% N_2 (Commonwealth Industrial Gases, Brisbane, QLD, Australia), was used to establish retention times and response factors for different components of the gas mixture. Data were processed using a Shimadzu C-R6A integrator.

Four treatments including air, 37 to 40, were also incorporated in the experiment. Fruit were stored in a CA element through which compressed air continually flowed at 50 mL/min for treatment 37, in lidded C30 containers for treatments 38 and 39, and in a muslin-covered, but otherwise unsealed, C30 container placed in a CA element vented to air for treatment 40.

Microbiological counts

Microbiological testing was conducted at 0, 11 and 25 days. At each storage time, about 30g of fruit (≈4 dice) were tested for aerobic total counts and yeast and mold counts using the procedures of O'Connor-Shaw et al. (1995). Anaerobic total counts, made at 11 and 25 days, were enumerated from 1 mL inoculum, on standard methods agar plates incubated anaerobically for 3 days at 25°C in a GasPak® anaerobic jar with GasPak® *Plus* anaerobic system envelopes (Becton Dickinson Microbiology Systems, Cockeysville, MD, USA).

Sensory evaluation

Panelist selection and training and sensory testing were undertaken as described by O'Connor-Shaw et al. (1995) with the following modifications. Cantaloupe dice were scored for appearance quality, odor intensity, flavor quality, sweetness, texture quality, juiciness, softness and overall quality using graphic line scales. Panelists were asked to use a predetermined list of descriptors to amplify appearance, odor, flavor and texture (Table 1). Six panelists were used in each session.

Cantaloupe pieces were assessed for sensory characteristics immediately after dicing (time zero) and after 14 and 28 days storage. Five fruit were tasted per session, in two sessions/day corresponding to the alpha design used for fruit preparation. Before the commencement of a day's tasting, panelists were presented with fresh cantaloupe as a reference, to reacquaint them with the characteristics of fresh fruit. Storage elements were disconnected from the CA system, and panelists' samples removed in a laminar flow cabinet. The fruit was not mixed prior to sampling to minimize risk of microbial contamination. Because of the possibility of pathogen growth during storage, microbiological testing was conducted 3 days prior to sensory evaluation (at 11 and 25 days). Fruit pieces with total microorganism or yeast counts $>5\times10^3$ CFU/g were discarded and replaced with fresh melon dice to provide five samples for sensory assessments. Before sensory evaluation, product was also examined for macroscopic evidence of microbial growth, i.e. colonies on fruit pieces and turbidity in juice. If detected, testing of that fruit was discontinued, and fresh melon was tasted instead. Four pieces of melon from each treatment were served to each panelist in coded transparent bowls. The order of presentation of samples was balanced across the panel, and assessments were made in individual booths under white light (daylight equivalent).

Statistical analysis

Panelists' sensory scores for all treatments were averaged, and changes in sensory scores from time zero to 28 days for all treatments were analyzed by analysis of variance according to the incomplete block design. Adjusted means from this analysis are presented. Analysis of variance was also performed on all sensory scores measured at time zero and 28 days. Where a significant ($p<0.05$) F ratio was found then an average least significant difference figure was calculated. A students t test was used to determine if changes in scores were different from 0.

Sensory evaluation results were presented by first considering treatments for which changes in scores between time zero and 28 days were not significantly different from 0 (best treatments). Then we discussed treatments for which changes in scores were significantly greater than those of the best treatments. Graphical summations were prepared of results for reduction scores for overall quality (Table 2, Fig. 1) and texture quality (Table 5, Fig. 2). These figures were produced by the scientific graphics package Coplot (Cohort software, Berkeley, CA). Contour lines are intended to show trends and do not indicate sharp lines of quality demarcation.

