QUALITY CHANGES OF FRESH-CUT HONEYDEW MELONS DURING CONTROLLED ATMOSPHERE STORAGE

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ABSTRACT

Quality, physiology, and microbial population were monitored with honeydew cubes held in air or controlled atmosphere (CA) of 2% 0_2 + 10% CO_2 at 5C and 4%0_2 + 10% CO_2 at 10C. The CA was beneficial in maintaining quality of honeydew cubes. Quality deteriorated rapidly with concomitant increase in respiration rate during the latter half of the 6-day at 10C or 10-day at 5C shelf-life. The shear force of samples was maintained by CA at 10C, but the visual quality was poor when that benefit was still noticeable. At 5C, an effect of CA was not noted because the low temperature did not allow the shear force to decrease. The bacterial population was less on honeydew cubes held in CA than in air. Modified atmosphere with these gas mixtures would be beneficial in maintaining quality and retarding microbial growth on honeydew cubes, but strict temperature control is essential to avoid anaerobic respiration.

INTRODUCTION

The shelf-life of fresh-cut honeydew cubes in the supermarket is very limited. If the honeydew cubes are prepared at the supermarket, the "sale by date" is only 2 or 3 days after preparation. If the cubes are prepared by a regional processor, the anticipated shelf life is about 5 days at the supermarket. O'Connor-Shaw *et al.* (1994) indicated that a 14-day shelf-life can be attained with honeydews and a 4-day shelf-life with cantaloupe held at 4C in a closed polypropylene container. In

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a subsequent study, using a very sterile system and controlled atmosphere (CA), they were able to obtain 28 days of shelf-life for cantaloupe, which is a dramatic 7-fold extension of shelf-life (O'Connor-Shaw *et al.* 1996).

The extended shelf-life demonstrated by O'Connor-Shaw *et al.* (1996) probably was possible due to accurate control of initial quality, sanitation, temperature and gas mixture. Sterile system minimizes contamination and sanitation reduces the natural microbial load. Microbial load is reduced by dipping honeydew cubes in hypochlorite solution of 200 ppm chlorine at pH 6 (Ayhan *et al.* 1998). Low temperature is very important for maintaining the shelf-life of all fresh products, including fresh-cut products (Watada *et al.* 1996); however, for some chilling sensitive commodities, 5C is preferred over 0C (Izumi and Watada 1995). CA has been shown to extend the shelf-life of fresh-cut vegetables, which include broccoli florets (Bastrash *et al.* 1993), shredded cabbage (Hiroaki *et al.* 1993), carrots (Izumi *et al.* 1996), lettuce (Hamza *et al.* 1996) and spinach (Ko *et al.* 1996). Benefits have been noted on a few fresh-cut fruits, which include cantaloupe, (O'Connor-Shaw *et al.* 1996), persimmons and peaches (Wright and Kader 1997a), pomegranate (Gil *et al.* 1996), strawberries (Wright and Kader 1997b), and apple slices (O'Bieme 1990). To our knowledge, no study has been reported on the effects of CA on the quality attributes of whole honeydew fruit or the cubes of honeydew.

We found the O_2 content in the film wrapped packages of honeydew cubes in supermarkets to be as low as 1% O_2 and the CO_2 to be as high as 15% (personal observation). Since fresh-cut products are often held at temperatures above those recommended, we were not surprised to see the O_2 level be so low. Films that are used for fresh-cut melons generally have an oxygen transmission rate of 500 mL• 100 sq. in.$^{-1}$ 24 h^{-1}, which results in a modified atmosphere of about 2-3% O_2 and 10-15% CO_2 if proper holding temperature is maintained (personal communication, Cryovac) The minimum O_2 level that is desirable for maintaining quality of honeydew melons is not known.

We report here a study on the effects of low O_2 and slightly elevated CO_2 on the quality changes of honeydew cubes held at 5 and 10C. To have the desired gas mixture immediately and to minimize changes in gas mixture, CA was used instead of modified atmosphere.

MATERIALS AND METHODS

Honeydew melons, *Cucumis melo* var. *inodorus*, of unknown cultivar were obtained from the Maryland Wholesale Distribution Center in Jessup, Maryland. Preliminary study indicated that honeydews with about 9% soluble solids (ss) were not sweet or satisfactory, thus those with 10 to 13% ss were selected for the studies.

The average weight of each melon was approximately 2200 g. Fifteen melons, free of defects, were selected visually for similarity in maturity and size, rinsed with tap water, immersed in sodium hypochlorite solution (150 ppm chlorine) for 5 min and then air dried at room temperature. The melons were separated into three groups of 5 fruit each (3 replicates) and each fruit was sliced into 8 slices. The skin of each slice was removed and the slices were cut into cubes (4 cm x 2 cm x 3 cm). The cubes were mixed and a subsample of approximately 300 g was used for each sample.

