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EFFECT OF MODIFIED ATMOSPHERE, PRECOOLING, AND STORAGE TEMPERATURE ON QUALITY AND RESPIRATION RATE OF STRAWBERRY FRUITS

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ABSTRACT: Mature strawberry fruits *(Fragaria x ananassa* Duch.*)*, "Honeoye" cv were exposed to precooling treatment, and then stored under different modified atmosphere treatments (MA) (O_2 at: 0, 1.5, 3.5%; and Co_2 at: 0, 15, and 25%) at two different storage temperature; either cold storage (2 °C) or ambient room temperature (21 °C). Fruit physical and chemical characteristics were assessed. A slight reduction in fruit weight loss occurred due to precooling treatment. Low temperature (2°C) reduced weight loss of strawberries when compared with storage at 21C. In addition, There were significant differences in fruit weight loss among the MA treatments stored at room temperatures.The least fruit weight loss occurred in precooled fruits which received MA treatments with 15 CO_2 +zero O_2 and 25% CO_2 + zero O_2. No fungal growth was observed in strawberry fruits stored at 2°C. In addition, fungal growth was not observed in fruits stored under high CO_2 treatments (15 or 25 % CO_2). Non-precooled fruits which stored in 21°C had the greatest mold growth percentage. Cold storage retarded fruit respiration rate. The respiration rate decreased from 28.5 ml CO_2 /kg/hr in fruits stored at 21°C to 7.6 ml CO_2 /kg/hr in fruits stored at 2°C. No significant differences were observed in fruit respiration rate between precooling and non precooling treatments. At cold storage MA treatments did not affect fruit respiration rate. Ethylene production was not detected in fruits stored at 2°C during the storage period (7 days). Ethylene production rate was inhibited very slightly due to precooling treatment. Ethylene production rate of berries held in ambient room temperature was greater than of berries that held in cold storage treatment.

INTRODUCTION

Modified atmosphere (MA) storage (with increased CO_2 and / or reduced O_2) has been used successfully to extend postharvest longevity of strawberries (Holcroft and Kader, 1999a; Holcroft and Kader, 1999b). Elevated concentrations of CO_2 inhibit decay and retard softening (Herner, 1987). Moreover, high concentrations of CO_2 and / or low concentrations of O_2 reduce fruit respiration rate and inhibit fungal growth, and extend storage life (Kader, 1985). In addition, 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).On the other hand, low concentrations of oxygen (0.5 % or less) reduced the decay of fresh strawberries caused by *B. cinerea* (Wszelaki and Mitcham, 2000). The resultant effect of some combination of high CO_2 and low O_2 modified atmospheres is synergistic (Li and Kader, 1989) . Kubod *et al.*(1990) reported that modified atmosphere treatment suppressed respiration and delayed ripening of strawberry fruits, but such results cannot be achieved with either O_2 or CO_2 controlled atmospheres alone. Temperature management is the most important method of maintaining the postharvest quality of fruits and postharvest losses also can be minimized by forced air cooling of the fruits after harvest (Harvey *et al.*, 1966; Hardenburg *et al.*,1986). The purpose of this research was to determine whether or not precooling, modified atmosphere and cold storage could be used to maintain the quality of strawberry fruits, and to determine the effect of combinations of low O_2 and / or high CO_2 concentrations on weight loss (%), mold growth (%), fruit respiration rate, and fruit ethylene production.

MATERIALS AND METHODS

This experiment was conducted during the two successive seasons of 2001 and 2002 in the Hort. Dept., College of Agric., King Saud Univ., Al-Qassium, Kingdom of Saudi Arabia to study the effect of modified atmosphere, precooling and storage temperature on fruits quality of strawberry .Fresh strawberry (*Fragaria x ananassa,* Duch.) fruits were used in this study.The Strawberry fruits were produced at a local commercial farm. Fruits were harvested at the red-ripe stage and transported immediately to the laboratory. One-half of the strawberry 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. Sample weight was approximately 300g per replicate, distributed in plastic mesh baskets in each MA chamber.