RESULTS & DISCUSSION

Microbiological counts

All 120 rockmelons processed in these trials had an initial total count of ≤13 CFU/g. At 11 days, aerobic and anaerobic counts of dice from 115 melons were <5 CFU/g. Dice from four melons had aerobic and anaerobic counts of $>5\times10^3$ CFU/g, and dice from another melon had an aerobic count of 10 CFU/g and an anaerobic count of 30 CFU/g at 11 days. At 25 days, aerobic and anaerobic total counts of dice from 110 melons were <5 CFU/g. Dice from eight melons had aerobic and anaerobic counts of $>5\times10^3$ CFU/g. Another two melons had aerobic counts of 1.2×10^2 CFU/g and 2.8×10^2 CFU/g; corresponding anaerobic counts were <5 and 8.8×10^2 CFU/

Table 2—Effect of CO_2 and O_2 on overall quality[a] of cantaloupe pieces stored for 28 days at 4.5°C

O_2 (%)	CO_2 (%) 0	6	9.5	15	19.5	26
3.5	*1* 56 27	*2* 55 14	*3* 63 **10**	*4* 57 13	*5* 63 35	*6* 63 31
6	*7* 62 39	*8* 52 **8**	*9* 60 14	*10* 45 **7**	*11* 56 22	*12* 61 15
10.5	*13* 63 39	*14* 55 20	*15* 53 12	*16* 57 29	*17* 54 27	*18* 56 27
13	*19* 53 23	*20* 59 17	*21* 64 27	*22* 56 25	*23* 49 23	*24* 59 34
15.5	*25* 60 26	*26* 55 18	*27* 49 12	*28* 60 34	*29* 61 31	*30* 59 31
17	*31* 58 33	*32* 58 21	*33* 55 22	*34* 63 18	*35* 65 35	*36* 58 30
Air	*37* 55 21	*38* 62 21	*39* 59 25	*40* 49 13		

[a] For each box, treatment number in italics is indicated at top left, score at time zero at top right and score reduction over 28 days at bottom. Average standard error of difference for time zero scores, 6.3; average least significant difference for score reductions, 17.0. Reductions not significantly greater ($p>0.05$) than 0 are in boldface type.

Table 3—Effect of CO_2 and O_2 on flavor quality[a] of cantaloupe pieces stored for 28 days at 4.5°C

O_2 (%)	CO_2 (%) 0	6	9.5	15	19.5	26
3.5	*1* 53 23	*2* 55 13	*3* 63 10	*4* 56 8	*5* 66 33	*6* 63 31
6	*7* 62 41	*8* 54 12	*9* 59 11	*10* 45 2	*11* 58 23	*12* 59 19
10.5	*13* 62 39	*14* 57 19	*15* 53 11	*16* 57 25	*17* 55 27	*18* 58 30
13	*19* 54 22	*20* 58 15	*21* 64 34	*22* 54 20	*23* 52 21	*24* 60 32
15.5	*25* 61 27	*26* 56 18	*27* 53 17	*28* 66 36	*29* 61 30	*30* 58 27
17	*31* 59 35	*32* 57 18	*33* 57 23	*34* 61 14	*35* 63 29	*36* 58 30
Air	*37* 53 19	*38* 59 18	*39* 61 26	*40* 47 13		

[a] For each box, treatment number in italics is indicated at top left, score at time zero at top right and score reduction over 28 days at bottom. Average standard error of difference for time zero scores, 5.7; average least significant different for score reductions, 16.5. Reductions not significantly greater ($p>0.05$) than 0 are in boldface type.

g, respectively. After 25 day storage, colonies were visible on fruit pieces from one melon, which had aerobic and anaerobic total counts of 2.5×10^4 CFU/g. Yeasts were not detected on dice from any melon at any time during storage.

Generally the boiling water, aseptic dicing procedures produced sterile dice. That microorganisms were found in some fruit after storage reflects the insensitivity of the time zero testing procedure. It does not indicate that some atmospheric conditions may be more inhibitory to microbial growth than others. The boiling water treatment was used for several reasons. It reduced microbial contamination of the peel (results not shown) and thus numbers of microorganisms transferred to the flesh during processing. It appeared less likely to damage the flesh than treatments applied directly to the cut surface. The temperature of 100°C was easy to maintain and agitation by air bubbles during boiling assisted in removal of organic material and microorganisms from the skin.

