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EFFECT OF MODIFIED ATMOSPHERE TREATMENTS ON RESPIRATION RATE AND QUALITY OF HONEOYE STRAWBERRY FRUITS

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ABSTRACT: **Mature strawberry fruits *(Fragaria x ananassa* Duch.*)*, cv Honeoye, were exposed to different modified atmosphere (MA) treatments (O_2 at: 0, 1.5, 3.5%; and Co_2 at: 0, 15, and 25%), and stored at either cold storage (2°C) or at ambient room temperature (21 °C). Fruits physical and chemical characteristics were assessed. Low temperature storage (2°C) reduced significantly fruit weight loss compared with that stored at 21°C. Little weight loss occurred in fruits stored at 15 and 25% CO_2, and the greatest loss occurred at control treatment. During the first 7 days of the experiment, no fungal growth was observed in fruits stored at low temperature (2°C). Strawberries treated with 3.5 % O_2 + 25% CO_2 and held at ambient room temperature (21°C) had less percentage of mold growth than all other treatments at the same storing temperature. Fruits stored at ambient room temperature (21°C) showed a proportional relationship between O_2 concentration in the MA and the respiration rate. Fruit ethylene production rate was inhibited completely by a lack of O_2. In most cases, ethylene production rate of berries held in air was greater than that of the fruits held in any of the MA treatments.**

Key words: *Fragaria x ananassa* **Duch., modified atmosphere, post-harvest, cold storage, ethylene production, respiration rate.**

INTRODUCTION

Fresh Strawberries are perishable and have a maximum shelf life of five to seven days (Couter and Kitson, 1988). They are susceptible to rapid decay due to gray mold rot, which is caused by *Botrytis cinerea* (El – Kazzaz *et al.* 1983; and Courter and Kitson, 1988). The respiration rate of strawberry is high and suitable postharvest handling methods are required to minimize postharvest losses (Kubod *et al.* 1990). Temperature management is the most important method of maintaining the postharvest quality of fruits (Mohamed *et al.* 1986). Modified atmospheres (MA) are gaseous environments that have a composition different from that of normal air (Kader, 1985). High concentration of CO_2 and / or low concentrations of O_2 reduce fruit respiration rate and inhibit fungal growth, thus extended storage life (Kader, 1985). Increasing carbon dioxide concentrations improved strawberry fruit quality (Holcroft and Kader, 1999 a; Holcroft and Kader, 1999 b; Plotto *et al.* 1999; Sanz *et al.* 1999; Wasna *et al.*, 1999; Wszelaki and Mitcham, 2000). CA storage with increased CO_2 and / or reduced O_2 has been used successfully to extend postharvest longevity of strawberries. Elevated concentrations of CO_2 inhibit decay and retard softening without impairing the delecate flavor of the berries. Furthermore, the effects of elevated CO_2 persisted after removal to air (Herner, 1987). However, Kader (1985) reported that a specific concentration of CO_2 or O_2 in the storage atmosphere may be beneficial at a specific temperature.

The objective of this research was to determine the effect of combinations of low O_2 and / or high CO_2 concentrations on weight loss, mold growth percentage, respiration rate, and ethylene production rate of 'Honeoye' strawberry fruits stored at different storage temperatures.

MATERIALS AND METHODS

June-bearing ' Honeoye' strawberry (*Fragaria x ananassa* Duch.) was used for this research. This experiment was conducted for two successive seasons of 2001 and 2002 in the Hort. Dept., College of Agric., King Saud Univ., Al-Qassium. Fruits were obtained from a local commercial grower. Fruits were harvested at the red-ripe stage and transported immediately to the laboratory. Fruits were fast-cooled to 5 C immediately by using forced-air cooling for 30 to 45 min. Berries then were sorted by color and size. Fruit samples were distributed into plastic mesh baskets and stored in MA chambers. The weight of each sample was approximately 300g, each sample was considered as a replicate. Fruits were treated with the following modified atmosphere treatments (MA):

1) 1.5 % O_2, 2) 3.5% O_2, 3) 25 % CO_2, 4) 1.5%O_2+ 15% CO_2, 5) 1.5 % O_2 +25 % CO_2, 6) 3.5%O_2+ 15 % CO_2, 7) 3.5 % O_2 + 25 % CO_2, and 8) air as a control treatment. The rest of the atmospheric volume was filled with nitrogen gas (N_2). One-half of the plastic mesh baskets were placed in a cold room at 2°C, and another half were stored at room temperature (21°C). Mixtures of the desired test atmosphere were obtained. Test atmospheres were passed through MA chambers at one air exchange per hour by using capillary tubes for flow control.