The fruits were exposed to different modified atmosphere treatments (MA) as follows:

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) normal air as a control treatment. The rest of the atmospheric volume was filled with nitrogen gas (N_2). Fruits were stored at either a cold room (at 2°C) or at room temperature (21°C). Samples of the test atmospheres were collected at inlets (every 24 hs) and outlets (every 12 hs) of the MA chambers and analyzed by using a Varian model 3700 gas chromatography. The test atmospheres were humidified (85 to 90% relative humidity) as described previously (Diesburg *et al.*, 1989). After seven days in the test atmosphere, final fruit fresh weight and percentage of *B. cinerea* incidence were measured. CO_2 and C_2H_4 production rates were calculated by the following formula described by Kader , 1985:

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

Statistical analysis: A factorial experiment was conducted by using split-split design. Data of both seasons of the study were Statistical analyzed. Analysis of variance, with four replicates per each treatment, was performed (general linear model , PROC GLM) to test the effects of the various treatments (SAS Institute , 1985) . When F values were significant, LSD compared means at the 5% level.

RESULTS AND DISCUSSION

Weight Loss

Data in Table 1 clearly indicate that a slight reduction in fruit weight loss occurred due to precooling treatment. However, there were significant differences in fruit weight loss due to storage temperature. Low temperature (2°C) reduced significantly weight loss of strawberries when compared with storage at 21°C (Table 1). In addition, There were significant differences in fruit weight loss among the MA treatments stored at room temperatures (Fig.2).The least fruit weight loss occurred with precooled fruits which received MA treatments with 15% CO_2 +zero% O_2 and 25% CO_2 + zero% O_2.In addition, the greatest fruit weight was recorded at fruits that did not receive precooling treatment and stored under MA conditions with zero CO_2 +3.5% O_2 and the control treatment (Fig. 2). 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

No fungal growth was observed in strawberry fruits stored at 2°C (Table 1). In case of fruits treated with MA treatments and stored at 21°C, although there were slight differences between precooled and non precooled treatments regarding fungal growth (%) on the fruits . However, these differences were not significant (Table 1). In addition, fungal growth was not observed in fruits stored under high CO_2 concentrations (15 or 25 % CO_2) and held in either zero % O_2 + 25 % CO_2 or zero % O_2 + 15 % CO_2 (Fig. 3). Whereas, fruits which were not precooled and stored in the air at 21°C had the greatest mold growth percentage, followed by those which were precooled and stored in the air at 21°C, and fruits which were precooled and stored at MA with 1.5% O_2 + 3.5% (Fig .3). These results indicated that cold storage; i.e., 2°C proved to be the most capable treatment in reducing the percentage of fruits decay. Moreover, modified atmosphere treatment 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 fruits decay in grapes.

Respiration Rate

Data in Table 1 clearly show that the cold storage had a sound effect on retarding respiration rate in strawberry fruits. The respiration rate decreased from 28.5 ml CO_2 /kg/hr in precoold fruits which were stored at 21 °C to 7.6 ml CO_2 /kg/hr in precoold fruits which were stored at 2 °C. No significant differences were observed between precooling and non precooling treatments regarding with their influence on fruits respiration rate, whether the fruits were stored at room temperature or at 2°C (Table 1).

In addition,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, i.e.7 days (Data are not presented). The lowest rate of respiration was obtained from non precooled fruits which were stored at 2 °C under MA conditions. Whereas, the highest rate of respiration was obtained from non precooled fruits which were stored at 21 °C under MA conditions. These results are in line with those of Li and Kader (1989). Plotto *et al.* (1999) reported that modified atmosphere treatment suppressed respiration and delayed ripening of fruit.

Ethylene Production Rate

Ethylene production was not detected in strawberry fruits during the storage period (7 days) for the fruits which were stored at 2°C (Table 1). This observation took place whether the fruits were precooled or not before storing them. But ethylene was detected in fruits stored at 21°C (Table 1). Ethylene production rate was inhibited very slightly due to precooling treatment (Table 1). In all cases, ethylene production rate of berries that held in ambient room temperature was greater than the ethylene production rate of berries held in cold storage treatment 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 treatments and forced – air cooling on weight loss , ethylene production in ` Honeoye ` strawberry during seven days of storage at different temperatures .