For commercial application, the level of microbial contamination during preparation, above which microbial spoilage would become limiting for shelf-life of cantaloupe pieces stored under modified atmospheres, needs to be established. The preparatory procedures we used require modification before they would be suitable for commercial application. Laboratory procedures relied heavily on processing of individual fruit (i.e., dice

Table 4—Effect of CO_2 and O_2 on sweetness[a] of cantaloupe pieces stored for 28 days at 4.5°C[a]

O_2 (%)	CO_2 (%) 0	6	9.5	15	19.5	26
3.5	*1* 59 19	*2* 58 **7**	*3* 58 **6**	*4* 54 13	*5* 62 10	*6* 61 15
6	*7* 57 24	*8* 45 **8**	*9* 50 **5**	*10* 39 **−6**	*11* 55 **8**	*12* 56 **5**
10.5	*13* 61 **7**	*14* 49 19	*15* 50 13	*16* 54 **6**	*17* 53 13	*18* 55 21
13	*19* 53 13	*20* 58 20	*21* 61 **6**	*22* 46 12	*23* 50 11	*24* 54 14
15.5	*25* 57 19	*26* 55 17	*27* 43 **4**	*28* 63 31	*29* 54 16	*30* 54 **8**
17	*31* 54 15	*32* 55 15	*33* 57 12	*34* 64 18	*35* 64 16	*36* 58 13
Air	*37* 50 21	*38* 56 13	*39* 63 21	*40* 50 10		

[a] For each box, treatment number in italics is indicated at top left, score at time zero at top right and score reduction over 28 days at bottom. Average standard error of difference for time zero scores, 7.0; average least significant difference for score reductions, 15.0. Reductions not significantly greater ($p>0.05$) than 0 are in boldface type.

from different melons were not bulked at any stage), and aseptic dicing. The boiling water treatment involved a much higher temperature than the more usual hot water sanitation regimes of 43 to 60°C for 1 to 20 min (Eckert, 1975). The source of microbial contamination should be identified to determine whether it would be most appropriate to apply antimicrobial treatments to the skin of whole fruit prior to processing or to cut surfaces. Powrie et al., (1988) reported that microbiological spoilage of MA packed papaya pieces could be inhibited for 4 mo at 1°C, by dipping fruit pieces into 5% citric acid solution for 5 min to reduce the pH of surface tissue to <4.5.

More research is needed on the effects of modified atmospheres on microorganisms (Hotchkiss and Banco, 1992; Labuza et al., 1992). Key issues include study of the effects of CO_2 and O_2 on growth of spoilage and pathogenic microorganisms, specifically on lag time and growth rate during logarithmic phase, and the interactive effects of temperature and CO_2. A major safety consideration is associated with the storage of horticultural commodities under modified atmospheres. While obvious spoilage may be prevented, the growth of pathogenic microorganisms, which may not be visibly evident, may continue considering the prolonged storage times made possible by modified atmospheres.

Sensory evaluation

Quality at time zero. The overall quality of fruit at time zero ranged between 45 and 65 (mean 57.4, Table 2). Appearance quality scores ranged between 48 and 70 (mean 64.0, results for individual treatments not shown). Fruit had medium odor intensity with scores between 35 and 55 (results not shown). Flavor quality scores ranged between 45 and 66 (mean 57.7, Table 3) and from 39 to 64 (mean 54.7) for sweetness (Table 4). High juiciness scores, 66 to 81 points (mean 72.1, results not shown), contributed to high texture quality scores, which varied from 51 to 73 (mean 65.7, Table 5). Fruit scored close to the neutral point between firm and soft, scores varying between 39 and 64 (mean 54.7, Table 6). No significant differences ($p>0.05$) between fruit were found for any sensory parameter at time zero.