The samples were placed in sealed glass jars, which were stored at 5 or 10C. Air or CA of 2% O_2 + 10% CO_2 at 5C and air or CA of 4% O_2 + 10% CO_2 at 10C was passed through the jars at a rate of 10 and 15 mL • min^{-1}, respectively. Preliminary study indicated that a gas mixture of 2% O_2 + 10% CO_2 caused anaerobic respiration at 10C, thus the O_2 was increased to 4% at 10C.

Quality changes can be predicted by changes in respiration rate, thus O_2 and CO_2 contents of inlet and outlet streams of each jar were monitored every 8 h with an O_2 and CO_2 analyzer (Model S-3AII and Model CD-3A, Ameteck, Pittsburgh, PA). Ethylene of the outlet stream also was measured every 8 h with a gas chromatograph containing Poropak Q column and FID. Daily averages of O_2 uptake or CO_2 and C_2H_4 production are presented. At 3, 6, and 10 days, 3 sample jars from each treatment were removed from storage for analyses of visual quality, ascorbic acid, shear force (texture), pH, ss, and microbial count. The visual quality was scored by 4 staff members, using 9 = excellent, 7 = good, 5 = fair, 3 = poor, and 1 = unedible. Color was based on the L', a', b' values obtained with the Minolta Chromameter (Japan). Ascorbic acid was determined using an HPLC equipped with a PLRP-S 100-A column (25 cm x 4.66 mm, 5 μm) (Polymer Laboratories Co.) and an electrochemical detector (Model 400; EG&G, Princeton, NJ) as described elsewhere (Izumi and Watada 1995). Shear force of a 100 g sample was determined with a Kramer-Shear Cell attached to a Texture Test System (Food Technology Corp., Rockville, MD) as described elsewhere (Izumi and Watada 1995). Total mesophilic aerobic microorganisms (mostly bacteria) was determined by incubating the culture on tryptic soy agar (TSA, Difco Laboratories, Detroit, MI) at 30C for 24 h and yeast from culture incubated on potato dextrose agar (PDA, Difco) for 30C for 36 h as described elsewhere (Babic *et al* 1996).

The study was repeated three times during 1996. PROC GLM of SAS Version 6.12 (SAS Institute Inc. 1989) was used for analysis of variance. The repeated studies were treated as blocks in the analysis of variance.

RESULTS AND DISCUSSION

Analysis of variance (Table 1) showed that the visual quality, shear force, ascorbic acid, and microbial population were significantly different with respect to

temperature, atmosphere, storage time and date of experiment. Most of the interaction between temperature, atmosphere and storage time were significant for the five attributes measured, indicating the need to compare the means of combination of two temperatures, two atmosphere and storage period (Table 2).

TABLE 1.
F-VALUES, SIGNIFICANT LEVELS AND CV (%) FROM ANALYSIS OF VARIANCE PERFORMED ON QUALITY SCORE, SHEAR FORCE, ASCORBIC ACID CONTENT, AND POPULATION OF MICROORGANISMS INCUBATED ON TRYPTIC SOY AGAR OR POTATO DEXTROSE AGAR OF HONEYDEW MELON CUBES STORED AT 2 TEMPERATURES AND 2 ATMOSPHERES FOR 4 STORAGE PERIOD REPEATED AT THREE DIFFERENT DATES (DATE)

Source	DF	Quality score	Shear force	Tryptic soy agar	Potato dextrose agar	Ascorbic acid
Date	2	7.18 **	4.81*	21.91**	16.45**	14.39**
Temperature	1	6.64*	30.04**	29.32**	57.22**	83.10**
Atmosphere	1	5.70*	76.42**	5.81*	35.23**	37.66**
Temperature×atmosphere	1	<1	36.46**	<1	<1	5.51*
Storage	3	3.91*	75.00**	89.43**	169.67**	365.8**
Temperature×storage	3	3.86*	4.68**	3.68*	6.82**	15.93**
Atmosphere×storage	3	<1	21.09**	<1	4.69**	5.49**
Temperature×atmosphere×storage	3	<1	10.21**	1.49	2.76	2.05
CV (%)		10.27	8.78	14.52	9.20	9.27

*$p<0.05$, **$p<0.01$.

The visual quality of honeydew cubes deteriorated with storage and the average quality score of all samples dropped from excellent (score of "9") to good or fair ("7" or "5") by day 3 (Table 2). At 10C, quality was poor or lower (score of "3" or lower) by day 6 and dropped to an unedible condition ("1") by day 10. Quality of these melons was better under CA storage than air storage up to day 6.