Treatments	Weight loss (%)	Mold growth (%)	Respiration rate (ml CO_2 / kg/hr)	Ethylene production rate (µl C_2H_4 /kg/hr)
MA at 2 °C				
Cool	7.85	0.0	7.6	0.0
No cool	8.27	0.0	6.6	0.0
LSD (0.05)	2.09	0.0	2.9	0.0
MA at 21 °C				
Cool	60.99	58.85	28.5	0.054
No cool	70.23	62.23	29.4	0.063
LSD (0.05)	14.30	5.83	2.7	0.030

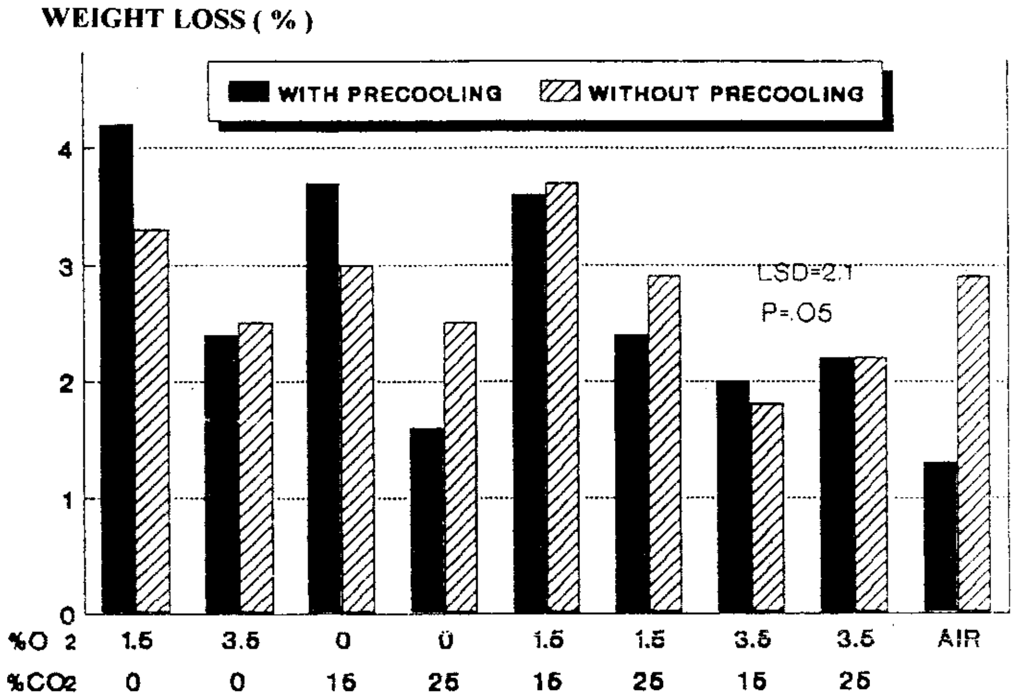

Figure 1. Influence of modified atmosphere storage treatments on weight loss of precooled and nonprecooled 'Honeoye' strawberry fruits after seven days of storage at 2°C.

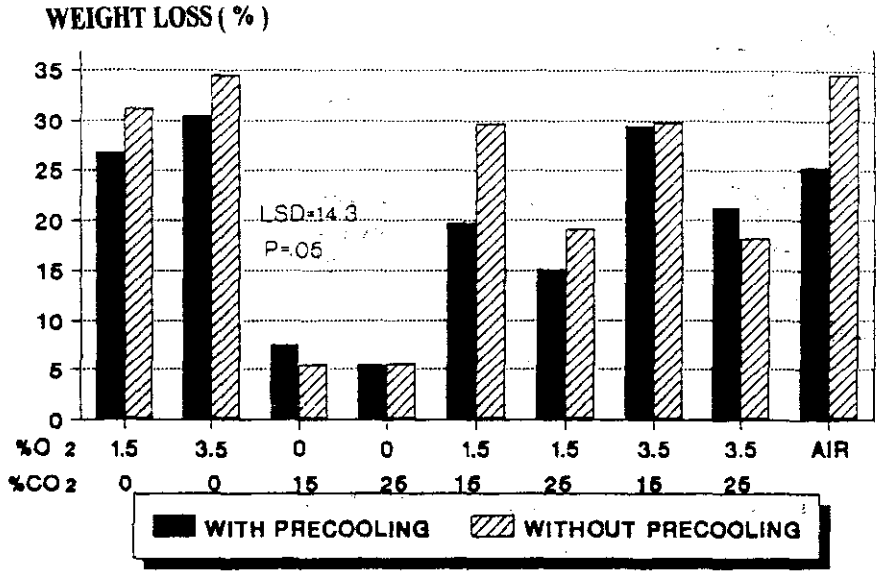

Figure 2. Influence of modified atmosphere storage treatments on weight loss of precooled and nonprecooled ' Honeoye ' strawberry fruits after seven days on storage at 21°C.