Effect of storage period on quality. Changes in scores between time zero and 28 days were significantly different between treatments for all attributes other than appearance quality, odor intensity and juiciness. For those attributes at 28 days scores ranged between 35 and 59 (mean 50.5) for appearance quality, from 19 to 51 (mean 34.9) for odor intensity, and from 59 to 82 (mean 70.4) for juiciness. At 28 days, panelists described the appearance of fruit from treatments 3, 4, 6, 9, 11,

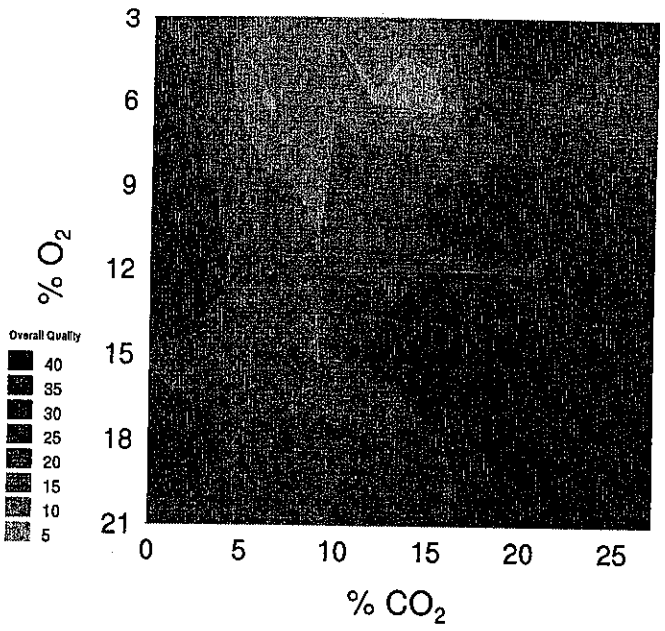

Fig. 1—Contour plot showing reductions in overall quality scores of cantaloupe dice stored for 28 days at 4.5°C displayed in relation to the atmospheric matrix. The lighter the area the smaller the reduction in score.

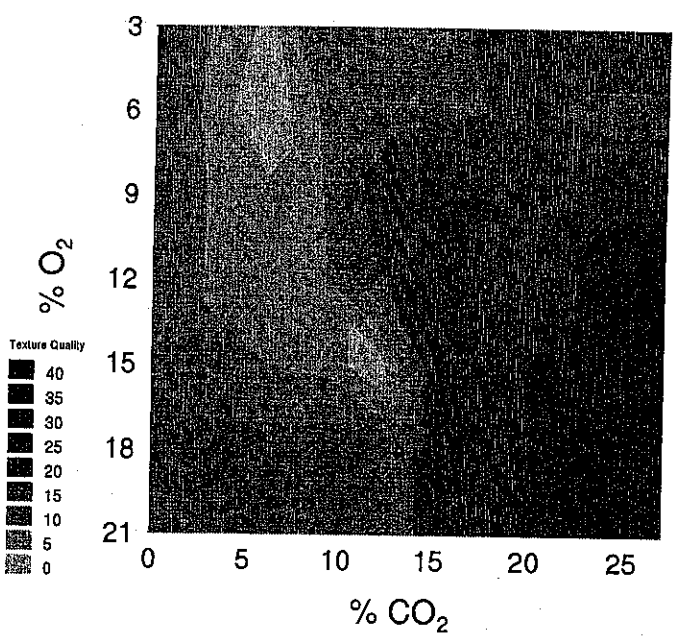

Fig. 2—Contour plot showing reductions in texture quality scores of cantaloupe dice stored for 28 days at 4.5°C displayed in relation to the atmospheric matrix. The lighter the area the smaller the reduction in score.