Samples of the test atmospheres were collected at inlets (every 24 hs) and outlets (every 12 hs) of the desiccators and analyzed by using a Varian model 3700 gas chromatography. The test atmospheres were humidified to 85-90 % relative humidity. After seven days in the test atmosphere, final fresh weight and percentage of *B. Cinerea* incidence were measured. Production rate of both CO_2 and C_2H_4 were calculated by the following formula described by Kader(1985) :

$$\frac{(O_2\ \%,\ CO_2\ \text{or ul}\ C_2H_4\ /L/100)\ \text{X flow rate (ml/ hr)}}{\text{sample weight (kg)}}$$

A factorial experiment with three replicates per each treatment was designed. The factors two storage temperatures (2°C and 21°C), and eight MA treatments, respectively. Analysis of variance was performed (general linear model , PROC GLM) to test the effects of the various treatments (SAS Institute , 1985) . When F values were significant, LSD was used to compare means at the 5% level.

RESULTS AND DISCUSSION

Weight Loss

Low temperature storage (2°C) reduced significantly weight loss of 'Honeoye' strawberries when compared with fruits stored at 21°C (Table 1). Moreover, there were significant differences in weight loss of 'Honeoye' strawberry fruits among the MA treatments at both storage temperatures (Table 1).The least fruit weight loss occurred when MA with 15 and 25% CO_2 was used, and the greatest weight loss occurred when MA treatment contained 1.5 % O_2, 3.5% O_2, or air without the addition of carbon dioxide (Table 1). The combined O_2 and lower CO_2 concentrations (1.5 % O_2 + 15 % CO_2 and 3.5 % O_2 +15% CO_2) resulted in a similar effect as the 1.5 % O_2 and air treatments. These results are in line with those of Browne *et al.* (1984) and El Rayes and Ahmed (2001) who reported that cold storage and high CO_2 concentrations reduced fruit weight loss of stored mango fruits.

Fungal Growth

Fungal growth caused by *B. cinerea* was the only form observed. No Fungal growth was observed in strawberry fruits stored at low temperature (2°C) (data were not presented). Moreover, for fruits stored under room temperature (21°C), fungal growth was not observed under high CO_2 treatments (15 or 25 % CO_2). Berries held in 1.5 % O_2 + 25 % CO_2 , 3.5 % O_2 + zero% CO_2 , showed a lower mold growth percentage compared with those treated with 1.5% O_2 + 15% CO_2 , or control treatment. Whereas, 3.5 % O_2 + 15% CO_2 treatment showed the greatest percentage of mold growth among all MA treatments which contained supplementary carbon dioxide. Berries held in 3.5 %O_2 + 25% CO_2 had less percentage of mold growth on fruits than all other pervious MA treatments (Fig .1). Mohamed *et al.*(1986) reported that germination of spores and young mycelia of some *Rhizopus spp.* are controlled properly when fruits are stored at approximately 5°C because they are sensitive to low temperature. Moreover, some researches indicated that Low concentrations of oxygen reduced the decay of fresh strawberries caused by *B. cinerea* (Plotto *et al.* 1999). Moreover, modified atmosphere treatments with high carbon dioxide concentrations; i.e., 15% and 25 % showed a great potential to reduce fungal growth during storage period. This effect was magnified when low oxygen concentrations were used. These results are confirmed with those of Ahmed and El Rayes, 2001, who reported that carbon dioxide treatment could be used as a potential alternate to sulfur dioxide to control fruit decay in grapes.

Respiration Rate

There was no significant difference among modified atmosphere treatments regarding fruit respiration rate for fruits stored at cold storage (2°C) during the storage period (7 days)(Table 2). However, for fruits stored at ambient room temperature (21°C), in most cases, there was a proportional relationship between storage period and respiration rate. As the only apparent trend there was a general increase in the respiration rate as the time in storage increases, and in some cases there was a slight decrease in fruit respiration rate at the end of the experiment (Table 3). The lowest rate of respiration was obtained form fruits stored under the MA treatments that contained zero% O_2, but differences among MA treatments were not observed consistently. These results are in line with those of Li and Kader (1989) as they stated that the resultant effect of some combinations of high CO_2 and low O_2 atmospheres is synergistic. Plotto *et al.* (1999) reported that the commonly used storage atmospheres of 2 to 4 % O_2 and 5 to 7 % CO_2 suppressed respiration and delayed ripening of fruit , but such results cannot be achieved with eitherO_2 or CO_2 controlled atmospheres alone .

Ethylene Production Rate

Ethylene production was not detected in Honeoye strawberry fruits during the first seven days of the storage period for the fruits stored at 2C (data were not presented). But ethylene was detected in ' Honeoye ' fruits stored at 21°C (Table 4). Ethylene production rate was inhibited completely by a lack of O_2 during the seven days of the storage of the fruits (Table 4). In most cases, ethylene production rate of berries held in air was greater than the ethylene production rate of berries held in any of the MA treatments conducted in this study. These results are in line with those of Kubod *et al.*(1990).

