

The Effect of Modified Atmosphere Storage on the Quality of Fresh Dill (*Anethum graveolens* L.)

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Abstract

Because of its high perishability, fresh dill (*Anethum graveolens* L.) cannot be stored for more than a few days, even at low temperature. The present study was therefore undertaken to determine whether modified atmospheres based on changes in CO₂ and O₂ concentrations would benefit dill storage. Dill cv. Ducat was cultivated between October 2009 and January 2010. Plants were harvested at the fresh market stage (before flowering) and randomly selected leaves were weighed, placed in airtight plastic bags and stored for 10 days at 5°C. The atmospheres within the containers (O₂-CO₂-N₂) were initially as follows: (1) 20-0-80 (air), (2) 20-10-70, (3) 10-0-90, and (4): 10-10-80. The changes in O₂-CO₂ concentrations were monitored during storage; fresh weight, chlorophyll, vitamin C and total phenolics concentrations were measured before and after storage. The oxygen concentration within the bags during storage fell to 12.5% (treatment 1) and 17.9% (treatment 2) indicating a reduction of respiration due to the inclusion of 10% CO₂ within the initial atmosphere (20% O₂). At an initial concentration of 10% O₂, the oxygen level decreased to 5.5% and 5.8% in the absence or presence of 10% CO₂ (treatments 3 and 4), respectively. In each case, the decrease in O₂ was accompanied by a corresponding increase in CO₂ concentration. Weight loss during storage ranged from 2.6-5.3% and the total phenolics levels decreased in all treatments except treatment 3 (10-0-90). Vitamin C and chlorophyll concentrations decreased during storage. Vitamin C loss was similar in all treatments, but chlorophyll loss was significantly higher in the treatments with 10% CO₂. In consequence, although modified atmospheres containing 10% CO₂ reduce respiratory activity they are of questionable value for dill because the decrease in chlorophyll concentration causes a decrease in quality.

INTRODUCTION

The shelf-life of fresh vegetable produce is limited by physiological ageing and water loss (O'Beirne, 1990). Water loss leads to weight loss and shriveling whereas physiological ageing (senescence) occurs when the starch/sugar stored within the product is consumed during respiration; therefore shelf-life is inversely proportional to respiration rate (Day 1990). Modified Atmosphere Packaging (MAP) addresses both these factors and enables significant product-specific shelf-life extension (Wills et al., 1989; Church, 1995). Under conditions of MAP the O₂ tension within the storage atmosphere falls, thus reducing the rate of respiration. However, the O₂ level must not decrease below the point at which anaerobic respiration occurs.

The MAP procedure most often used for fresh fruit and vegetables is to enclose a small amount of produce in a film package and periodically monitor the resulting

atmosphere and product quality (Salveit, 2003). For example, 22 species of fresh herbs are exported from Israel to Europe, mainly during winter, packed in cartons and transported by air (Aharoni et al., 1989). When these herbs are subsequently exposed to warm air during marketing, they are vulnerable to yellowing and decay. Packaging in cartons with non-sealed NP-PE liners was found to delay leaf senescence (Hruschka and Wang, 1979) possibly due to the elevation of CO₂ concentration within the PE liners (Aharoni et al., 1988).

Apart from low temperatures, modified atmospheres are the most effective method to retard senescence of harvested leafy vegetables (Lipton, 1975). Chlorophyll loss is delayed equally well by low O₂ (<5%) and by elevated CO₂ (>5%). The combination of these two gases is slightly more effective than either one alone (Lipton and Mackey, 1987). However, the creation of modified atmospheres by film packaging can be harmful if the temperature is not carefully controlled during storage. Fluctuations in temperature will affect the respiration rate and may lead to an improper balance between CO₂ and O₂, resulting in anaerobiosis (Hardenburg, 1971).

The objective of this experiment was to determine the effect of low O₂ and high CO₂ on the storage behavior and quality characteristics of dill.

MATERIALS AND METHODS

The experiment was carried out at the Agricultural University of Athens. Seeds of dill (*Anethum graveolens* L. cv. Ducat) were sown in trays containing a commercial peat compost (Klasmann TS-2, Klasmann-Deilmann GmbH, Geeste, Germany) in October 2009 and placed in an unheated greenhouse. At the stage of 3-4 true leaves (30 days after sowing) the plants were transplanted to 11 L pots containing a (1:1v/v) mixture of peat and perlite (Perloflor P4, Perlite Hellas, Piraeus, Greece) enriched with 150g potassium monophosphate, 40g potassium sulphate, 20g magnesium sulphate, 10g trace elements (Nutrileaf) and 300g marble dust per m³. Each pot contained four plants. The pots were spaced at 50 x 50 cm in an unheated, glass-covered greenhouse. During cultivation plants were fertilized with 300 ppm N twice a week. Plants were harvested in January 2010, just prior to flowering. At harvest, plants were cut 1cm above the soil and any old, senesced leaves removed.

Immediately after harvest, leaves were weighed and the percent dry matter content determined by drying at 72°C for 3 days. Randomly selected leaves were placed in sealed, airtight polyethylene food-bags, and stored for 10 days at 5°C. Each bag (with volume 600 ml) contained 3 leaves (together with their petioles), weighing 15g. The atmospheres within the bags (O₂-CO₂-N₂) were initially as follows: (1) 20-0-80 (air), (2) 20-10-70, (3) 10-0-90, and (4): 10-10-80. Changes in O₂ and CO₂ concentrations were monitored after storage. At the end of storage, leaves were weighed to determine weight loss and then dried at 72°C for 3 days for the determination of dry matter. Quality characteristics were monitored before and after storage. Chlorophyll a, chlorophyll b and total chlorophyll concentration were measured using the method of Arnon (1949), vitamin C (L-ascorbic acid) was measured according to Bajaj and Kaur (1981), while total phenolics were measured by the method of Lisiewska et al. (2006).