Table 5—Effect of CO_2 and O_2 on texture quality[a] of cantaloupe pieces stored for 28 days at 4.5°C

O_2 (%)	CO_2 (%) 0	6	9.5	15	19.5	26
3.5	*1* 68 23	*2* 62 **2**	*3* 73 18	*4* 68 **12**	*5* 66 28	*6* 68 28
6	*7* 69 19	*8* 58 **0**	*9* 71 **11**	*10* 64 18	*11* 65 20	*12* 69 17
10.5	*13* 63 **11**	*14* 66 **5**	*15* 63 **9**	*16* 71 40	*17* 65 31	*18* 64 27
13	*19* 61 15	*20* 64 **9**	*21* 70 **0**	*22* 65 25	*23* 51 21	*24* 68 38
15.5	*25* 66 **8**	*26* 66 **11**	*27* 60 **10**	*28* 59 23	*29* 72 31	*30* 63 24
17	*31* 68 21	*32* 66 16	*33* 66 17	*34* 70 18	*35* 69 34	*36* 61 25
Air	*37* 70 18	*38* 68 **8**	*39* 71 21	*40* 63 **12**		

[a] For each box, treatment number in italics is indicated at top left, score at time zero at top right and score reduction over 28 days at bottom. Average standard error of difference for time zero scores, 7.3; average least significant difference for score reductions, 21.7. Reductions not significantly greater ($p>0.05$) than 0 are in boldface type.

Table 6—Effect of CO_2 and O_2 on softness[a] of cantaloupe pieces stored for 28 days at 4.5°C

O_2 (%)	CO_2 (%) 0	6	9.5	15	19.5	26
3.5	*1* 54 **7**	*2* 57 **3**	*3* 58 13	*4* 51 **−6**	*5* 61 −17	*6* 49 −24
6	*7* 54 **4**	*8* 62 **9**	*9* 60 **12**	*10* 50 **−1**	*11* 57 **−6**	*12* 47 −14
10.5	*13* 47 **−5**	*14* 61 **11**	*15* 52 **10**	*16* 54 −23	*17* 53 −18	*18* 51 −27
13	*19* 60 **−1**	*20* 58 **10**	*21* 60 **7**	*22* 53 **−5**	*23* 64 **−12**	*24* 55 −24
15.5	*25* 58 **3**	*26* 63 **6**	*27* 56 **4**	*28* 66 **−8**	*29* 49 −24	*30* 56 −15
17	*31* 53 **1**	*32* 54 **9**	*33* 55 **6**	*34* 59 **−4**	*35* 55 −17	*36* 68 **−10**
Air	*37* 54 **8**	*38* 56 9	*39* 62 **9**	*40* 60 **−2**		

[a] For each box, treatment number in italics is indicated at top left, score at time zero is indicated at top right and change in score (time zero score − 28 day score) at bottom. Average standard error of difference for time zero scores, 7.3; average least significant difference for score reductions, 20.0. Changes in scores not significantly different ($p>0.05$) to 0 are in boldface type.

15, and 16 as normal, of fruit treated with 0% CO_2 (irrespective of O_2 concentration) and from treatments 30, 35, 37 and 39 as translucent, and of fruit from most remaining treatments as pale. Significant differences between fruit were found for all sensory parameters at 28 days with the exception of appearance quality and sweetness.

Effect of treatment on quality. Small reductions in overall quality scores generally coincided with CO_2 concentrations between 9.5 and 15% and O_2 concentrations of about 6% (Fig. 1). On the contour plots (Fig. 1, 2), the lightest area is a notional representation of the gas composition in which the least reduction in quality score occurred during storage of dice. The overall quality of fruit treated with 9.5% CO_2 and 3.5% O_2 (treatment 3), 6% CO_2 and 6% O_2 (treatment 8) and 15% CO_2 and 6% O_2 (treatment 10) reduced by only 7 to 10 points during 28 day storage (Table 2). These reductions were not different from 0. All other treatments caused significant reductions in overall quality. Fruit from 12 treatments had significantly higher overall quality reduction scores than the highest score from treatments 3, 8 and 10. Eleven of these involved 0, 19.5 or 26% CO_2.