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Table 1: Influence of modified atmosphere storage treatmentson weight loss of "Honeoye" strawberry fruits after seven days of storage at different temperatures.

Treatments		Weight Loss (%)	
O_2 (%)	CO_2 (%)	2 °C	21 °C
1.5	0.0	3.7	28.9
3.5	0.0	2.4	32.4
0.0	15.0	3.8	6.5
0.0	25.0	2.1	5.5
1.5	15.0	3.6	24.7
1.5	25.0	2.6	17.1
3.5	15.0	1.9	29.6
3.5	25.0	2.2	19.6
Control (Air)		2.1	29.9
MA LSD (0.05)		1.5	10.1

Table 2 : Influence of modified atmosphere storage treatments on respiration rate(ml CO_2 / kg / hr) of ` Honeoye` strawberry during seven days of storage at 2 °C .

Treatments		Days in storage					
$O_{2(\%)}$	$CO_{2(\%)}$	2	3	4	5	6	7
1.5	0.0	5.2	6.2	6.3	7.1	7.1	7.6
3.5	0.0	10.4	9.3	7.9	8.9	9.0	12.0
0.0	15.0	5.1	9.5	7.4	6.5	5.6	6.0
0.0	25.0	9.2	7.2	6.0	5.1	3.0	6.6
1.5	15.0	8.7	6.3	8.8	7.6	7.9	10.5
1.5	25.0	12.9	9.7	11.9	6.9	8.6	8.5
3.5	15.0	9.1	8.2	4.4	4.6	6.2	14.3
3.5	25.0	5.4	7.3	6.8	9.3	8.9	12.0
Air Control		4.3	2.3	3.0	5.2	6.0	8.1
LSD (0.05)		NS	NS	NS	NS	NS	NS

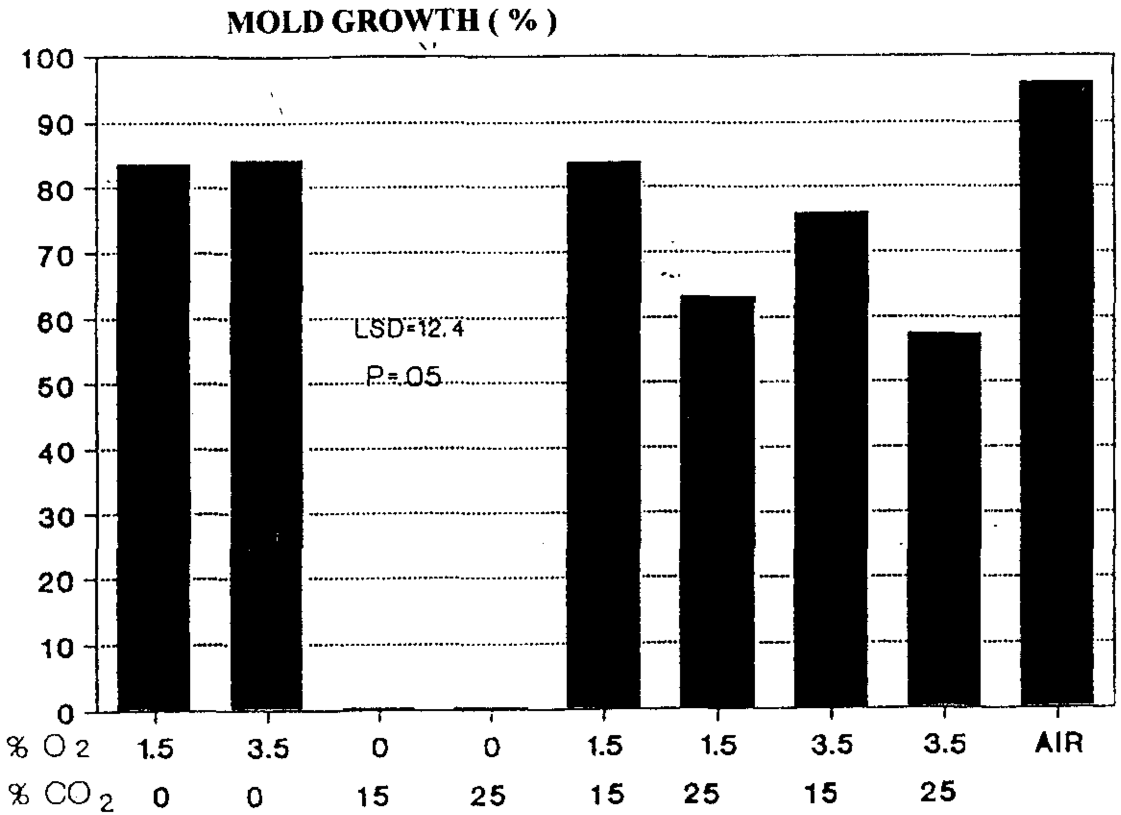

Figure 1 . Influence of modified atmosphere on mold growth percentage of ' Honeoye ' strawberry after seven days of storage at 21°C .