TABLE 2.
MEAN VALUES[z] OF QUALITY SCORE, SHEAR FORCE, MICROORGANISM POPULATION INCUBATED ON TRYPTIC SOY AGAR OR POTATO DEXTROSE AGAR, AND ASCORBIC ACID CONTENT OF HONEYDEW CUBES HELD AT 5 OR 10C INI AIR OR CONTROLLED ATMOSPHERE (CA)[y] STORAGE FOR 0, 3, 6 OR 10 DAYS

Storage (days)	Temp. (C)	Atmos.	Quality[x] score	Shear force (n)	TSA (log_{10} cfu · g^{-1})	PDA (log_{10} cfu · g^{-1})	Ascorbic acid (mg · 100 g^{-1} f.wt.)
0			9.0 h[w]	975 g	3.02 a	2.23 a	29.9 bc
3	5	Air	6.3 fg	801 def	4.28 b	3.11 bc	30.2 bcd
		CA	7.1 g	839 ef	3.97 b	2.75 ab	35.5 d
	10	Air	5.6 e	696 cd	7.24 cd	4.31 f	30.7 bcd
		CA	6.3 fg	787 de	5.39 bc	3.51 cd	34.5 cd
6	5	Air	4.2 d	692 cd	7.17 cd	4.10 ef	33.3 cd
		CA	6.1 ef	712 cd	5.95 c	3.72 de	34.3 cd
	10	Air	2.2 b	328 b	8.46 d	5.77 g	30.7 bcd
		CA	3.1 c	719 cd	8.22 d	4.36 f	34.4 cd
10	5	Air	2.1 b	630 c	8.44 d	5.62 g	32.7 bcd
		CA	4.7 d	786 de	7.13 cd	4.28 ef	34.6 cd
	10	Air	1.0 a	207 a	10.08 e	6.50 h	25.0 a
		CA	1.7 ab	900 fg	10.01 e	5.82 g	27.8 ab

[z] Data are means of three blocks, each block represents different dates of experiment.

[y] Controlled atmosphere of 2% O_2 and 10% CO_2 at 5 C and 4% O_2 and 10% CO_2 at 10 C.

[x] Quality score: 9 = excellent, 7 = good, 5 = fair, 3 = poor, 1 = unedible.

[w] Means with the same letter within the column are not significantly different at 5% level (LSD test).

At 5C, quality dropped to below the fair condition by day 6 with melons in air, whereas it was above fair condition with samples in CA. By day 10, samples in air were below the poor level and those in CA were rated slightly below the fair level, so CA was beneficial with honeydew cubes held at 5C. Quality score was based on fresh appearance, dryness or watery condition, and decay. Offending odor was noted when the quality score was "3" or lower with samples at 10C (data not shown).

The respiration rate began to increase after the samples had deteriorated to a fair condition. The CO_2 production of samples at 10C began to increase after day 3, which was when the quality score was about fair ("5"), and the increase was greater with samples in air than in CA (Fig. 1). The CO_2 production of samples in air at 5C began to increase on day 6 (data not shown), which was when the quality was rated at slightly below fair. The respiration rate of samples in CA at 5C remained unchanged (data not shown). The pattern of O_2 consumption was similar to that of CO_2 production for all samples (data not shown). It appears as though tissue breakdown occurred after the samples deteriorated to fair condition, which caused the respiration rate to increase.

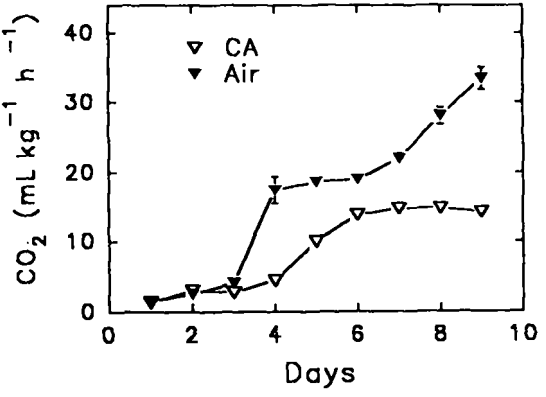

FIG. 1. RATES OF CO_2 PRODUCTION BY HONEYDEW CUBES HELD IN AIR OR CA(4% O_2 + 10% CO_2) AT 10C
Vertical lines represent SE. SE bars were not shown when masked by the symbol.

The respiratory quotients for fruit in air and CA were 0.34 and 0.78, respectively, at 10C, and 0.36 and 0.96, respectively at 5C (data not shown). This implied that the O_2 level of 2% at 5C and 4% at 10C was not sufficient for the aerobic pathway (TCA cycle) to perform at an equal rate as the anaerobic pathway (glycolysis). This did not have a deleterious effect on quality because the quality of samples in CA were better than those in air, particularly at 5C.