Overall quality scores reflected flavor quality scores. Fruit for which flavor reductions over 28 days were not greater than 0 also showed nonsignificant reductions in overall quality. Fruit recording large flavor reductions showed large reductions in overall quality. The flavor quality of fruit treated with 15% CO_2 and 3.5% O_2 (treatment 4) and 15% CO_2 and 6% O_2 (treatment 10) decreased by only 8 and 2 points, respectively, during 28 days storage (Table 3). This was a nonsignificant change from 0. All other treatments caused reductions of flavor quality. Fruit from 17 treatments had higher flavor reduction scores than from either treatments 4 or 10. Thirteen of these treatments involved CO_2 concentrations of 0, 19.5 or 26%. At 28 days, panelists described fruit from 25 treatments as lacking in flavor. There was no obvious relationship between this defect and atmospheric composition. Fruit from treatments 3, 8 and 10, which did not incur losses in overall quality during 28 days storage, still had

a predominant characteristic flavor at 28 days. Musty and stale were descriptors most frequently used to describe flavor of 28 day stored fruit.

Sweetness intensity scores of fruit from treatments 2, 3, 8, 9, 11, 12, 13, 16, 21, 27, and 30 reduced by only 4 to 8 points over 28 days, and fruit from treatment 10 was rated 6 points higher than at time zero (Table 4). None of these changes were different from 0. These treatments were randomly distributed throughout the matrix of atmospheres tested. An unexpected reduction in sweetness was noted for treatment 4, which was the best of the treatments in terms of flavor quality. Nonsignificant changes in sweetness accompanied large reductions in flavor quality scores in treatments 13, 16, 21 and 30. Neither sweetness scores nor descriptors suggested reliable interpretations of mechanisms involved in such flavor deteriorations.

The patterns observed for overall quality and texture quality changes in the matrix differed. Small reductions in texture quality scores generally coincided with CO_2 concentrations of about 6% (i.e. irrespective of O_2 concentration) and treatments with 0% CO_2 had a smaller effect on texture quality than on overall quality (Fig. 2). Texture quality scores of fruit from 14 treatments reduced by <13 points over 28 days (Table 5). These reductions were not different from 0. Nine of these cases involved storage under 6 or 9.5% CO_2. The largest reductions in texture quality scores over 28 days were generally recorded for fruit treated with 19.5 or 26% CO_2.

Softness scores did not change from 0 over 28 days for fruit from 29 treatments, for which they varied by $\pm$ 12 points from time zero scores. These treatments involved 0, 6, 9.5 or 15% CO_2, and included air treatments (Table 6). Treatment with 19.5 or 26% CO_2 generally resulted in softer fruit, which were also described as such by the panel and were downgraded for texture and overall quality.

For treatments stored in air, changes in scores between time 0 and 28 days were not significantly different for any sensory parameter.

For all quality attributes we could identify treatments for which changes in scores between time zero and 28 days were not different from zero, and treatments for which changes in score were significantly greater than those of the best treatments. The remaining treatments, which often included storage in air, resulted in changes in score significantly different from 0 but not significantly different from best treatments. For example, the best treatment for maintaining overall quality was treatment 10, for which the reduction score after 28 days was not different from 0. Yet with the exception of treatment 39, none of the air treatments had reduction scores significantly greater than that of treatment 10, and on that basis should be regarded as being equally as effective as treatment 10. Air treatments 38 to 40 were simpler and lower cost than treatments involving modification of atmospheric composition. Possibly further testing, based on atmospheres which showed promise, i.e. 6 to 15% CO_2 and 0 to 15.5% O_2, would give more logical results and enable refinement of appropriate gas mixtures. Further work, using a longer storage interval, should also be undertaken to quantify the shelf-life using the best treatments.

Little information is available on ideal atmospheric storage conditions for minimally processed fruit and resultant shelf life under such conditions. Overall, our results showed that sterile cantaloupe dice could be CA stored under 6% CO_2 and 6% O_2, 9.5% CO_2 and 3.5% O_2, and 15% CO_2 and 6% O_2, at 4.5°C for up to 28 days without incurring significant losses in overall quality.

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