The results were subjected to analysis of variance (ANOVA) and means compared by the application of Duncan's multiple range test using the statistical package Statgraphics plus 5.1.

RESULTS

Weight loss during storage ranged from 2.6-5.3% and was significantly lower in treatment 1 (20/0/80) than the other treatments (Table 1). The oxygen concentration within the bags during storage fell to 12.5% (treatment 1) and 17.9% (treatment 2) indicating a reduction in respiration rate due to the inclusion of 10% CO₂ within the initial atmosphere (20% O₂). With an initial concentration of 10% O₂, the oxygen level decreased to 5.5-5.8% in the absence or presence of 10% CO₂ indicating no effect of CO₂ on respiration rate at a low O₂ tension (Table 2). In treatments with reduced O₂ (10%) the concentration of CO₂ within the bags at the end of storage was lower than in the corresponding treatments with 20% O₂ (Table 2).

The concentration of vitamin C decreased during storage and after 10 days was significantly lower in the treatment with 10% O₂ and 10% CO₂ (Table 3). Total phenolics levels tended to decrease during storage but not to a statistically significant level (Table 3). However, the concentration of chlorophyll (a, b and total) decreased significantly during storage only in treatments with 10% CO₂ (Table 4).

DISCUSSION

Recommended for modified atmospheres for the storage of the herbs chervil, chives, coriander, dill, sorrel and watercress are 5-10% O₂ and 4% CO₂ at a temperature range of 0-5°C, with optimum 1°C (Salveit, 2003).

Aharoni et al. (1989) found that packaging in a sealed PE (S.P.E.) lined carton resulted in the maximal reduction of both yellowing and decay. Measuring the changes of respiratory gases inside the packages of chives revealed that the accumulation of CO₂ (5.7%) rather than the decrease in O₂ (12%) was the reason for retardation of senescence. In order to efficiently retard the yellowing of watercress without the development of off-odors during storage, the CO₂ level should be above 7% and the O₂ level should not drop below 5%. In both dill and chives 5% CO₂ markedly retarded chlorophyll loss.

Positive effects of increased CO₂ concentration on the maintenance of vitamin C is known in leafy vegetables (Sousan and Abd el-Aal 2007), while the opposite effect has been observed for phenolics (Oboh, 2005). Ishi and Okubo (1984) found that an increase in CO₂ concentration leads to a reduction in respiration, as well as better maintenance of the concentration of chlorophyll and vitamin C. For cardamom (Aharoni et al., 1989) and parsley (Saltveit, 1989), the best storage conditions are 0-2°C with a CO₂ concentration of 10%. Elevated levels of CO₂ slow down the loss of chlorophyll and the degradation of green colour of plant leaves due to the reduction of respiration (Kader, 1986).

In conclusion, the respiratory activity of dill foliage is reduced by MAP containing 10% O₂ (with or without CO₂) or 20% O₂ +10% CO₂, as indicated by the relative changes of O₂ and CO₂ concentrations within the bags. Since, however, the presence of CO₂ (10%) causes a decrease in chlorophyll and vitamin C concentration, which means a reduction in quality, it is clearly preferable to reduce the O₂ concentration, rather than increase CO₂, during MAP storage of dill.

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Tables

Table 1. The effect of modified atmospheres on the weight loss (%) of foliage biomass after 10 days storage of dill leaves.

Modified Atmosphere	Weight loss of foliage biomass (%)
A1 (20.0.80)	2.63 b
A2 (20.10.70)	5.30 a
A3 (10.0.90)	4.72 a
A4 (10.10.80)	4.57 a

Means followed by the same letter are not significantly different at P=0.05.

Table 2. The effect of modified atmospheres on the final concentration O₂ (%) and CO₂ (%) after 10 days storage of dill leaves.

Modified Atmosphere	% O₂	% CO₂
A1 (20.0.80)	12.50 b	7.75 c
A2 (20.10.70)	17.93 a	15.58 a
A3 (10.0.90)	5.81 c	3.79 d
A4 (10.10.80)	5.49 c	13.82 b

Means followed by the same letter are not significantly different at P=0.05.

Table 3 The effect of modified atmospheres on the concentration of vitamin C (mg/100g fresh matter) and total phenolics (mg GAE/100g fresh matter) of dill leaves.

Modified Atmospheres	Vitamin C (mg / 100g f.w.)	Total phenolics (mg GAE/100g f.w.)
A0 (Fresh)	511.77 a	273.90
A1 (20.0.80)	253.57 b	255.62
A2 (20.10.70)	224.37 bc	255.34
A3 (10.0.90)	254.20 b	271.05
A4 (10.10.80)	219.08 c	263.55

Means followed by the same letter are not significantly different at P=0.05.

Table 4. The effect of modified atmospheres on the concentration of chlorophyll a, chlorophyll b and total chlorophyll (mg/100g fresh matter) of dill leaves.

Modified Atmospheres	Chlorophyll a	Chlorophyll b	Total Chlorophyll
	mg / 100 g f.w.		
A0 (Fresh)	94.83 a	38.74 a	133.57 a
A1 (20.0.80)	85.70 a	40.50 a	126.20 a
A2 (20.10.70)	52.35 b	21.90 b	74.25 b
A3 (10.0.90)	90.77 a	34.45 a	115.76 a
A4 (10.10.80)	41.62 b	16.65 b	58.27 b

Means followed by the same letter are not significantly different at P=0.05.