The ethylene production by honeydew cubes increased during storage with samples held in air at 10C (Fig. 2) and 5C (data not shown). The increase occurred sharply after day 3 at 10C, when the honeydew cubes began to deteriorate rapidly, whereas the increase was smaller and later with samples at 5C. The amount of ethylene production was very small, ranging from 0.02 to 0.06 $\mu L \cdot kg^{-1} \cdot hr^{-1}$, at 5C (data not shown), compared with 1 to 42 $\mu L \cdot kg^{-1} \cdot h^{-1}$ at 10C. CA retarded ethylene production. The increased ethylene production probably was due to breakdown of tissue rather due to climacteric noted with ripening.

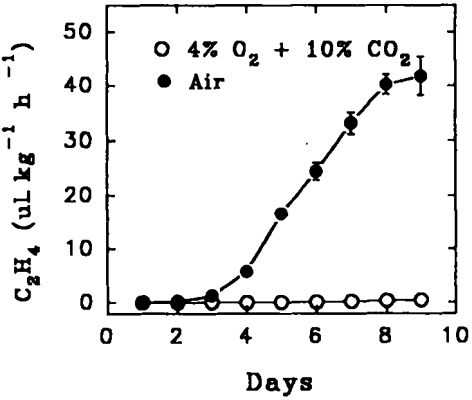

FIG. 2. ETHYLENE PRODUCTION BY HONEYDEW CUBES HELD IN AIR OR CA (4% O_2 +10% CO_2) AT 10C
Vertical lines represent SE. SE bars were not shown when masked by the symbol.

The shear force of samples in air decreased sharply during the first six days and the decrease was much greater at 10C than that at 5C (Table 2). By day 6, the average shear force dropped by 66% at 10C and by 29% at 5C; whereas in CA, the shear force dropped by 27% at both 5 and 10C. At 5C, the low temperature retarded the continual drop in shear force, so any effect of CA was not apparent, except at 10C, where the shear force dropped sharply, CA retarded the drop. However, the benefit of CA at 10C has no value, because the quality of melons were poor by day 6. The reason for the increase in shear force of samples in CA at 10C is unknown. All samples lost weight within the first 3 days and changes after the third day were not consistent and significant (data not shown).

The ascorbic acid content remained about the same during the first 6 days of samples held at 10C, and then decreased between day 6 and 10; however, only the decrease of melons in air was significant (Table 2). The content of samples at 5C did not change during the 10 days of storage. The lack of change during storage at 5C was unexpected, because, ascorbic acid content decreases during storage and the decrease is greater at the higher storage temperature (Watada 1987). The lack of change may be due to biosynthesis of ascorbic acid, low temperature, or the short storage period.

The ss content initially was 13% and decreased slightly to 12.2 to 12.5% among samples stored at different temperatures and atmospheres with no significant differences (data not shown). The honeydew cubes were tasted for sweetness, but changes with storage could not be detected.

The pH decreased slightly from 6.1 to 5.7 by day 9 with samples stored in CA at 5 and 10C, and to 5.0 with samples in air at both temperatures (data not shown).

The microbial population increased sharply during storage (Table 2). The rate of increase in bacteria (TSA supported microorganisms) was greater with samples at 10C than at 5C and with samples in air than in CA. With samples in air, the

average bacterial population on day 6 at 10C was similar to that on day 10 at 5C (Log_{10} 8.46 vs 8.44 CFU • g^{-1}) With samples in CA, the bacterial population on day 6 at 10C was more than 10-fold greater than that on day 10 at 5C. The populations of mold and yeast (PDA supported microorganisms) were not as great as that of bacteria (Table 2). Like the bacteria population, the increase in mold and yeast numbers was greater on samples at 10C than at 5C, and on samples in air than in CA. The effect of CA was more apparent at 5C than at 10C. For example, on day 6, the average population on PDA at 5C in air and CA was log_{10} 4.10 and 3.72 CFU g^{-1}, respectively; whereas at 10C, the population was log_{10} 5.77 and 4.36, respectively. Growth of microorganisms probably is dependent on the integrity or quality of the honeydew cubes, but there appeared to be no correlation between the average population of the microorganisms and the quality scores.

These results showed that CA of 2% O_2 + 10% CO_2 at 5C or 4% O_2 + 10% CO_2 at 10C was beneficial in retaining the quality and retarding increased metabolism and microbial growth. It is important to recognize that these combination of gases is desirable only when temperature is strictly controlled. In supermarkets, the temperature fluctuates widely and can be as high as 15C (Personal survey). At 15C, the respiration rate could be 3.5 fold greater than that at 5C (Watada *et al.* 1996), and if the gas transmission through the film or container cannot increase with the increased respiration rate, anaerobic condition can develop. Thus for commercial use, a higher O_2 level should be considered for modified atmosphere packaging of honeydew cubes.

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