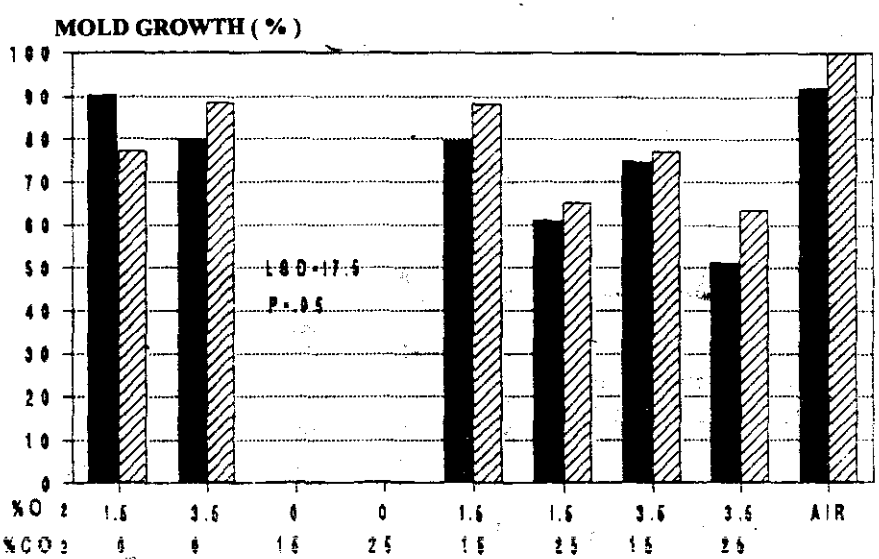

Figure 3. Influence of modified atmosphere storage treatments on Mold growth percentage of precooled and nonprecooled 'Honeoye' strawberry after seven days of storage at 21°C

تأثير المعاملة بالجو الغازي المعدل و التبريد المبدئي و التخزين المبرد علي جودة ثمار الفراولة ومعدل تنفسها

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تـم تعـريض ثمار الفراولة صنف "هوينوى" للتبريد المبدئي ثم معاملتها بمعاملات مخـتلفة مـن 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

بالإضـافة إلي الجو الغازي العا دى (معاملة المقارنة). و لقد تم حفظ الثمار أثناء تعرضها للجـو الغازي المعدل إما في درجة حرارة الغرفة (٢١ م°) أو تحت ظروف التخزين المبرد (٢ م°) و ذلك بهدف دراسة تأثير التركيزات المختلفة من الجو الغازي المعدل و تأثير كل مـن التـبريد المبدئي و درجات حرارة التخزين علي جودة ثمار الفراولة. و لقد تم دراسة الصـفات الطبيعية و الكيماوية للثمار و كذلك معدل تنفسها و معدل إنتاج الإثيلين . و كانت أهم النتائج المتحصل عليها ما يلي:

أدت معاملـة الـثمار بالتبريد المبدئي إلي تقليل الفاقد في وزن الثمار بدرجة بسيطة ، في حين حدث إنخفاض كبير في الفاقد في وزن الثمار عندما تم حفظ هذه الثمار علي ٢ م° . و كان أقل معدل فاقد في وزن الثمار في المعاملات التي تم فيها إجراء تبريد مبدئي ثم حفظت الثمار علي ٢ م° تحت جو غازي معدل مكون من ١٥ أو ٢٥ % غاز ثاني أكسيد الكربون + صفر % أوكسجين. كما لـم تلاحظ أي إصابات فطرية علي الثمار التي تم تخزينها علي درجة حرارة ٢ م° تحت جو غازي معدل مكون من ١٥ أو ٢٥ % غاز ثاني أكسيد الكربون ، في حين كانت أعلي نسبة إصابات فطرية علـي الـثمار التـي اجري لها تبريد مبدئي ثم تم تخزينها علي درجة حرارة الغرفة (٢١ م°) . و بالـرغم مـن أن كل من معاملات الجو الغازي المعدل و التبريد المبدئي لم تؤثر معنويا علي معدل التنفس ، إلا أن التخزين المبرد أدي إلي تقليل معدل تنفس الثمار. ولقد أوضحت النتائج أن استخدام معـاملات الجـو الغازي المعدل و التبريد المبدئي تؤدي إلي تقليل معدل إنتاج غاز الإثيلين بواسطة الثمار ، كما أن التخزين المبرد قد منع تقريبا إنتاج غاز الإثيلين بواسطة الثمار .