Table 3 : Influence of modified atmosphere treatments on respiration rate (ml CO_2 / kg / hr) of `Honeoye` strawberry during seven days of storage at 21° C .

Treatments		Days in storage					
O_2 (%)	CO_2 (%)	2	3	4	5	6	7
1.5	0.0	25.2	23.1	35.2	39.95	45.15	44.2
3.5	0.0	29.95	34.7	51.35	52..3	48.95	51.8
0.0	15.0	18.85	11.5	18.35	18.85	14.75	15.51
0.0	25.0	7.9	5.4	7.9	11.5	10.95	14.55
1.5	15.0	16.95	15.6	29.75	38.0	42.3	16.6
1.5	25.0	20.7	24.7	28.3	26.65	17.6	26.65
3.5	15.0	18.1	25.2	36.6	38.35	34.7	41.65
3.5	25.0	20.0	15.5	24.5	27.55	27.35	26.9
Air control		33.75	26.6	44.2	54.15	71.3	50.35
LSD (0.05)		NS	11.67	18.73	13.9	13.87	19.01

Table (4) : Influence of modified atmosphere treatments on ethylene production (µl C_2H_4 / kg / hr) of `Honeoye` strawberry during seven days of storage at 21 °C .

Treatments		Days in storage					
O_2 (%)	CO_2 (%)	2	3	4	5	6	7
1.5	0.0	0.0	0.0	0.005	0.015	0.0	0.093
3.5	0.0	0.04	0.154	0.135	0.130	0.0	0.0
0.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0
1.5	15.0	0.0	0.025	0.115	0.005	0.055	0.015
1.5	25.0	0.0	0.0	0.0	0.0	0.0018	0.0
3.5	15.0	0.009	0.108	0.245	0.170	0.044	0.03
3.5	25.0	0.0	0.0	0.012	0.089	0.018	0.0075
Air control		0.365	0.510	0.330	0.195	0.145	0.112
LSD (0.05)		0.10	0.163	0.185	NS	NS	NS

تأثيرالمعاملة بالجو الغازي المعدل على معدل التنفس وجودة ثمار الفراولة صنف "هوينوى"

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تم تعريض ثمار الفراولة صنف "هوينوى" لمعاملات مختلفة من الجو الغازي المعدل حيث تم إستخدام تركيزات مختلفة من كل من غازي ثاني أكسيد الكربون و الأكسجين بالمعدلات الاتية :

1) 1.5 % O_2 2) 3.5% O_2 3) 25 % CO_2 4) 1.5%O_2+ 15% CO_2
5) 1.5% O_2 +25% CO_2 6) 3.5%O_2+ 15% CO_2 7) 3.5%O_2 + 25% CO_2

بالإضافة إلي الجو الغازي العا دى الذى إستخدم للمقارنة. و لقد تم حفظ الثمار المعاملة إما في درجة حرارة الغرفة (21°C) أو تحت ظروف التخزين المبرد (2°C) و ذلك بهدف دراسة تأثير التركيزات المختلفة من الجو الغازي المعدل و تأثير درجات حرارة التخزين علي جودة ثمار الفراولة و معدل تنفسها. و لقد تم دراسة الصفات الطبيعية و الكيماوية للثمار و كذلك معدل تنفسها و معدل إنتاج الإثيلين . و كانت أهم النتائج المتحصل عليها ما يلي:

أدت معاملة الثمار بكل من درجات الحرارة المنخفضة (2°C) و التركيزات المرتفعة من غاز ثاني أكسيد الكربون (25%) إلي تقليل الفقد في وزن الثمار مقارنة بثمار المقارنة. كما لم تلاحظ أي إصابات مرضية علي الثمار التي خزنت في درجات الحرارة المنخفضة (2°C) طوال فترة التخزين (٧ أيام) . أما الثمار التي حفظت في درجة حرارة الغرفة (21°C) فلقد تفاوتت درجة الإصابة بها . و كانت أقل نسبة إصابة في الثمار التي خزنت في الجو الغازي المعدل المركب من 3.5 % O_2 + 25% CO_2 . و لقد أظهرت الثمار التي تم تخزينها في درجة حرارة الغرفة (21°C) علاقة طردية بين تركيز الأوكسجين في الوسط ومعدل التنفس. كما أدت المعاملة بتركيزات الأوكسجين المنخفضة إلي إنخفاض حاد في معدل إنتاج الإثيلين بواسطة الثمار . و بصفة عامة فلقد إنخفض معدل إنتاج الإثيلين بواسطة الثمار المخزنة في الجو الغازي المعدل مقارنة بتلك المخزنة في الجو الغازي العادي .